SECOND EDITION

A FISHERY MANAGER'S GUIDEBOOK

EDITED BY KEVERN L. COCHRANE AND SERGE M. GARCIA

WILEY-BLACKWELL

FAO FIAT PANIS

A Fishery Manager's Guidebook

A Fishery Manager's Guidebook

Second Edition

Edited by

Kevern L. Cochrane

Chief of the Fisheries Management and Conservation Service
Fisheries and Aquaculture Department, FAO
Rome, Italy

Serge M. Garcia

Former Director of the FAO Fisheries and Aquaculture Management Division
Fisheries and Aquaculture Department, FAO
Rome, Italy

Published by
The Food and Agriculture Organization of the United Nations
and
Wiley-Blackwell

WILEY-BLACKWELL

A John Wiley & Sons, Ltd., Publication

This edition first published 2009
© FAO 2009

Blackwell Publishing was acquired by John Wiley & Sons in February 2007. Blackwell's publishing programme has been merged with Wiley's global Scientific, Technical, and Medical business to form Wiley-Blackwell.

Registered office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

Editorial offices
9600 Garsington Road, Oxford, OX4 2DQ, United Kingdom
2121 State Avenue, Ames, Iowa 50014-8300, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. Reproduction and dissemination of material in this information product for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holder provided the source is fully acknowledged. Reproduction of material in this information product for resale or other commercial purposes is prohibited without written permission of the copyright holder. Applications for such permission should be addressed to the Chief, Electronic Publishing Policy and Support Branch, Communication Division, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy or by e-mail to copyright@fao.org.

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by the Food and Agriculture Organization of the United Nations in preference to others of a similar nature that are not mentioned. The views expressed herein are those of the authors and do not necessarily represent those of the Food and Agriculture Organization of the United Nations.

Cover image credits:
Front: main photo – Kevern Cochrane, FAO; inset photos, left to right – Anthony Charles, St Mary's University, Canada; Ayeisha Brinson, University of Miami, USA; Fikret Berkes, University of Manitoba, Canada; Jeanette Van Acker, © FAO/ Jeanette Van Acker.
Back: top to bottom – Anthony Charles, St Mary's University, Canada; Fikret Berkes, University of Manitoba, Canada; Maria Namundjebo, © FAO/Maria Namundjebo.

Library of Congress Cataloging-in-Publication Data
A fishery manager's guidebook / edited by Kevern L. Cochrane and Serge M. Garcia — 2nd ed.
p. cm
"Published by The Food and Agriculture Organization of the United Nations and Blackwell Publishing."
Includes bibliographical references and index.
ISBN 978-1-4051-7085-7 (hardback : alk. paper) 1. Fishery management. I. Cochrane, K. L. II. Garcia, Serge. III. Food and Agriculture Organization of the United Nations.

SH328.F576 2009
639.2—dc22

2009001748

A catalogue record for this book is available from the British Library.

Set in 10/12 pt Times by Macmillan Publishing Solutions, Chennai, India
Printed in Singapore by

1 2009

FAO's ISBN: 978-92-5-105963-0

Contents

Contributors xi
Preface xiii
List of Acronyms xv

Chapter 1 Introduction – Fisheries Management 1
Kevern L. Cochrane and Serge M. Garcia

1.1 Why do we need this handbook? 1
1.2 What is fisheries management? 2
1.3 The fisheries manager 4
1.4 Fisheries management and fisheries governance 6
1.5 Some working principles for fisheries management 6
1.6 An objective-driven process 7
1.7 Management plans, measures and strategies 9
1.8 The structure of this guidebook 10
Sources and recommended reading 16

Part I The Primary Dimensions of Fisheries

Chapter 2 Biology and Ecology Considerations for the Fishery Manager 21
Yvonne Sadovy de Mitcheson

2.1 Introduction 21
2.2 Why marine resource managers need to know about biology and ecology 24
2.3 What managers need to know about biology and ecology 25
2.4 Emerging issues 45
2.5 Concluding comments 50
Acknowledgements 50
Sources and recommended reading 50
Web resources 51

Chapter 3 Social Aspects of Fisheries Management 52
Fikret Berkes

3.1 Introduction 52
3.2 Dealing with the 'tragedy of the commons' 53

3.3 Changing perspectives on resource management 57
3.4 Fisheries as linked social–ecological systems 58
3.5 Why broaden management objectives? 60
3.6 Is fishers' knowledge relevant to management? 63
3.7 Why are institutions important? 65
3.8 The broader issues of fisheries governance 67
3.9 Synthesis and outlook 69
Acknowledgements 73
Sources and recommended reading 73
Web resources 74

Chapter 4 Economic Principles: An Economic Perspective on Fishing 75
Arne Eide

4.1 An economic approach to fisheries 75
4.2 Bioeconomic reasoning and reference equilibriums 83
4.3 An economic perspective on fisheries regulations 90
4.4 Fisheries development 96
4.5 Synthesis 100
Sources and recommended reading 101

Part II Legal and Institutional Considerations

Chapter 5 Legal Aspects 105
Blaise Kuemlangan

5.1 Introduction 105
5.2 Fisheries law 107
5.3 Fisheries management regime in the legal framework 114
5.4 Monitoring, control and surveillance 123
5.5 Significant issues and their legal aspects 128
5.6 Law review and the manager 131
5.7 Synthesis and outlook 132
Sources and recommended reading 133
Web resources 134

Chapter 6 The Fishery Management Institutions 135
François Feral

6.1 Introduction 135
6.2 The manager in the institutional environment 136
6.3 Institutional environment and decision-making 146
6.4 Synthesis 160
Sources and recommended reading 161
Additional reading 162
Web resources 163

Part III Management Measures and Tools

Chapter 7 Regulation of Fishing Gears and Methods 167
Åsmund Bjordal

7.1 Introduction 167
7.2 Fishing gears 168
7.3 Passive fishing gears 168
7.4 Active fishing gears 176
7.5 Gear selectivity and ecosystem effects of fishing 183
7.6 Management considerations: selectivity and other ecosystem effects of fishing 192
7.7 Synthesis and outlook 193
Sources and recommended reading 194

Chapter 8 Area and Time Restrictions 196
Stephen Hall

8.1 What are area and time restrictions? 196
8.2 Why would you establish area or time restrictions? 197
8.3 What are the advantages and disadvantages of area and time restrictions? 202
8.4 Case studies 204
8.5 What are the practical steps towards establishing time and area restrictions? 211
8.6 Synthesis and outlook 217
Sources and recommended reading 218

Chapter 9 Input and Output Controls: The Practice of Fishing Effort and Catch Management in Responsible Fisheries 220
John Pope

9.1 Introduction 220
9.2 What are input and output controls? 222
9.3 Why would you want to use effort or catch management? 223
9.4 How would you impose fishing effort management and catch management? 225
9.5 What structures do you need for effort and catch management? 236
9.6 What problems exist with the application of effort management and catch management and how might they be circumvented? 239
9.7 Where can you see examples of effort management and catch management in action? 247
9.8 Synthesis and outlook 249
Sources and recommended reading and web resources 250

Chapter 10 Rights-Based Fisheries Management: The Role of Use Rights in Managing Access and Harvesting 253
Anthony Charles

10.1 What is rights-based fishery management? 253
10.2 Why are use rights relevant to fishery management? 258
10.3 What initial considerations arise with use rights? 260
10.4 What forms of use rights are there? 262
10.5 What implementation decisions arise with use rights? 269
10.6 Synthesis 278
Acknowledgments 280
Sources and recommended reading 280

Chapter 11 Partnerships in Management 283
Evelyn Pinkerton

11.1 Introduction – partnerships solve problems, but are little known by managers 283
11.2 Partnerships of small and large scope 284
11.3 Partnerships of small and large scale 287
11.4 Partnerships with dual or multiple parties 289
11.5 Partnerships with different levels of community empowerment: accountability 291
11.6 Unusual partnerships solving particular equity problems: linking offshore fisheries to coastal communities 292
11.7 Power differentials of diverse actors on regional boards 294
11.8 Conditions for effective partnerships 296
11.9 Community partners may add value to the resource 297
11.10 Conclusion 298
Acknowledgements 298
Sources and recommended reading 298

Part IV Scientific Information and Advice

Chapter 12 Which Indicators for What Management? The Challenge of Connecting Offer and Demand of Indicators 303
Serge M. Garcia, Hélène Rey-Valette, and Clotilde Bodiguel

12.1 Introduction 303
12.2 Evolution of the demand 304
12.3 Development of a system of indicators 306
12.4 Typology of indicators 314
12.5 Main issues and challenges 322
12.6 Synthesis 328
Sources and recommended reading 328
Web resources 332

Chapter 13 The Use of Scientific Information 336
Kevern L. Cochrane

13.1 Why and when are data and information needed in fisheries management? 336
13.2 Types of knowledge and the role of the scientist 341
13.3 Uncertainty and the precautionary approach 343
13.4 What tools can be used to generate information to advise management? 347
13.5 Scientific advice for management 353
13.6 Using the knowledge in decision-making 362
13.7 Presenting information to decision-makers 363
13.8 Adaptive management 366
13.9 Synthesis and outlook 367
Sources and recommended reading 368

Part V Implementation

Chapter 14 Fishery Monitoring, Control and Surveillance 373
Per Erik Bergh and Sandy Davies

14.1 Introduction 373
14.2 The MCS solution 376
14.3 Core components 384
14.4 Facilitating for MCS 391
14.5 System performance and planning 395
14.6 Synthesis and outlook 399
Sources and recommended reading 401
Web resources 403

Chapter 15 Special Considerations for Small-Scale Fisheries Management in Developing Countries 404
John Kurien and Rolf Willmann

15.1 Why small-scale fisheries need special consideration 404
15.2 Characterizing small-scale fisheries 405
15.3 A vision for small-scale fisheries 406
15.4 Substantive contribution of small-scale fisheries 407
15.5 Management objectives for small-scale fisheries 410
15.6 Management approaches for small-scale fisheries 410
15.7 Institutional arrangements for small-scale fisheries 413
15.8 Making a management plan for a small-scale fishery 414
15.9 Implementation of small-scale fisheries management 416
15.10 Capacity building for small-scale fisheries management 418
15.11 Emerging issues 419
Sources and recommended reading 421

Chapter 16 Fisheries Management Plans 425
David J. Die

16.1 Introduction 425
16.2 Designing a management plan 426
16.3 Implementation of management plans 431
16.4 Reviewing and amending management plans 431
16.5 FMP within the context of the EAF 433
16.6 Examples of management plans 436
16.7 Synthesis and emerging issues 442
Sources and recommended reading 443
Web resources 444

PART VI Conclusions

Chapter 17 From Past Management to Future Governance: A Perspective View 447
Serge M. Garcia and Kevern L. Cochrane

17.1 Introduction 447
17.2 Historical trends 448
17.3 Emerging practices 452
17.4 The future of fishery governance 467
Sources and recommended reading 471

Glossary 473
Index 507

Colour plate section follows page *000*

Contributors

Per Erik Bergh, Nordenfjeldske Development Services AS, Private Bag 351 no. 145, Postnet Kgale, Gaborone, Botswana, Tel: +267 3926298, Email: pebergh@nfds.info

Fikret Berkes, Natural Resources Institute, 70 Dysart Road, University of Manitoba, Winnipeg, Manitoba R3T 2N2 Canada, Tel: +-204-474-6731, Email: berkes@cc.umanitoba.ca

Åsmund Bjordal, Centre for Development Cooperation in Fisheries, Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway, Tel: +47 55 23 86 90, Email: aasmund@imr.no

Clotilde Bodiguel, IDDRA, 135 rue Nivose, Les Terrasses de Marianne, 34 000 Montpellier, France, Tel: 133 467996766, Email: bodiguel@iddra.org

Anthony Charles, Management Science/Environmental Studies, Saint Mary's University, Halifax, Nova Scotia, Canada B3H3C3, Tel: (902) 420-5732, Email: tony.charles@smu.ca

Kevern L. Cochrane, FAO, Fisheries and Aquaculture Department, Viale delle Terme di Caracalla, 00153 Rome, Italy, Tel: +39 0657056109, Email: kevern.cochrane@fao.org

Sandy Davies, Nordenfjeldske Development Services AS, Private Bag 351 no.145, Postnet Kgale, Gaborone, Botswana, Tel: +267 3926298, Email: sdavies@nfds.info

David J. Die, RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149 USA, Tel: +1 305 421 4607, Email: ddie@rsmas.miami.edu

Arne Eide, Norwegian College of Fisheries Science, University of Tromsø, Breivika, NO-9037 Tromsø, Norway, Email: arne.eide@nfh.uit.no

François Feral, Centre d'étude des politiques (CERTAP), Université de Perpignan, France, Email: feral@univ-perp.fr

Serge Michel Garcia, Via Perdasdefogu, 14, 00050 Aranova (Rome), Italy, Tel: + 39 0661705228, Email: Garcia.sergemichel@gmail.com

Stephen J. Hall, The WorldFish Centre, P.O. Box 500 GPO, 10670 Penang, Malaysia, Email: s.hall@cgiar.org

Blaise Kuemlangan, FAO, Legal Office, Viale delle Terme di Caracalla, 00153 Rome, Italy, Tel: 139 0657054080, Email: blaise.kuemlangan@fao.org

John Kurien, Centre for Development Studies, Trivandrum-695 011, Kerala, India, Email: kurien.john@gmail.com

Evelyn Pinkerton, School of Resource and Environmental Management, Simon Fraser University, British Columbia, Canada V5A 1S6, Tel: 778-782-4912, Email: epinkert@sfu.ca

John G. Pope, NRC (Europe) Ltd, The Old Rectory, Staithe Road, Burgh St Peter, Norfolk, UK, NR34 0BT, Tel: +44 (0)1502 677377, Email: popejg@aol.com

Hélène Rey-Valette, Lameta, Faculté de Sciences Economiques, CS 79606 34960 Montpellier Cedex 2 France, Tel: 33 467 15 83 97 or 33 682 87 71 89, Email: helene.rey-valette@univ-montp1.fr

Yvonne Sadovy de Mitcheson, Division of Ecology and Biodiversity, University of Hong Kong, Pok Fu Lam Road, Hong Kong, Tel: 852-2299-0603, Email: yjsadovy@hku.hk

Rolf Willmann, FAO, Fisheries and Aquaculture Department, Viale delle Terme di Caracalla, 00153 Rome, Italy, Tel: +39 0657053408, Email: rolf.willmann@fao.org

Preface

A fishery managers' guidebook was first published as an FAO Fisheries Technical Paper in 2002 (Cochrane, 2002) to meet the need for information and guidance on the broad and often complex task of fisheries management. Based on subsequent experience and feedback gained from publication of the first edition, this new volume, co-published by FAO and Blackwell, has been expanded to provide broader coverage of the key elements of the task and updated in order to keep track of the rapid developments in theory and practice as academics and practitioners struggle to confront the many challenges facing modern fisheries management.

The editors of this volume would like to thank a number of people who have assisted in its preparation. First and foremost we wish to thank the authors of the chapters for their expertise and hard work in preparing their chapters as well as their cooperation and patience in meeting our many requests. We thank Rick Sutton of Cotswold Publishing Consultants for his contribution to managing the review process and for undertaking much of the copy-editing. Without his assistance, this book would still be in the form of manuscripts in various states of completion waiting for us to take them to the next stage. Rine Sola-Ronchetti and Anne van Lierde also made invaluable contributions in formatting and checking the final manuscripts.

All of the chapters were peer-reviewed, and in addition to the chapter authors who helped to review other chapters, the following are thanked for their thorough and constructive comments and suggestions: Alain Bonzon, Gabriella Bianchi, Ratana Chuenpagdee, John Fitzpatrick, Erik Franckx, Ray Hilborn, Kwame Koranteng, Michele Kuruc, Jean-Jacques Maguire, Rebecca Metzner, Ana Parma, Robert Pomeroy, Jean-Francois Pulvenis, Andre Punt, Tony Pitcher, Merle Sowman, Judith Swan and Marcelo Vasconcellos.

Finally, readers will note that there are frequent references throughout the book to informative website addresses. The authors have attempted to ensure that, at the time of printing, these addresses were valid. However, websites are often dynamic and addresses do change. Readers may therefore find that with time, some of the addresses may no longer be valid. Nevertheless, we hope that where this occurs the references will still enable you to find your way to the same information even if at a different address.

Kevern L. Cochrane
Serge M. Garcia

Reference

Cochrane, K.L. (ed.). 2002. A fishery manager's guidebook. Management measures and their application. FAO Fisheries Technical Paper No. 424. Rome, FAO. 231p.

List of Acronyms

ABC	Allowable Biological Catch
AFMA	The Australian Fisheries Management Authority (Australia)
APFIC	Asia-Pacific Fishery Commission
BMSY	Biomass at Maximum Sustainable Yield
CBA	Capture-Based Aquaculture
CBD	Convention on Biological Diversity
CBM	Community-Based Management
CCAMLR	Convention on the Conservation of Antarctic Living Marine Resources
CECAF	Fishery Committee for the Eastern Central Atlantic
CFP	Common Fisheries Policy
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMT	Customary Marine Tenure
COFI	FAO Committee on Fisheries
CPUE	Catch per unit Effort
DPSIR	Driving force-Pressure-State-Impact-Response
EAF	Ecosystem Approach to Fisheries
EBFM	Ecosystem-Based Fisheries Management
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ESD	Ecologically Sustainable Development
FAO	The Food and Agriculture Organization of the United Nations
FFA	Forum Fisheries Agency
FINSS	Fisheries Information and Statistical System
FMA	Fisheries Management Administration
FMP	Fishery Management Plan
FRCC	The Fisheries Resource Conservation Council (Canada)
FSM	Flag State Measure
GDP	Gross Domestic Product
GFAL	General Fisheries and Aquaculture Law, 1991 (Chile)
GSI	Gonado-Somatic Index
HCR	Harvest Control Law
HDI	Human Development Index
IBI	Index of Biological Integrity
ICAM	Integrated Coastal Area Management

ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	The International Council for the Exploration of the Sea
ICSF	International Collective in Support of Fishworkers
IIP	The Mozambique Fisheries Research Institute (Mozambique)
INTQ	Individual Non-transferable Quota
IOTC	Indian Ocean Tuna Commission
IPOA	International Plans of Action
IPOA-CAPACITY	International Plan of Action for the Management of Fishing Capacity
IPOA-IUU	International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
ISO	International Organization for Standardization
ITQ	Individual Transferable Quota
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated Fishing
IWC	International Whaling Commission
LCA	Life Cycle Analysis
LOS or LOSC	UN Law of the Sea Convention
MAC	Management Advisory Committee (Australia)
MCS	Monitoring Control and Surveillance
MDG	Millennium Development Goal
MEY	Maximum Economic Yield
MPA	Marine Protected Area
MPE	Management Procedure Evaluation
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
NAFO	Northwest Atlantic Fisheries Organization
NEAFC	North East Atlantic Fisheries Commission
NGO	Non-Governmental Organization
NPF	Northern Prawn Fishery (Australia)
NPOA-IUU	National Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
OMP	Operational Management Procedure
OSY	Optimum Sustainable Yield
PAF	Precautionary Approach to Fisheries
PCI	Principle Criteria Indicators
PIP	Policies, Institutions and Processes
PSM	Port State Measures
RFB	Regional Fisheries Body
RFMO	Regional Fisheries Management Organization
SAR	Synthetic Aperture Radar
SDRS	Sustainable Development Reference Systems

SEEA	System of Integrated Environmental and Economics Accounting
SLA	Sustainable Livelihood Approach
SMART objectives	Objectives that are Specific, Measurable, Achievable, Relevant and Time-bound
SPR	Spawning Potential Ratio
SSB	Spawning Stock Biomass
SSBR	Spawning-Stock-Biomass-per-Recruit
TAC	Total Allowable Catch
TEK	Traditional Ecological Knowledge
TED	Turtle Excluder Device
TL	Trophic Level
TURF	Territorial Use Rights in Fisheries or Territorial Use Rights in Fishing
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNGA	UN General Assembly
VME	Vulnerable Marine Ecosystem
VMS	Vessel Monitoring System
VPA	Virtual Population Analysis
WCPFC	Western and Central Pacific Fisheries Commission
WSSD	World Summit on Sustainable Development, 2002
WWF	Worldwide Fund for Nature
YPR	Yield-per-Recruit

Chapter 1

Introduction – Fisheries Management

Kevern L. Cochrane and Serge M. Garcia

1.1 Why do we need this handbook?

Fisheries around the world make essential contributions to human well-being, providing basic food supplies, employment, livelihoods, recreational opportunities, sources of foreign currency or recreational opportunities for hundreds of millions of people. They are an integral component of communities and societies almost wherever humans have access to water bodies: oceans, seas, lakes and rivers. So far, so good, but a problem arises because, in addition to providing benefits for society, fisheries also have negative impacts which, if not sufficiently controlled, can not only destroy or diminish the benefits they provide but also lead to damage to the ecosystem with resulting negative impacts on other important goods and services for humans, including the conservation value of the ecosystems.

Fisheries management is the process that has evolved to ensure that fisheries operate in a manner that not only provides the immediate benefits but also does not result in excessive or irreversible damage to the exploited fish stocks or the diversity, integrity and structure of the ecosystem, so that the stocks and ecosystem will continue to provide the full range of benefits in the future. Fisheries management has been successful in some cases but it has become widely recognised in recent decades that there have also been many, many cases of failure. As a result, there is global concern about the state of most aquatic ecosystems and their ability to continue to provide benefits, not least the production of fish for human use.

There are many reasons for this widespread problem, including amongst others: scientific uncertainty; an inherent conflict between short-term social and economic needs and goals and the longer-term need for sustainability; poor management practices in the past, particularly the absence of long-term rights and failing to ensure that stakeholders participate in management; insufficient capacity within the management agencies and others. This guidebook is designed to contribute to addressing the problem of insufficient capacity within the management agencies by providing a broad overview of the different tasks and responsibilities that collectively make up fisheries management; to show how those tasks interact and fit together and to identify approaches to addressing some of the particular problems that make management as a whole more difficult. The book deals with capture fisheries and particularly with marine capture fisheries although much of the information presented here is also relevant to inland (freshwater) capture fisheries.

The chapters in this book clearly demonstrate that fisheries management is currently undergoing a marked and rapid transition, as fisheries managers and stakeholders respond in practice to the realisation that the conventional fisheries management that dominated much of the second half of the 20th century, although effective up to a point when properly applied, was

insufficient to ensure sustainable use of aquatic ecosystems. Instead, a wider approach is now being called for, one which goes under many different names. In this book, in accordance with the terminology used within the Food and Agriculture Organization of the United Nations (FAO), it is referred to as an ecosystem approach to fisheries (EAF). It would be wrong, however, to equate EAF itself with all the new insights and changes being implemented as the limitations of conventional fisheries management have been explored and revealed through a number of independent processes. Recognising this, EAF attempts to bring them all together. In summary, the new approach differs from the old in three key areas: (i) incorporation, into management objectives and actions, of the interactions between the fishery and the ecosystem as a whole, including both ecosystem and human well-being rather than considering only the target species; (ii) greater awareness of knowledge gaps and uncertainties in information available for decision-making and the need to take them into account and (iii) recognition of the fundamental need to involve the stakeholders in all aspects of management.

The new awareness is leading to changes in approach and practice, changes that not only build on the many necessary and successful aspects of conventional management but also adapt and supplement them. The changes are slow, lessons are still being learned and many additional ones still need to be revealed. As a result, there are a number of key areas in fisheries management where, at present, there are few successful models to emulate and where important practices have to be based more on theory than on tested experience. The chapters in this book attempt to address the new awareness and were written to reflect this new reality, presenting both the valid and essential elements of the conventional approach and the available knowledge on best practices for the new, wider approaches. Some chapters that the authors considered to be applicable to future developments conclude with a section entitled 'Synthesis and Outlook' in which they have presented their view of important new developments within the chapter topic, which may require changes and responses in management practices in the future.

1.2 What is fisheries management?

There is no clear and generally accepted definition of fisheries management and this in itself can cause problems in practice. Definitions can be dangerous if over-interpreted and we do not wish to get embroiled in a debate about exactly what fisheries management is or is not. We use here the working definition provided in the FAO Technical Guidelines on fisheries management (FAO, 1997) to provide a summary of the task of fisheries management:

> The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives.

At the outset it must be understood that in this definition, 'fisheries activities' and 'fisheries objectives' need to be understood within the framework of EAF. We therefore provide, upfront, first the rationale for EAF and then the definition, both taken from the FAO Technical Guidelines on EAF (FAO, 2003):

> Rationale – The purpose of an ecosystem approach to fisheries is to plan, develop and manage fisheries in a manner that addresses the multiplicity of societal needs and desires, without

jeopardising the options for future generations to benefit from the full range of goods and services provided by marine ecosystems.

Definition – An Ecosystem Approach to Fisheries strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries.

From all of these, it can be seen that fisheries management involves a complex and wide-ranging set of tasks, which collectively have the underlying goal of the achievement of sustained optimal benefits from the resources (Figure 1.1).

The most widely accepted standard for what constitutes good management is the FAO Code of Conduct for Responsible Fisheries adopted by all FAO Member States in 1995 (FAO, 1995)

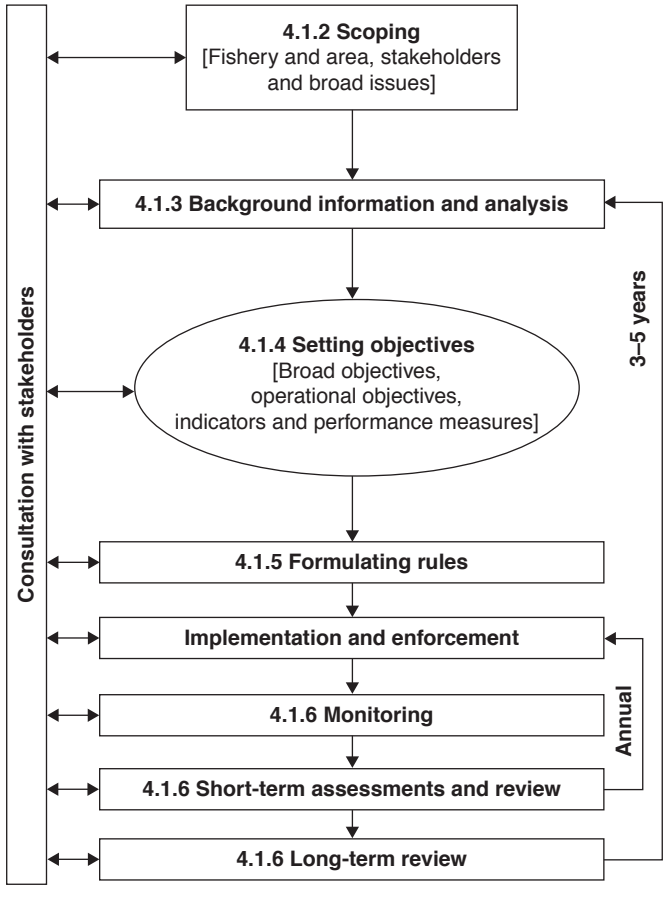


Figure 1.1 Process for developing and implementing a management plan. Evaluation and review should occur on a variety of time scales, for example as shown here, a tactical review of the management measures every year and a comprehensive strategic review every 3–5 years. From the FAO Technical Guidelines on EAF (FAO, 2003): the numbers shown at each step in the Figure refer to the relevant sections explaining the step in those Guidelines.

and referred to throughout this book as 'The FAO Code of Conduct'. The six substantive articles of the Code (Articles 6–12) outline the critical features of responsible fisheries (which, in the Code, are taken to include aquaculture), encompassing all the elements of the ecosystem approach. The FAO Code of Conduct is therefore used as the basis for best practice throughout the book and frequent reference is made to relevant Articles and paragraphs.

Effective fisheries management needs both strategic and tactical planning and implementation. Strategic management is linked to the policy goals and takes a long-term view of the fishery: what the policy goals are and how, in broad-based terms, they are to be achieved. Because of the long-term view and therefore high uncertainty about how conditions and circumstances may change over time, strategic management must be inherently adaptable. In contrast, tactical management deals with the short term, for example the next 3–5 years. It is therefore directly linked to the more specific operational objectives and requires the selection and implementation of clear and precise actions. For example, from the strategic perspective, a decision may have been made in a hypothetical case that the fishing is best controlled through regulation of fishing effort because the fishery is a multi-species fishery and monitoring of catches and enforcement of catch limits would be impossible with the available capacity. Tactical management would need to decide exactly how to measure effort, the maximum effort that could be allowed each year, and how to monitor and regulate the effort being applied.

1.3 The fisheries manager

1.3.1 Who is the fisheries manager and who is this book aimed at?

In fact, despite deliberately using the term in the title of this book, we suggest that in modern fisheries management, there is rarely a single individual who fulfils the functions of 'fisheries manager'. The head of the authority charged with managing fisheries, for example a Director of the Department of Fisheries, may have overall responsibility for implementing fisheries management. As such he or she will be accountable and responsible for the advice passed on from the Department to the political decision-maker or decision-makers and is likely to have an overall coordinating role for fisheries management. However, this individual is very unlikely to have sole responsibility for receiving information, formulating advice and making and implementing decisions. Those different functions will typically be delegated to other subdepartments and specialists within those subdepartments. In addition, as reflected in Paragraph 7.1.2 of the FAO Code of Conduct and a persistent theme throughout this book, fisheries management should also involve the legitimate interested parties in the management process. Indeed, in many cases the tasks of management are formally shared between government and the stakeholders. The importance and implications of such a comanagement approach are examined in various sections throughout this book.

The guidebook is therefore aimed at a broad audience but is intended, above all, to be a practical guide to those actively engaged in fisheries management. At the core of this group are those people charged with over-seeing and implementing fisheries management, be it at national, regional, local or individual fishery level. However, the editors and authors of this book hope that, by providing an holistic, integrated synopsis of fisheries management, the book will also be useful to the many others participating in different tasks and components of management – the fishers, the managers of fishing companies, conservationists, the range of

technical and scientific experts typically involved in management including natural scientists, economists, social scientists, lawyers and others.

The book is not, and could not be, designed to go into great technical and operational detail on each function or task, which would require a set of handbooks. Instead, it is intended to give a holistic picture of the different functions – how they should interact in the fisheries management process in order to develop appropriate objectives and integrated sets of management measures culminating in management plans and how to facilitate implementation of those plans. The fundamental premise of this book is that, like a car or boat engine, fisheries management is an integration of many different components and will not work properly unless all the individual components are not only functioning effectively themselves but also properly connected and synchronised with all the others.

1.3.2 The demands of management

Although we may refer to fisheries management as a discreet job or task, in reality it is a process, a circular and multi-pronged process that never ends as long as the fishery continues (Figure 1.1). The fisheries manager, in the sense of the government authority as explained in the previous section, fulfils a key role in that process both as the representative of the management authority and as the facilitator of the process.

A glance at the contents pages of this book demonstrates that fisheries management is a multi-disciplinary process, requiring input from many different specialists. The manager can never be knowledgeable, an expert, on all of these but the best managers will have enough background in the different disciplines to understand the issues and potential solutions, to discuss them with the specialists and to be able to contribute, as a facilitator, to making decisions and resolving conflicts related to them. A good manager, therefore, will have at least a basic knowledge of the biology, ecology, stock assessment, economics, social dimensions, legal principles, monitoring, control and surveillance (MCS), and nature and characteristics of the fisheries and the stakeholders relevant to their mandate. Stakeholders and others involved in the management process would also benefit from such a 'helicopter view'. This book attempts to help all of these reinforce their knowledge in these areas.

Going beyond the core contents of this book, a bit of psychology, public relations and political acumen will also help fisheries managers in difficult situations. Coupled with this, and at least as important, the effective manager should be a good leader and skilled in negotiation, communication and conflict resolution. However, he or she must also be an effective delegator and must rely on the specialists to provide specialist advice, not making the mistake of confusing or equating his or her own basic knowledge with expert opinion, or presuming to know the stakeholders' views better than they do themselves.

Of course, the formally designated manager is also usually responsible for administering and managing an office or department, which will require skills in planning, project development and implementation, office management, organisation and administration, budgeting and financial planning and more. Fisheries management is not a task for someone who has settled into neutral gear mentally; it requires a dynamic, multi-skilled and widely informed 'hybrid'. This may seem intimidating but is it too much to ask of someone who has been charged with managing and facilitating a process that has profound consequences not only for people and ecosystems today but also for generations to come?

1.4 Fisheries management and fisheries governance

The term 'governance' has become a common catchword in the field of sustainable development and, for example, the Plan of Implementation of the World Summit on Sustainable Development (WSSD) in 2002 stressed that good governance within each country and at the international level is essential for sustainable development. As with the term 'fisheries management', the word 'governance' is confusing to many and frequently understood simply to mean the same as management or, sometimes, everything outside formal management. Section 3.8 explains and discusses governance, defining it as 'the whole of public as well as private interactions taken to solve societal problems and create societal opportunities'. It therefore includes management but is much wider than management. This guidebook is about management but recognises that good management will only be fully effective if it is being implemented within the wider environment of good governance. Fisheries managers need to be aware of the impacts and implications as well as the strengths and weaknesses of the governance regime in which the fisheries under their care are embedded and take measures accordingly. For example, in an environment characterised by good governance, self-motivated compliance with regulations is likely to be higher, meaning less rigorous enforcement should be required, than within an environment marked by poor governance.

1.5 Some working principles for fisheries management

The definitions of fisheries management and EAF provided in Section 1.2 reflect, perhaps above all, the problems of conflicts and uncertainty that so often confound attempts to manage fisheries effectively. The harsh reality is that these are fundamental features of most if not all fisheries and the manager needs to confront and address them in nearly all aspects of fisheries management. Key reasons why fisheries are dominated by conflict and uncertainty, and factors that will help to address them, can be seen by looking at the underlying principles in a fisheries system, where a fisheries system is one type of what is referred to in Chapter 3 as 'a social–ecological system'. There are both benefits and risks in attempting to simplify a subject, and over-simplification can lead to the neglect of important details. However, simplification can facilitate understanding important principles and highlighting the broad areas that need attention. Arising from the considerations discussed earlier, the following key principles have been suggested and serve to focus attention on the starting points for effective fisheries management (after Cochrane, 2000).

1. The fishing sector consists of a number of dynamic components, also commonly interacting with other sectors through the ecosystem and biological resources, the stakeholders and the market. The overall evolution of the sector and its components is therefore hard to predict in the long term.
2. Fish stocks and communities are finite and biological production constrains the potential yield from a fishery.
3. Biological production of a stock is a function of the size and structure of the stock and of the ecological environment with which it interacts and is influenced by natural and human-induced changes in this environment.

4. Human consumptive demands on fish resources are fundamentally in conflict with the constraint of maintaining a suitably low risk to the resource. Further, modern technology provides humans with the means, and demand for its benefits provides the motivation to extract fish biomass at rates much higher than it can be produced.
5. In a multi-species fishery, which description encompasses almost all fisheries, it is impossible to maximise or optimise the yield from all species or stocks simultaneously.
6. Uncertainty pervades fisheries management and hinders informed decision-making. The greater the uncertainty, the more conservative should be the approach (i.e. as uncertainty increases, realised yield as a proportion of estimated maximum average yield should be decreased).
7. The short-term dependency of society on a fishery will determine the relative priority of the immediate social and/or economic goals in relation to the longer-term goal of sustainable utilisation.
8. A sense of security of tenure and a long-term stake in the resource for those (individuals, communities or groups) with access ought to be most conducive to maintaining responsible fisheries.
9. Genuine participation in the management process by fully informed stakeholders is consistent with the democratic principle, facilitates identification of acceptable management systems and encourages compliance with laws and regulations.

In keeping with the integrated nature of fisheries ecosystems, these principles cannot be seen in isolation in considering how best to manage fisheries: their implications and consequences overlap, complement and confound each other, which is what makes fisheries management so demanding and challenging. Nevertheless, the consequences of the principles for fisheries give rise to the fundamental nature and tasks of fisheries management and hence to the general structure of this handbook.

1.6 An objective-driven process

Throughout this book, the word 'goal' is used to describe a broad aim. The term 'objective' is used to mean the object of an action, or what is intended to be achieved. Describing an objective will typically require a more precise description of the desired end point than for a goal. An objective must include explicit statements against which progress can be measured and it is helpful to think in terms of SMART objectives, that is, objectives should be Specific, Measurable, Achievable, Relevant and Time-bound. A goal may therefore be, for example, to harvest a particular stock sustainably. One of the objectives necessary to achieve this goal could be to ensure that fishing mortality does not lead to a reduction in the biomass of the stock below the biomass capable of producing maximum sustainable yield.

The over-riding goal of fisheries management could be summarised as the long-term sustainable use of the fisheries resources (e.g. the FAO Code of Conduct, Paragraph 7.2.1). Achieving this requires a proactive approach and should involve actively seeking ways to optimise the benefits derived from the resources available. This rarely happens in reality, though, and fisheries management is still most commonly practised as a reactive activity in which decisions are made and actions taken largely in response to problems or crises. A number of years ago, it was proposed by John Pope, the author of Chapter 9 of this book, that

the unspoken goal of most fisheries managers was to achieve 'minimum sustainable whinge'. This was a deliberate take on the well-known reference point of maximum sustainable yield and suggested that fisheries managers would commonly try to find solutions to problems that gave enough to each group of stakeholders to stop them complaining. The crisis decisions from such reactive management are then commonly attempts merely to solve the immediate problems without properly considering the broader perspective and the longer-term objectives. Such an approach may succeed in the short term to keep levels of dissatisfaction amongst stakeholders sufficiently low to avoid major conflict, but it is extremely unlikely to result in the best long-term use of the resources being exploited by the fishery.

The first step in proactive fisheries management has to be identifying the objectives for the fishery, in other words to determine, from the combined perspective of all stakeholders, what can be considered the optimal benefits for a particular fishery, group of fisheries or ecosystem. The goals for the fishery sector as a whole, usually stated in the fisheries policy, would be the starting point for this (Figure 1.2) but will need to be translated into specific objectives for each fishery, group of fisheries and ecosystem. In fisheries and in this book, these specific objectives are referred to as operational objectives and it should be possible for

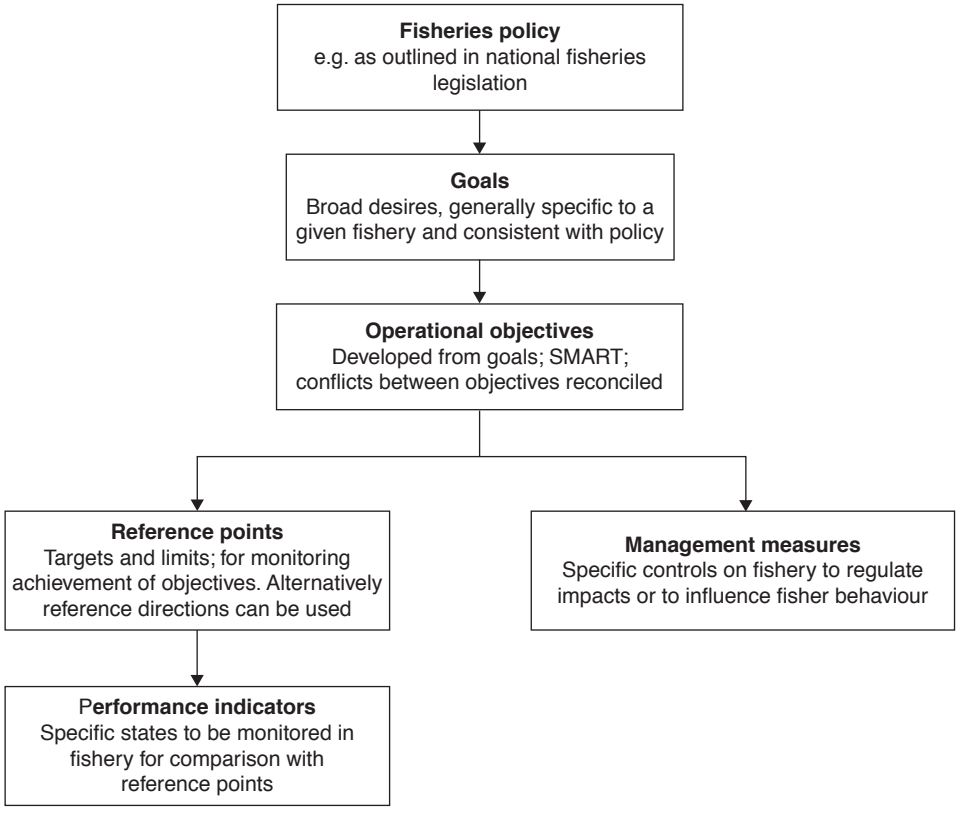


Figure 1.2 The hierarchical relationships between the different intentions (policy, goals and objectives), standards (reference points and indicators) and actions (management measures). Collectively these make up the management strategy and would be described in the management plan.

any observer, including the manager, to establish whether or not they are being achieved and hence whether or not the management strategy is appropriate and being successfully implemented. Operational objectives should also be used as the foundation for reference points (see Chapter 12), which are essentially the operational objectives expressed in a way that can be estimated or simulated in a fisheries' assessment (Figure 1.2). Once operational objectives have been agreed upon, a management strategy can be developed, including the suite of different management measures required to achieve those objectives.

The objectives for a fishery must encompass the bio-ecological, social, economic and governance dimensions of the fishery. Before they can actually be applied in fisheries management as operational objectives, any conflicts among different objectives would need to be identified and suitable and acceptable compromises found, so that the reconciled set of operational objectives can be simultaneously achieved. For example, it is very unlikely that management strategies that aim to maximise net incomes will also maximise employment opportunities. In setting objectives for a fishery with both goals, some compromise between them would have to be agreed upon before they could be expressed as operational objectives and an effective set of management measures devised to achieve them.

All of this may sound complex, but in reality is no more than most people do in order, for example, to develop a budget for their personal finances. Most of us have realistic but imprecisely expressed hopes and needs for our lifestyle as well as knowledge of the nature of the resource (in this case our net income). These hopes and needs are the goals of our budget but they will all compete for the same resource, our net income, so there are conflicts that need to be resolved. Therefore we have to modify our goals and express them more precisely: we develop operational objectives in which we specify what we can realistically achieve in terms of food, housing, education, etc. Thereafter, we need to decide on our budgeting strategy in order to meet those objectives: what type and quantities of food and clothing should we be buying; what type of housing can we consider; can we consider a regular visit to a distant relative, etc.

Clearly, our operational objectives must be consistent with the yield that we can expect from the resource (our income). Normally, the process of developing realistic objectives will require trade-offs and most of us find, for example, that we cannot allocate as much for entertainment or travel as we would like and at the same time make our rental or mortgage payments. Therefore priorities are established and compromises made until eventually we arrive at realistic objectives that balance our desires with our income and that provide a good guide on how to manage our finances from month to month and in the longer term. At the end of this, we should have a feasible financial management strategy that, barring totally unexpected events, will have a predictable outcome. If we have done our calculations correctly and responsibly, the strategy should mean we enjoy a reasonable lifestyle without being sued for bankruptcy. This is little different from the basic task, and overall hope, of the fisheries manager.

1.7 Management plans, measures and strategies

There is a lot of terminology floating around in fisheries management that, unless clearly understood, can cause further confusion in an already confusing environment. This book, of necessity, makes use of a lot of it. For example, in addition to the words goals and operational

objectives, the terms management plans, management measures and management strategies will crop up on many occasions. Chapters 7–10 each address different types of management measure. It is possible that in some hypothetical case, perhaps some single species fishery, the objectives for the fishery could be achieved by a single management measure, such as a specified total allowable catch (TAC). In practice, however, a number of management measures, for example encompassing all of gear regulations, area and time closures, input and output controls, and a system of user rights will be necessary to achieve the operational objectives. The goals, operational objectives and the sum of all these management measures are referred to as a management strategy. It should be noted that an effective management strategy should not contain so many management measures that compliance and enforcement become so difficult as to be practically impossible.

Once the operational objectives have been agreed upon, the manager needs to monitor how the fishery is performing and this requires the use of reference points: quantitative or qualitative descriptions of a target to be aimed for (e.g. average annual yield) or limits to be avoided (e.g. more than 10% unemployment in the fishery). If there is insufficient information to determine reference points, reference directions may be useful guides. Performance indicators, discussed in depth in Chapter 12, show the manager where the fishery system is in relation to the reference points. Performance indicators are pointers, for example the biomass of the stock or the average annual income of the fishers, that reveal the status of, trends and variations in key elements of a system. Indicators and reference points should be linked directly to operational objectives (Figure 1.2) because they serve the function of informing the manager as to how well the fishery is performing in relation to the specified objectives.

All of these goals, objectives, measures and strategies should be described in the management plan as described in Chapter 16.

1.8 The structure of this guidebook

Fisheries are social–ecological systems that exist in order to provide human benefits, and the task of the fisheries manager is to ensure that the fisheries under his or her mandate achieve their goals. Fisheries systems are invariably inherently complex in both the social and the ecological domains and as a result, the task of fisheries management is equally complex with many different facets, requiring a wide range of processes, methods and types of expertise. The task of the fisheries manager and of all those participating in fisheries management is to bring together, consider and integrate all of these different aspects to arrive at optimal solutions.

The danger arising from the complexity of the task is that one or a few aspects of fisheries management will tend to dominate whereas other aspects will be neglected. For example, at the advisory level, we have seen the disproportionate prominence given to single-species biological approaches in the recent past leading to unbalanced scientific advice whereas, often in the same systems, disproportionate weight has frequently been given to short-term social and economic considerations in flawed decision-making processes. Sometimes, 'magic bullets' have been promoted and implemented as the single key to successful management. Stock assessment, community-based management (CBM), individual transferable quotas (ITQs), marine protected areas (MPAs) and territorial use rights in fisheries (TURFs) are all management measures that have at times been promoted in this way. However, while each of these will have a role to play in certain situations, there is no such magic bullet and the hard but

not insurmountable reality is that fisheries management must be approached and practiced in a manner that brings together and combines the many different measures and components into a whole, balanced and functioning unit.

This guidebook is intended to demonstrate how fisheries management should be practiced as such a system. By definition, it is no easy task to describe a complex system, so how best can the fisheries management system be described? As editors, we struggled with this problem but in the end fell back on the tried and tested, but by no means perfect, method of breaking the task down into its major components. Therefore this book has been divided into a number of chapters (17 in total), each written by an expert or experts in that field and covering the major components of fisheries management. In addition to this introduction, the chapters are divided into six Parts: Part I covers the primary dimensions or features of fisheries management; Part II, the legal environment and institutional structure; Part III, the measures and tools available for managing fisheries; Part IV, the information that the manager will need for making good decisions; and Part V, some key aspects and aids for implementing fisheries management. Finally in Part VI, Chapter 17, we attempt to extract some key lessons from this book as a whole and to forecast changes and developments that can be anticipated in fisheries and fisheries management in the future.

The danger of such a fragmented approach is that it could fail to demonstrate clearly the linkages and necessary interactions between the different components – how they work together as a well-tuned engine. We and the other authors hope that we have avoided or at least minimised this risk in this guidebook by indicating, in each chapter, the linkages and interactions with the others and by showing, in the introductory and concluding chapters, how they all come together. As a result, none of the chapters should be seen as a remote island in a lonely sea but more as a vibrant hub within a busy network. Some chapters by their nature reflect the wholeness of fisheries management: most obviously and importantly of those is Chapter 16 on fisheries management plans. Other chapters that are also fundamentally multi-dimensional include those on institutional structure, partnerships, indicators and reference points, use of scientific information and on small-scale fisheries. We urge the reader to read this book in the same integrated manner as the editors and authors have attempted to assemble it.

1.8.1 The key dimensions of fisheries management

In Part I, Chapters 2–4 describe the fundamental dimensions of fisheries. These dimensions characterise a fishery and without them fisheries would not exist. The first of these dimensions, addressed in Chapter 2, encompasses the fish resources and the ecosystems in which they exist. This chapter explains why knowledge of the natural resources is essential for effective management and highlights the key properties and processes of the resources and ecosystem that influence their productivity and resilience. Recognising the necessity of pursuing an ecosystem approach in fisheries management, it includes discussion on the importance of habitat protection, interactions between species and of the state of the ecosystem as a whole. Climate change is identified as one of the several issues that are likely to have far-reaching impacts on fisheries in the future.

Chapter 3 looks at a fundamental human dimension and discusses the social aspects of fisheries management. It emphasises that fisheries management is really ‘people management’ and adopts an interdisciplinary, social–ecological approach to examine the social dimension. Major topics covered include the still common problem of open-access in fisheries and how

to deal with it where it occurs as well as the need to re-evaluate conventional science-based approaches to management and, instead, to understand fisheries as dynamic social–ecological systems that will never be completely understood but which we nevertheless need to manage. For such management to succeed a number of fundamental changes will be required and the chapter discusses, amongst other topics, the contribution of fishers' knowledge and the importance of ensuring that the management authority adopts a suitable institutional framework, in particular to enable genuinely participatory management.

As a means for survival and growth, human societies are heavily involved in and dependent on economics, that is, the 'production, consumption and transfer of wealth'.[1] Chapter 4, therefore, examines fishing as an economic activity. It starts by considering how failures in the market have contributed to failures in fisheries management and examines fishing as a production process and the influences of opportunity costs. It also considers, from an economic perspective, the very difficult but widespread problems associated with open-access to fisheries. The chapter goes on to use a bio-economic approach to consider the economics of fisheries and how this knowledge and understanding can contribute to effective management. It explores the economics underpinning fisheries within the context of development, considering the relationships between fisheries and poverty and how management decisions can influence this relationship.

1.8.2 The legal and institutional framework

Fisheries management is possible only in the presence of a suitable and functioning legal framework. Chapter 5 examines the legal aspects of fisheries management, working from the premise that fisheries law, nested in more general law, should enable, facilitate and support fisheries management. The chapter discusses national and international fisheries law and the relationship between them. Using a comparative approach, it considers the principle sources of the law and how the legal framework influences the administrative and management functions of a fisheries management agency and the powers, rights and functions that it prescribes. It also gives particular attention to the significance of the legal framework for the MCS functions and responsibilities of a management agency and manager.

In Chapter 3 it was stressed that fisheries management is about managing people and Chapter 6 develops this point through consideration of the practical ways in which management must be organised and explicitly allocated to the public and private institutions to ensure that the roles and responsibilities of the different stakeholders can be properly implemented. The chapter defines the formal fisheries manager as the natural person invested by the state with the responsibility for the exploitation of the aquatic resources, and explores the differing legal environments and institutional frameworks in which the manager may have to operate according to the principles adopted by the state, or regional body, in which he or she is working.

1.8.3 The fishery manager's toolbox

The motor mechanic repairing a car or outboard engine has a limited set of tools for the task and most readers will have experienced the frustration of finding that you do not have the

[1] From the compact Oxford English Dictionary, http://www.askoxford.com/?view=uk

correct spanner (wrench), screwdriver or some other gadget for a particular job. At best, not having the right tool will lead to minor delays, at worst it can lead to serious damage to the car, the amateur mechanic or both. Fisheries managers also have a set of tools at their disposal and need to ensure that they use the best one for the job or they will encounter similar problems, but of much greater scale, to those experienced by the hapless mechanic. Regrettably, selecting and applying the correct tool is a much more demanding task for the fisheries manager than for the mechanic. In Part III, this guidebook takes a broad view of what can be considered a 'tool' and explores not only the approaches that can be used to regulate direct impacts of the fishery on the resources and ecosystems but also tools that can assist in modifying the behaviour and actions of the fishers and other stakeholders.

Starting with the tools to regulate impacts, Chapter 7 focuses on regulation of fishing gear and describes the range of fishing gears used around the world, their catching principles, construction, operation and the species for which they are typically used. It goes on to examine gear selectivity and ecosystem effects of the different types of fishing gear in relation to size and composition of species, habitat effects and other impacts on the environment. This information is used to compare the performance of different gears against each attribute.

Fishing takes place in specific localities at specific times and Chapter 8 examines regulation of where and when fishing can take place as a measure to facilitate achieving some management objectives. It first answers the question of why a manager would want, or need, to use spatial or temporal measures and elaborates a number of objectives they could contribute to achieving. These include biological, ecological and social objectives. It considers the advantages and disadvantages of using area and time restrictions and then presents a number of case studies in which they have been successfully applied. Finally, it outlines the practical steps that are necessary for implementation of the measures.

Whatever other management measures are in place, ultimately the key factor determining whether or not harvest of a resource is sustainable will be the number (or biomass) of fish caught in relation to the population size or biomass as a whole. Gear restrictions and time and area regulations can all contribute to regulating this proportion but they will almost always need to be coupled with direct measures to regulate the amount of fishing. Such direct measures can be either restrictions on the intensity of use of fishing gear (called input controls) or direct limits on the amount of fish actually caught (called output controls). Chapter 9 deals with these two approaches and, as was the case with Chapter 7, starts by raising and answering the question of why one would use them, the answer to which is linked directly to the fishery management objectives. The chapter goes on to consider how to implement catch and effort controls, the structures required for their implementation and the problems that are commonly encountered in their use. It also provides some examples.

No matter what tools and measures are decided upon, their ultimate success depends on compliance and this is heavily dependent on the attitude of the fishers. Again, we come to the point of 'people management'. Chapter 10 addresses use rights in fisheries, a tool that is now recognised to be critical for effective fisheries management, or a potentially critical constraint if the manager does not get it right. This chapter also starts with asking the question of why use rights are relevant to the fisheries manager. In practice, use rights already exist in many fisheries, although these are not always formally recognised by the authorities, and the chapter stresses the need to consider any existing schemes before beginning to implement a new one or to make changes. Different types of use rights are described followed by consideration of the different attributes of use rights including the nature of the rights-holder, the allocation process, the duration of the right and whether or not they should be transferable. The

degree of success, or failure, of a system of use rights for the fisheries sector will be heavily dependent on choosing the best set of properties for the case in hand.

Finally in Part III, Chapter 11 describes the importance of partnerships in fisheries management. For convenience, partnerships are included in this guidebook as a tool but they are, in fact, much more than this and should be seen as a core property or essential attribute of successful fisheries management. Despite this, as presented in the chapter, partnerships in fisheries at present are more the exception than the rule. The author warns that partnerships must be carefully designed for each situation and that partnerships will not be successful under all conditions. The author also explains that many lessons have been learned from experience and good information is now available on the conditions and circumstances under which partnerships are likely to succeed. This chapter summarises that knowledge and provides guidance on how to implement effective partnerships under different conditions.

1.8.4 Information: knowing what is happening and using it to inform decisions

It is a fundamental principle of any management decision and action that it needs to be based on the best available information. Fisheries are no exception to this principle but the complexity and high degrees of uncertainty that are so common in fisheries management frequently make it very difficult to implement. In Part IV, Chapters 12 and 13 address approaches to ensuring that the best available information is used and in a suitable manner to support decision-making.

Indicators, or measures of the state of key elements in a system, are essential for monitoring and communicating the state of the fishery being managed. Chapter 12 explains the evolution of the demand for information and the place of indicators in that demand. It explains a process for developing a system of indicators and examines the various functions of indicators in fisheries management: representation, measurement, audit and control, and reporting and communication. It examines the various types of indicators that can be used and the way in which they can be organised. Finally, it outlines some of the main challenges associated with development and application of indicators, including reaching a suitable compromise between the need for simplicity and the conflicting need for realism in a system of indicators, the need to institutionalise the set of indicators, capacity limitations and information gaps and uncertainty.

Chapter 13 discusses the use of scientific information, in a broad sense, in fisheries management. The need to use the best available information as a basis for management decisions and actions is a fundamental requirement of the precautionary approach and of good management in general. The chapter explores the role of information in fisheries management, how it should feed into the management process and the different types of knowledge that are typically available in fisheries. Even in the best studied and monitored fisheries, uncertainty is a major problem and taking this into account in decision-making is essential for success. The chapter describes a range of different methods that can be used to generate relevant information. It goes on to describe some approaches for presenting information and the importance of taking a responsive, or adaptive, approach to management.

1.8.5 Management implementation

Getting the preparation and planning right for any complex activity is critical but of little or no value unless the plan is implemented effectively. If all the planning has been done

thoroughly, using the best available information, and the key stakeholders have bought into it, there is a high likelihood that the plan will succeed. However, plans are never perfect and circumstances, particularly in fisheries, are usually very dynamic and can change rapidly from 1 year to the next or even from 1 day to the next. Recent alarm about climate change, volatility of fuel prices and currencies, and soaring food prices are all indicative of rapid change that impacts most, if not all, fisheries. Implementation must, therefore, be as proactive and responsive as planning, and as robust to uncertainties.

Much of the implementation is in the hands of the stakeholders rather than the managers and in most economies governments do not interfere in the activities of the stakeholders provided they are being executed in accordance with the prevailing law and regulations and codes of ethics. Legal behaviour is not always the case, however, and fisheries are frequently particularly susceptible to illegal activities that can undermine management plans and obstruct the honest stakeholders from achieving their objectives. A key task of the fisheries authority, and therefore of the fishery manager, is to ensure that all fishing activities take place according to the plan as reflected in law and regulations. Effective enforcement falls within the domain of monitoring, control and surveillance (MCS), which is addressed in Part V by Chapter 14. The chapter describes how MCS fits into the broader frame of fisheries management and explains how an MCS system can and should be designed to suit different types of fishery, the management measures being applied in the fishery, and the human and financial resources available for MCS. MCS can also be implemented at each of the different stages during the fishing process. All of these considerations are brought together to provide general overviews of the effectiveness, advantages and disadvantages of different MCS components for different purposes. The chapter also provides guidance on how to plan an MCS system that is best suited to the specific needs and circumstances under consideration.

1.8.6 The special case of small-scale fisheries

This guidebook is intended to cover all types of fisheries, from small-scale, artisanal fisheries in developing countries to technology-intensive, large-scale fisheries in well-resourced developed countries. However, at least until recently, the fisheries on the high value, commercial end of this spectrum have received the greatest attention in almost all countries around the world, whereas small-scale fisheries have been relatively, and in some cases completely, neglected. As a result, the methods that have been developed and the lessons learned have been strongly skewed towards those high-value fisheries, which usually target only one or a few species. Consequently, despite the many failures and the remaining uncertainties, there is a well-developed and tested framework for effective management of this type of fishery and commonly the human and financial resources necessary to implement the framework are or could be available.

The 'high-tech' model, however, cannot be directly transferred to small-scale fisheries which are frequently marked by greater ecological, social and operational complexity but, perversely, commonly much fewer financial resources and capacity for management. In recognition of this problem, Chapter 15 on small-scale fisheries highlights the unique features of small-scale fisheries and the implications of those features for management. It starts by describing their global importance and goes on to discuss their characteristics and contributions to national and global political economies. Thereafter it considers the specific characteristics and requirements for management of this class of fishery including the

common objectives underpinning them, broad management approaches, suitable institutional arrangements and management planning. It also discusses the needs and approaches to build capacity for improving management of these important fisheries.

1.8.7 Where it all comes together: the management plan

Strong emphasis is placed on management planning throughout this guidebook, reflecting not only its central importance but also the reality that effective, proactive planning is still badly neglected in many fisheries around the world. As revealed in the subsequent chapters, fishery management planning has to address and integrate many different facets of the fishery, and the management plan is the instrument that brings them all together and specifies how the fishery is to be conducted. Chapter 16 addresses management plans, starting with a description of what they should contain and who should design them, followed by outlining the major steps and a timetable for developing a management plan, and then presents some of the considerations in implementing a management plan. Fisheries are inherently dynamic and conditions and objectives can change rapidly. For a fisheries plan to remain relevant and effective, it needs to be adjusted to address changes in the fishery and a regular review of any management plan is therefore essential. The chapter provides important elements of a review process and strategy. It also addresses the need to be consistent with principles of ecologically sustainable development (also reflected in EAF) in a management plan and points out some of the issues that this will need to cover. Finally, to illustrate the key features of the chapter, it provides some examples of fishery management plans that have been developed for a number of fisheries around the world.

1.8.8 What the future holds: emerging issues and challenges

This book concludes with Chapter 17, which begins by presenting an historical perspective on fisheries. It examines the evolution of fisheries and fisheries management from the beginning of the 20th century, when the impacts of exploding technological development on fish and fisheries were beginning to be felt, through the expansion phase during the second half of the last century into the contemporary period of 'fisheries reform'. This background helps to explain the current crisis and modern approaches to resolving it. The chapter then explores the emerging best practices, drawing on the conclusions and perspectives presented in the preceding chapters. It finishes with an attempt to look further ahead and considers how fisheries management may evolve in the future. It does so by considering three possible governance scenarios: the (hopefully) extremes of a totally market-driven world and a world dominated by governance chaos. These are contrasted with the third, best-case, scenario of a transformed world.

On that forward-looking note, we wish you enjoyable reading and hope that you find ideas and information in this book that will assist you in whatever task or tasks you face in the challenging world of fisheries and their management.

Sources and recommended reading

Each chapter provides a list of sources and recommended reading as well as potentially useful websites for the subject it addresses. Therefore, only a few 'core' references and recommended works are provided here.

Berkes, F., Mahon, R., McConney, R., Pollnac, R. and Pomeroy, R. 2001. *Managing Small-scale Fisheries. Alternative Directions and Methods*. IDRC, Canada. 320 p.

Charles, A.T. 2001. *Sustainable Fishery Systems*. Blackwell Science, London. 384 p.

Cochrane, K.L. 2000. Reconciling sustainability, economic efficiency and equity in fisheries: The one that got away? *Fish and Fisheries*, 1: 3–21.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome, FAO. 41 p.

FAO. 1996. Precautionary approach to capture fisheries and species introductions. *Technical Guidelines for Responsible Fisheries No. 2*. Rome, FAO. 54 p.

FAO. 1997. Fisheries management. *Technical Guidelines for Responsible Fisheries No. 4*. Rome, FAO. 68 p.

FAO. 2003. The ecosystem approach to fisheries. *FAO Technical Guidelines for Responsible Fisheries. No. 4,* Suppl. 2. Rome, FAO. 112 p.

FAO. 2005. *Putting into Practice the Ecosystem Approach to Fisheries*. Rome, FAO. 76 p.

United Nations. 1998. *International Fisheries Instruments with Index*. Division for Ocean Affairs and the Law of the Sea, Office of Legal Affairs. United Nations, New York. 110 p.

Part I

The Primary Dimensions of Fisheries

Chapter 2

Biology and Ecology Considerations for the Fishery Manager

Yvonne Sadovy de Mitcheson

2.1 Introduction

To manage and conserve fisheries effectively in the long term requires an understanding not only of the resources and resource users but also of the wider ecosystem that supports fisheries. This chapter is about the resources: the biology and ecology of the fishes and invertebrates that provide food and livelihoods for billions of people and the ecosystems within which they exist. Although demand for seafood is growing and shifts over time according to fashions, opportunities and economics, the natural constraints of the underlying resources remain within a set of biological limits. With growth in human populations and the increased pressures these bring to bear on marine environments, the need to understand and operate within the biological 'limits' of target and non-target species and the ecosystems within which they function is ever more apparent.

This chapter identifies and explores key biological and ecological principles underlying the three pillars of modern-day fishery science: biological parameters of target and non-target species, habitat associations, and ecosystem and interspecific interactions. These are explored in the context of a sustainable* approach to fishery practices and the need to minimize threats to marine biodiversity and ecosystem function. The approach taken is mindful of the common limitations in access to, or capacity for, data collection and scientific study in many regions and of the enormous diversity of life histories of target and non-target species. It builds on the Precautionary Principle, the Convention on Biological Diversity (CBD), the Ecosystem Approach to Fisheries (EAF) and the FAO Code of Conduct, Article 7.2.2 (Table 2.1).

An exhaustive coverage of fishery-relevant biology and ecology is not possible in a single chapter, so the focus will be on the key information, concepts and principles that managers need to know and consider with reference to relevant literature for further detail. Recent insights and directions will be highlighted. To facilitate forward planning, emerging issues in fisheries are identified that are likely to attract greater interest and discussion in the near to mid term or are already subject to debate. These issues are briefly examined from biological and ecological perspectives and include marine protected areas (MPAs), mariculture and restocking, invasive and threatened species, and climate change.

* As defined by FAO to ensure use of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity of or any of its components.

Table 2.1 Some key provisions of selected instruments for sustainable use and biodiversity conservation of natural aquatic resources.

Instruments	Biodiversity	Spawning and nursery areas	Transboundary movement/migratory species	Bycatch or discards	Biological parameter and fishery-related information	Habitat and ecosystem
Convention on Biological Diversity	Conserve biodiversity. Identify and monitor activities likely to produce significant adverse impacts. Integrate actions into policy. Promote recovery of threatened species.	Identify special areas for protection of biodiversity.	Communicate threats to biodiversity to relevant jurisdictions and corrective action taken.		Exchange and collect information, inclusive of indigenous knowledge. Apply best available scientific information. Lack of knowledge no excuse for inaction.	Identify special areas needed to protect biodiversity. Maintain biodiversity at the biological community, habitat and genetic levels and viable populations, ecosystems and habitats. Promote protection of natural habitats and ecosystems.
FAO Code of Conduct for Sustainable Fisheries	Conserve target populations and species, and species belonging to the same ecosystem or associated with or dependent upon the target species. Endangered species protected.	Protect critical fisheries habitats and life phases, inclusive of nursery and spawning areas, juveniles and spawners.	Promote conservation and management, inclusive of compatible measures in areas within and beyond national jurisdiction. Address issues of transboundary fish stocks, etc., exploited by different states.	Minimize catch of non-target species, and impacts on associated or dependent species. Minimize waste through lost or abandoned gear and negative impacts on endangered species. Encourage implementation of technologies and methods that reduce non-target catch.	Undertake research and data collection to improve scientific and technical knowledge on status of fisheries and ecosystems, including data on bycatch, discards and waste and interactions with the ecosystem. Provide sufficient institutional and other support. Adopt appropriate measures, based on the best scientific evidence available.	Protect critical fisheries habitats in aquatic ecosystems, such as wetlands, mangroves, reefs, lagoons.

Ecosystem Approach to Fisheries	Avoid threats to endangered, threatened or protected species, genetic and ecosystem diversity and ecological processes. Promote responsible development of aquaculture in relation to genetic diversity and ecosystem integrity.	Maintain reproductive viability.	Conserve and manage straddling fish stocks and highly migratory fish stocks. Coordinate for compatible management across jurisdictions and the high seas.	Minimize bycatch and discards and avoid threats to bycatch species.	Maintain reproductive viability; fishing should not affect dependent or associated species or threaten reproduction.	Maintain ecosystem integrity by (i) maintenance of biodiversity at biological community, habitat, species and genetic levels, and (ii) maintenance of the ecological processes that support both biodiversity and resource productivity. Pay special attention to endangered, threatened or protected species.
Precautionary Principle	Apply the precautionary approach widely to conserve, manage and exploit living aquatic resources.	Maintain long-term reproductive viability.		Take account of impact of fishing activities, including discards, on non-target and associated or dependent species.	Ensure that stock-specific target reference points are not exceeded. The absence of adequate scientific information is not an excuse for inaction.	Manage conservatively to factor in uncertainty due to environmental fluctuations and catastrophic events, etc.

2.2 Why marine resource managers need to know about biology and ecology

Fishery managers must have a fundamental appreciation of how aquatic systems function, a clear set of objectives and the priorities and guidelines of Table 13.1. Nowadays, with information online readily available, access to expert consultancies or research institutions in many places, and a wide range of excellent literature, managers can make many important decisions even if they lack a permanent team of experts or operate exhaustive research programmes. In addition to old and new fishery models developed for fisheries and ecosystems, many of which are 'data-hungry', a range of guidelines, precedents and indicators can be consulted for making decisions under conditions of data scarcity and when management capacity is limited. Thus, there should never be an excuse not to discuss or consider biologically based management.

Given the diversity of life histories amongst exploited species, expanding market demand, increasing threats to species and habitats, and pressures from a growing diversity of stakeholders, managing fisheries resources effectively and in a sustainable way is a major challenge that calls for biological and ecological understanding of exploited species and the social and economic context of the fishery. Moreover, the lines are increasingly blurred between traditional and commercial fishery practices for food, and activities such as mariculture, restocking, artificial reefs, ecotourism and no-take MPAs. For example, there are now activities such as 'capture-based mariculture' and 'mariculture-based fisheries' that involve both wild capture fisheries and farming (hatchery production), may affect very different sectors of the same fishery and can require different management approaches from more conventional fisheries that seek mainly to maximize yield. Certain species can be the focus of different consumer markets, as in the case of reef or freshwater species of interest for both food and the ornamental trades. MPAs are increasingly advocated as a fishery management tool, yet while they show great promise, their fishery benefits are unknown in most cases. Moreover, there is often a lack of clarity regarding the degree of protection from fishing intended by proposed protected area management initiatives and whether partial, as opposed to complete protection, from fishing can carry significant benefits.

Managers need, therefore, to have a basic understanding of the underlying biological, ecological and socio-economic principles for good management. Another important reason why managers must understand the fundamentals of the species and fisheries they work with is to be able to communicate with others. For example, if fishing communities consider that a trend of declining fish numbers in their area has occurred because the fish have 'decided' to move somewhere else or into deeper water, and therefore conclude that site-based management in their area is meaningless; a manager should be able to explain what the declines likely indicate and the ways (including site-based) that declines could be addressed. In the absence of scientists being available or able to provide simple explanations of why, for example, 'nursery' areas are important for young fish or invertebrates, or why the millions of eggs produced by fish don't result in millions of fish, managers may need to provide clear descriptions. In a participatory assessment combining scientific and traditional knowledge, they must be able to play a mediating and facilitating role if needed.

Managers are often the critical link between the resource or user communities on the one hand and government, non governmental organizations (NGOs) or aid agencies on the other. They must be informed enough to be able to convey in simple terms the essentials, complexities and needs of the fisheries they steward to build the necessary understanding and constituency for support, action and change.

2.3 What managers need to know about biology and ecology

2.3.1 Back to basics

Once fishery objectives have been set, fishery managers need to address questions such as how many fish or how many fishers can be accommodated, what gears should be used and where and when can they be used to get the best yields each year from the fishery. This must be done without compromising long-term sustainability or ecosystem function among other possible objectives. There might also be questions about allocations among different fishing sectors, the need to consider very different stakeholders (e.g. recreational versus commercial users) or the implications of fishing practices on high-profile non-target species, such as seabirds and marine mammals. Consideration is also needed in respect of the long-term viability of non-target species in multi-species fisheries and of the ecosystem as a whole (Table 2.1).

As background to the knowledge base needed for fishery managers, a brief history of the changing perspectives of fishery science is given later, followed by the concepts and principles that managers need to know. Historically, fishery managers were interested in a few basic biological and fishery parameters that described inputs and outputs to the target fishery, notably recruitment, growth, fishing and natural mortality (Figure 2.1). Balancing rates

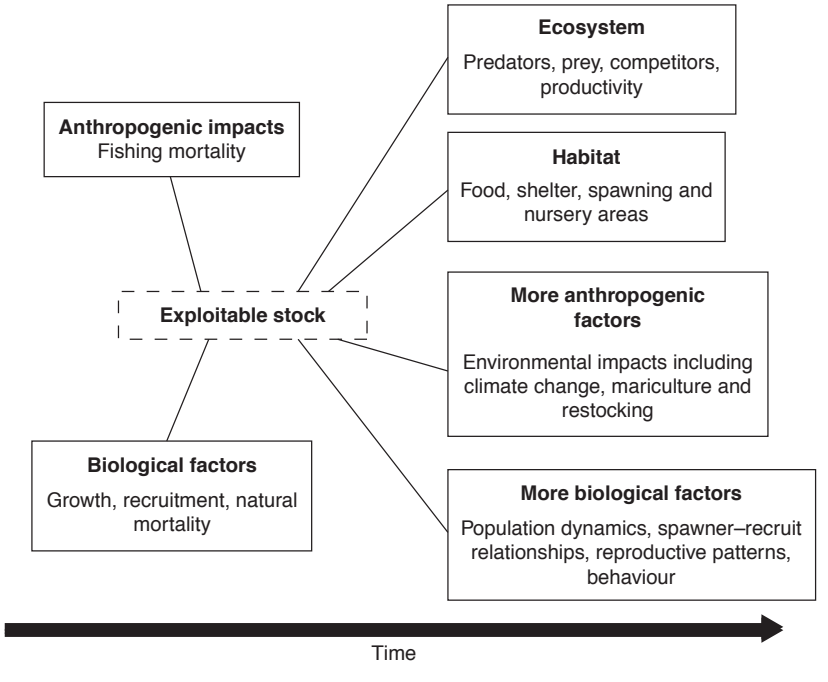


Figure 2.1 Historical and present-day perspectives on biological and ecological parameters and information of relevance for the sustainable management of aquatic natural resources. The time axis moves from the past (left) to the present. In the early years of fishery science, the information used was catch and effort with no biological or ecological components. As dynamic pool models developed, a few biological parameters shown lower left were applied. Awareness and understanding of the need for more detailed information has resulted in a much wider range of data being necessary for management (boxes on the right).

of population increase (growth and recruitment through reproduction) and declines through mortality were largely addressed by controlling fishing effort.

The earliest models considered only single species and included, for example, the surplus yield (production) models that require only catch and effort data and dynamic pool (per-recruit) models (Table 13.3). Since then, a complex range of ecosystem-based multi-species models has been developed (Table 13.4). The trend has been one of increasing complexities and data-needs in attempts to more closely reflect some of the natural realities of fished systems and address the growing range of fishery-related activities and concerns. The challenges of this approach are the assumptions that must be made to complete such models which are continually being refined. Although the details of fishery modelling are beyond the scope of this chapter, major biological and ecological parameters of relevance are identified, and many excellent publications are available for reference (see Sources and recommended reading).

The application of these early models did not lead to sustainable fisheries in many instances and it is important to explore some of the reasons why. A discussion of the technical and social challenges of management is beyond the scope of this chapter, but they are obviously major factors in the success or otherwise of fishery management (see also Chapter 17). With advances in our understanding of marine systems, however, factors have emerged in relation to the biology and ecology of marine systems that have alerted workers to fundamental shortcomings of some of the earlier models and approaches and point the way to better practices as well as inform technical advances. Examples include insights into details of fish behaviour in relation to fishing, habitat needs and unusual reproductive modes that variously influence responses to exploitation by populations in ways previously not considered or recognized. As a first step, we need to understand the dynamics of unexploited populations.

The underlying basis of fisheries can be found in the pattern of natural population growth of animals that generally conforms to the 'S-shaped' logistic, or similar, curve (Figure 2.2). When populations are small, they may grow quickly because competition between conspecifics is low, and food and shelter are plentiful. However, as the (unfished) population grows, it will eventually reach the natural 'carrying capacity' of the environment at which point no more animals can be supported because there is no more food or shelter for additional fish to survive, or because competition between individuals is too intense. The 'carrying capacity' asymptote, or upper limit, is important because, aside from natural variability around this level, population growth stops and the growth rate of individual fish slows down.

Population growth rate (i.e. increase in number of organisms per unit of time) will be greatest at intermediate population levels, that is, where the slope of the curve is at its steepest, and this is the point above (often well above) which fisheries should be maintained by good management. This point, the biomass at which maximum sustainable yield (MSY) occurs, is typically assumed to occur at 50% of carrying capacity (Figure 2.2), and modern fisheries management precautionarily aims to maintain biomass above that limit (how much above the limit is appropriate will depend on the species). If fishing pressure is too high and too many animals are removed too quickly, the compensatory density dependence shown at the intermediate population levels declines, population growth rate slows and low-population levels may even be compromised because too few spawning fish remain. At such low population levels, it is possible that fish densities are too low for mates to locate each other or for adequate protection from predators (for example, in schooling species), or for other reasons.

A fascinating aspect of fisheries is that, effectively managed, fished populations are more productive than non-fished ones. The generation of a sustainably fishable surplus yield or production in fished populations comes from the removal of fish at a rate that does not

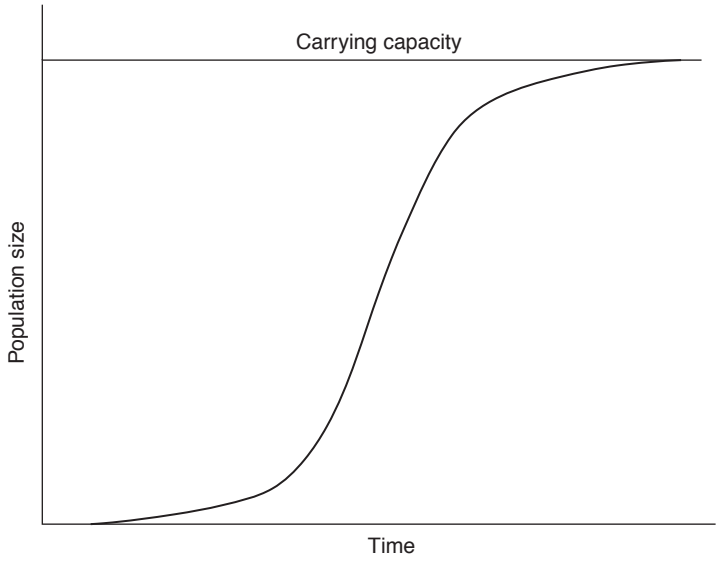


Figure 2.2 The 'S-shaped' logistic, or similar, curve describes the growth form, over time, of animal populations. Unexploited populations will generally be close to 'carrying capacity', the ability of the environment to support their numbers. This could be determined by limits to food, shelter or other ecological factors and might be the state in a typical unfished or 'virgin' stock. Population growth rates change according to population size in relation to the carrying capacity and show maximum growth rate at about 50% of carrying capacity.

exceed the ability of the target population to replace the removals from fishing, over the long term, through density-dependent responses. A well-managed fishery should remove fish at a rate that does not exceed that of replacement but only takes the 'surplus' to replacement. This 'surplus' is zero in a virgin stock and greatest at the steepest point of the population growth curve, the point at which MSY is produced. In early conventional fisheries management, it was suggested that fisheries management should aim to maintain the stock at this point. However, applications of the original 'surplus yield' models were limited in their ability to maintain stocks at MSY because they only used catch and effort data and ignored important biological and ecological attributes of individual target species. These attributes ranged from ecosystem and interspecific interactions to the importance of environmental stochasticity.

To manage better, managers needed to know much more about the basic attributes of the life history of exploited species of fish and invertebrates (Box 2.1; Section 2.3.2) as well as other critical processes that affect productivity and vulnerability to fishing, inclusive of multi-species and ecosystem considerations. Considering ecosystem and interspecific interactions is important because fishery production depends not only on the target species but also on the carrying capacity of its environment and on the other species on which it depends for food or shelter, or, indeed, those that might prey upon or parasitize it. Marine fishes and invertebrates depend on the environment in which they live, in direct and often complex ways, and more realistic models are only possible by factoring in these interdependencies and the feedback loops of which they form a part. These include the multi-species, ecosystem-based models referred to earlier.

Box 2.1 Bipartite Life Cycle

Most marine species of exploited fish or invertebrate have what is known as a 'bipartite' (two-phase or two-part) life cycle in which the tiny fertilized egg and larval phases are spent in the plankton (pelagic early phase), whereas the juvenile and adult phases occur in association with specific habitats, such as estuaries, around reefs (benthic phase), in the open ocean or over the continental shelf (Figure 2.3). Relatively, few fish species spend their entire life, including the adult phase, in the open ocean (i.e. have a pelagic adult phase as well) but several of those that do are very important to fisheries, including herring, mackerel and tuna. Most of the thousands to millions of eggs released in a bipartite life cycle perish before settlement.

Important exceptions to the typical bipartite pattern are the sharks and rays, which either produce a small number of large eggs deposited directly on the substrate or bear live young ready for independent life once released from the female. Also, several commercial marine species are live-bearers, such as certain rockfishes (*Sebastes* spp.), and some produce demersal eggs, such as rabbitfishes (Siganidae) or queen conch (*Strombus gigas*).

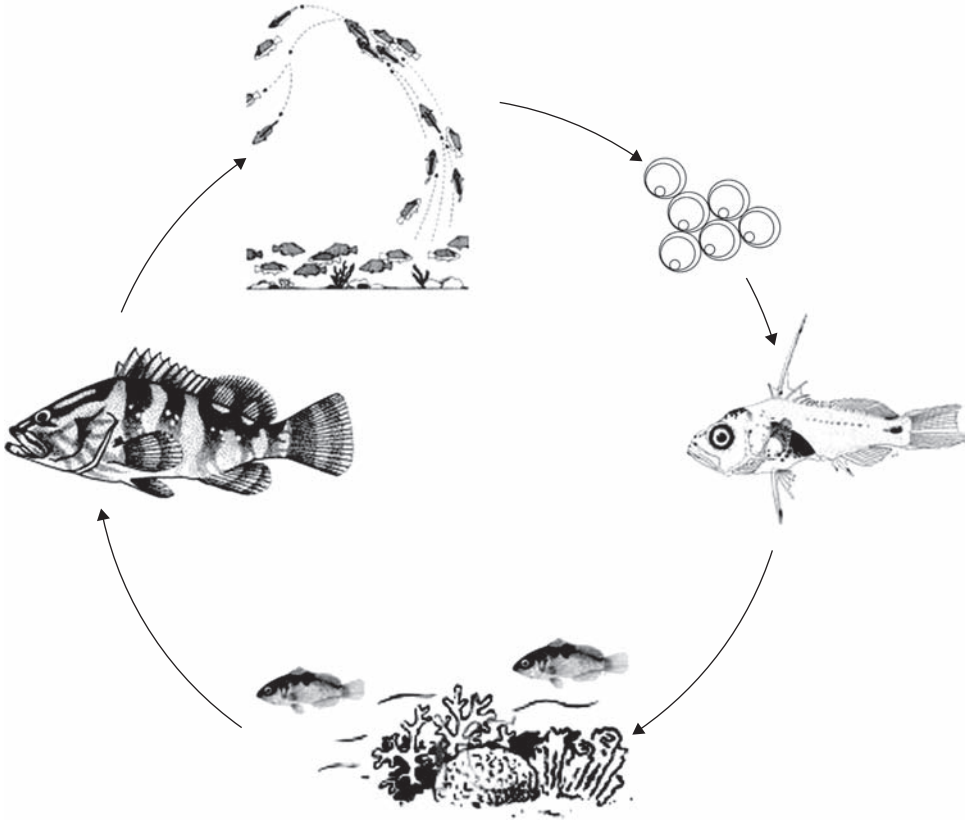


Figure 2.3 Modified from: Sadovy, Y. and Eklund, A.M. 1999. Synopsis of biological information on *Epinephelus striatus* (Bloch, 1972), the Nassau grouper, and *E. itajara* (Lichtenstein, 1822) the jewfish. U.S., Dep. Commer., NOAA Tech. Rep. NMFS 146; FAO Fisheries Synopsis 157, 65p.

2.3.2 *Building blocks: the foundation of fisheries science*

Three interrelated classes of factors, or pillars, determine not only how populations increase and decrease over time but also how assemblages of species can change under exploitation pressures and in response to wider environmental influences.

- *Biological parameters of target and non-target species*: natural mortality, growth, fecundity, reproductive rates, patterns and behaviours, spawner–recruit relationships, etc.
- *Habitat needs and shifts throughout life*: dispersal of larvae and adults, habitat shifts with growth, seasonal feeding or breeding migrations of adults, etc.
- *Ecosystems and interspecific interactions*: predator/prey and trophic relationships and other interspecific interactions, direct and indirect effects of species interrelationships, etc.

Each is addressed in the following sections and the reader is referred to key literature for further elaboration.

Biological parameters of target and non-target species

Biological parameters of particular relevance to fisheries describe key aspects of life history, such as growth rate, natural mortality, maximum size and age, size and age of sexual maturation, diet, spawning season and population dynamics. Although these differ enormously among the thousands of species of fish and shellfish exploited today, instructive associations between some of the parameters, or proxies for hard-to-obtain information, allow for some general conclusions of management relevance to be made without the need for comprehensive information. Using simple guidelines, for example, we can identify species likely to be more or less resilient to fishing, estimate size of sexual maturation or determine whether species are long-lived or aggregate to spawn and are, hence, particularly vulnerable if aggregations are targeted.

Vulnerability to fishing

The first step in evaluating the possible vulnerability of species to fishing is to examine a few key life history parameters or ecological factors. Large and long-lived species such as certain sharks, reef fishes, bivalves such as the giant clam and certain groundfishes, for example, tend to be much more susceptible to overfishing and support much less intensive fisheries than short-lived species that have rapid population growth rates, such as herrings or sardines (Jennings *et al*., 2001). Species that produce very few young each year, such as many sharks, seem to be particularly susceptible, although the converse is not true: high fecundity does not necessarily make species less vulnerable, and hence more resilient, to fishing (see later). Many deep-sea species that live in cold, food-poor, environments and have slow growth and reproduction rates are especially vulnerable when concentrated in specific habitats, such as seamounts, that are a focus of fisheries. Other potential risk factors are small geographic range, endemism and habitat specializations. Managers need to pay special attention to such species.

Examples of guidelines that allow for preliminary evaluation of little-known target and non-target species in terms of their likely susceptibility to fishing and possible management interventions include consideration of: large maximum size; longevity; large size or high age of sexual maturation; low natural mortality; behaviours that periodically and predictably concentrate a large proportion of the adults in a population and become the focus of fishing, and habitat specializations (Table 2.2). These points are expanded here.

Table 2.2 Guidelines for management options given differing knowledge bases.

Current knowledge base	Current management options	Planning for the future
No knowledge other than qualitative on typical sizes of key commercially important species in markets.	• Apply conservative and precautionary approach and refer to FAO Code and CBD. • Reliable planning for future income and food security or for new activities is compromised, and fishing pressure should not be increased until a knowledge base is established. • Encourage traditional customary use of biological resources compatible with sustainable use and conservation. • Apply 50% rule of thumb for sexual maturation estimate to reduce catch of immature fish of key commercial species. • Identify possible vulnerable target and non-target species and critical habitat from published literature and consultation. • Refer to IUCN Red List for listed threatened species.	• Develop knowledge base, at least for regular documentation of species composition, landings and effort information. • Conduct interviews to assess fishery status, and collect information on traditional ecological knowledge for fishery history. • Special attention to be paid to suspected, or potentially vulnerable, species, habitats or spawning aggregations. • Assess potential of MPAs/temporal measures as management tools.
Lumped species composition. Length data for major species/species groups by year. Short- or long-term catch data. No effort or bycatch data. No local biological studies.	• Apply conservative and precautionary approach and refer to FAO Code and CBD. • Avoid increase in fishing pressure until knowledge base strengthened. • Apply 50% rule of thumb for sexual maturation estimate to reduce catch of immature fish of key commercial species. • Assess length and catch data for any changes in length over time; declining average length or catches might signal overfishing. • Consider reductions in effort if substantial declines in length or catch. • Identify actual or possible threats to vulnerable target or non-target species and possible critical habitat from published literature and consultation. • Refer to IUCN Red List for listed threatened species.	• Strengthen knowledge base, including for species-specific information on target and non-target species. • Collect fishing effort data for major sectors. • Plan for biological and ecological studies on key commercial species. • Identify actually or potentially vulnerable species or habitats. • Apply traditional knowledge to reconstruct fishing history and assess perceptions on fishery status. • Assess potential of MPAs/temporal measures as management tools.
Species-specific composition and length data, short- or long-term landings and fishing effort data by year by major fishing sectors, limited bycatch information, biological studies conducted on few major species. Little ecological information.	• Able to move towards more sustainable use of resources. • Consider food security a priority objective if relevant. • Refer to Precautionary Principle, FAO Code, CBD and EAF. • Apply Biological Reference Points (BRPs) where possible. • Manage for sustainable yield concomitant with maintenance of biodiversity. • For long-term data sets can assess status (Garibaldi and Caddy, 2004).	• Conduct biological and ecological studies on key species. • Balance present use, conservation and sustainable use of resources. • Reduce excess fishing effort. • Explore the use of more selective fishing gears to reduce bycatch. • Ensure monitoring of landings and effort are standardized.

	• Manage vulnerable life history phases including for nursery and spawning where relevant. • Consider value of MPAs and temporal protection. • Reduce take of non-target species and immature fish or manage holistically if different fishing sectors focus on different life history phases of the same stock. • Refer to IUCN Red List for threatened species or to footnote.	• Special attention to be paid to suspected, or potentially vulnerable, species, habitats or spawning aggregations.
Detailed knowledge on all fishing sectors by year, biological and ecological information on key fisheries and major bycatch species, long-term catch and effort data series. Biological parameters for stock assessments determined.	• Capable of optimising use of resources concomitant with long-term sustainability and reducing threats. • Refer to Precautionary Principle, FAO Code, CBD and EAF. • Manage for sustainable yield concomitant with maintenance of biodiversity by applying stock assessments and other BRPs. • Address vulnerable life history phases including for nursery and spawning where relevant. • Explore improved gear selectivity to reduce unwanted outcomes such as habitat damage and bycatch. • Consider value of MPAs and temporal measure. • Refer to IUCN Red List for listed threatened species or to Footnote.	• Ecosystem-level analyses possible if relevant information and capacity acquired. • Balance present use, conservation and sustainable use of resources. • Reduce excess fishing effort. • Integrate fishery with coastal management planning. • Consider transboundary and other issues relevant to larger spatial scale management. • Ensure that the living resources in the exclusive economic zone are not endangered by over-exploitation. • Account for uncertainties relating to the size and productivity of the stocks and environmental conditions.

Guidelines to assess possible vulnerability of exploited species according to life history criteria. Adapted from Musick (1999).

	Vulnerability			
Life history parameter	Low	Medium	High	Very high
von Bertalanffy k	>0.3	0.16–0.30	0.05–0.15	<0.05
Age of sexual maturation (years)	<1	2–4	5–10	>10
Maximum age (years)	1–3	4–10	11–30	>30
Natural mortality (M) relative to fishing mortality (F)	High	Medium	Low	Very Low
Recruitment variability	Low	Medium	High	Very High

- *Large maximum size*: Larger species tend to be longer lived, in extreme cases exceeding 100 years but more typically having longevity of several decades, often more. There is a well-documented and strong correlation between vulnerability and large size, and information on maximum body size is readily available for most species. However, maximum size and vulnerability are not always related, as in the case of fast-growing pelagic species such as the dolphinfish, *Coryphaena hippurus*, or certain smaller groupers that are long-lived but may not exceed 50 cm (www.iucnredlist.org).
- *Size of sexual maturation*: Larger species typically become sexually mature at a bigger absolute size and higher age than smaller species. This has been shown for a number of families and provides a general rule of thumb that, in the absence of more detailed information, sexual maturation commonly occurs at about 50% of the maximum size of the species. This could be used as a guideline for, for example, setting a minimum size at first capture. Another guideline in fisheries that is sometimes applied is to allow species to attain a size whereby they can spawn at least once before capture. However, since long-lived species must live a long time to replace themselves on average, and older females frequently make larger contributions to future recruitment (Section Reproductive viability), it is advisable to allow several spawning events before capture for long-lived species in the absence of more detailed stock assessment.
- *Natural mortality*: Larger species within a given taxonomic group tend to have lower natural mortality rates than smaller species, and in general the larger and longer lived the species the lower the natural mortality (covered in more detail later).
- Aggregating behaviour: Many pelagic, estuarine and medium-to-large reef fish as well as some invertebrate species form short-term spawning aggregations as the only or principal means of reproduction. These can be very brief and occur regularly at specific locations each year. Such species can be highly susceptible to overfishing if the aggregations, or migrations to aggregation sites, are a target of fishing. A global survey of aggregating reef fishes suggests that most surveyed exploited aggregations are declining (Figure 2.4). Aggregation spawning may be the only spawning opportunities for some species and, if a large proportion of the adult population is concentrated in a few readily accessible sites, the potential for recruitment overfishing is especially high. Spawning sites should be protected as recommended in the FAO Code of Conduct.
- *Reproductive mode*: In some species, the mode of reproduction may call for special management attention. One example is hermaphroditism. Among hermaphrodites, most exploited species show some form of sequential sex change (usually female to male but the opposite direction also occurs). Such species naturally have skewed size-to-sex relationships, with the second sex relatively less abundant than the first sex. In female-first (protogynous) species, fishing pressure that focuses on larger individuals will tend to take more males than females. This could compromise reproduction if males become scarce and are not replaced quickly enough by female-to-male sex change, leading to heavily female-biased adult sex ratios. Adult sex ratios in such species should be monitored and stock assessments need to be adjusted to sex-changing species both because of skewed sex ratios (i.e. a one-to-one sex ratio cannot be assumed) and because male and female natural mortalities differ. In other species, special consideration may be necessary, such as live-bearing sharks or seahorses in which fecundity is low and the capture of a near-term pregnant adult removes not only the adult but also a substantial number of competent young.

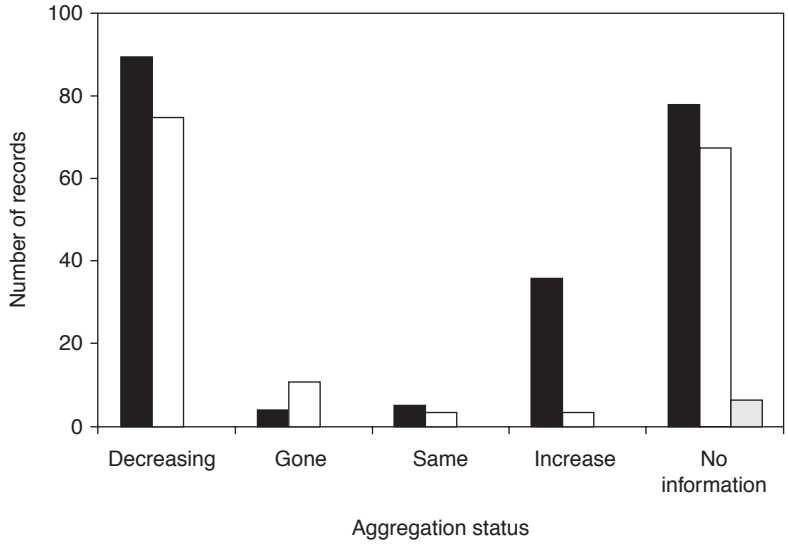


Figure 2.4 Records in the global database of the Society for the Conservation of Reef Fish Aggregations indicating the status of exploited spawning aggregations of reef fishes; each record represents one species at one site. Information was obtained from the published literature, fishery reports and semi-structured fisher interviews. 'Gone' (eliminated) indicates that the aggregation has not been found in recent years or that catches no longer occur in appreciable numbers. 'No information' indicates that no indication on status was available for known exploited aggregations. 'Same', 'Decreasing' or 'Increase' indicate unchanged, reduced or higher catches or CPUE relative to earlier reference points, respectively. Black bars are records from the Indo-West Pacific, white bars the western Atlantic, and the grey bar from the eastern Pacific. Modified from www.scrfa.org and Sadovy *et al*., 2008.

A note on fecundity in relation to vulnerability to fishing is relevant here given the widespread, but unfounded, assumption that high fecundity (number of eggs produced) confers especially high resilience to fishing. Although low fecundity is often associated with low resilience, the converse is not necessarily true; high fecundity does not make fish exceptionally able to withstand heavy fishing, according to life history theory. On average, and at equilibrium, the theory predicts that one male and one female will produce two young in their lifetimes irrespective of the type and number of eggs involved. In other words, strategies of 'many eggs and low survivorship per egg' are equivalent to one of 'few eggs and high survivorship per egg'. The fecundity of species like sharks and rays that produce just a few advanced young each year, therefore, cannot be directly compared with that of pelagic spawners, which produce thousands or millions of tiny (about 1 mm diameter) eggs each year, because survivorship of eggs to adulthood is so different between the two very different modes of reproduction. Many eggs are produced in the latter case as a strategy known as 'bet-hedging' that at least some will survive despite the high mortalities that such eggs are exposed to.

Indeed, highly fecund fishes can be threatened with extinction (Hutchings, 2001). Examples include species like the giant yellow croaker (*Bahaba taipingensis*) and the southern bluefin tuna (*Thunnus maccoyii*) that produce millions of eggs per year. Declines in highly fecund species can be further exacerbated by fishery-produced truncations of their age structure reducing the ability of populations to withstand environmental fluctuations (Hsieh *et al*., 2006).

Reproductive viability

A key focus of management today is to maintain sufficient spawning stock and avoid recruitment overfishing, an issue variously addressed by all of the instruments in Table 2.1. Ensuring the viability of exploited populations that are of particularly low resilience to fishing is especially challenging in the case of multi-species fisheries. This is because species that are more susceptible to fishing can become overfished while more resilient species in the same fishery continue to be viable.

Spawning stock not only depends on the numbers of reproductive adults but also on overall egg production and opportunities for eggs and sperm to meet. Across the wide range of exploited species, the number of eggs produced by females (fecundity) each year is highly variable both over time and also according to female size, with larger females having exponentially higher fecundity than smaller ones of their species. In one famous analysis, one large female red snapper produced the egg-equivalent of 212 smaller females of the species. Moreover, the eggs of older females of certain species may have higher viability compared to those of younger females. Hence, larger, older females may contribute disproportionately more recruits (through higher egg viability and number) to the population than younger females. This point is important because it means that assessment of spawning biomass is not simply a matter of total female weight, or of counting the number of female adults, but also depends on the relative proportions to future recruitment from females of different sizes, among other considerations. It also means that consideration might have to be given to protective measures for large females, or those obviously bearing eggs, as in the case of 'berried' lobsters.

Ensuring sufficient spawning biomass to avoid recruitment overfishing may require not only the maintenance of sufficient numbers (biomass) or densities of reproductive animals and sufficient large females, but also a consideration of sex ratios, places, frequencies and times of spawning. For example, certain sedentary (immobile, usually in the adult phase) species may require a minimum density or proximity of adjacent adults for successful reproduction. Examples include the queen conch (Strombus gigas) in which reproductive output is substantially reduced once population density is too low. The white abalone (Haliotis sorenseni) was depleted to the point that adults could no longer achieve sufficient densities for fertilization: indeed, densities are so low that the last successful breeding of the species was in 1969. Spawning sites and times are also beginning to receive some attention as foci for management intervention, while species in which sex ratios become skewed by size-selective fishing, such as many reef fishes which change sex, may need special management treatment. Moreover, not all adults of long-lived species necessarily spawn every year, a challenge when calculating annual spawning biomass.

A range of methods is available for the assessment of reproductive condition, seasonality, sexual pattern and sexual maturation, and the relevant literature should be consulted for details (examples of literature are included in the Sources and recommended reading). Various approaches can be used to determine minimum sizes of capture or to identify spawning seasons during which spawning animals may need protection. As examples, sexual maturation and reproductive cycles can be determined by histological preparation of the gonads (reproductive organs; more typically the ovaries are used), or more quickly but less precisely, by the gonado-somatic index (GSI 5 [gonad weight/body weight] 3 100). Care is needed to clearly define whether sexual maturation is expressed as a minimum size, or age or as a more representative, but less precautionary, size or age at which 50% of the stock has attained sexual maturity, which would be larger than the minimum size. For determining reproductive seasonality gonads can be evaluated macro- or microscopically, for which histological preparation of gonads is needed to assess sexual pattern (i.e. gonochorism, hermaphroditism).

With a growing focus over the last 20 years on the need to maintain reproductive viability has come renewed interest in the form of the relationship between the number of spawners (S) and the number of recruits (R) they generate (Box 2.2). The form of the S–R, or spawner-recruit, relationship is often ignored in practice because of the difficulty, in many species, of establishing a meaningful S–R curve and the high levels of uncertainty included in such curves. This has been partly responsible for the common assumption that recruits are largely independent of spawners, except at low population levels. Recent work has shown that the average number of

Box 2.2 Stock Recruitment Relationships

Understanding the relationship between the number of adult spawners (S) and the number of recruits (R) they produce is important, especially for providing insight into the effects of substantially reduced spawner biomass on recruitment potential. Although often neglected in the past, it is well recognized that spawner abundance is important for managing fish populations, that recruitment overfishing is not uncommon and that at very low population sizes, recovery can be compromised. Ensuring sufficient reproductive capacity is increasingly a challenge for managers.

The form of the relationship between spawners and the recruits they produce is notoriously difficult to describe for many species, because so many factors can influence the number of recruits that survive in any one spawning season, particularly in pelagic-spawning species. In the simplest case, it is possible to assume a simple non-linear form for the relationship between R and S according to two widely accepted S–R models (Ricker and Beverton-Holt) (Figure 2.5). The slope of the S–R relationship curve near the origin represents the maximum reproductive performance per spawning at low spawner abundance. Some stocks may show depensation at low population sizes, whereby reproductive output per spawner declines at low population levels. This may explain why some stocks fail to recover from very low population levels (Myers, 2001; Walters and Martell, 2004). Understanding this lower end of the S–R curve is important as more fished stocks come to approach low spawning stock biomass.

The challenge in developing a realistic S–R curve is compounded by the consideration of how to measure spawning biomass in a way that is meaningful. The challenges are that egg number (and possibly quality) varies with female size in a non-linear way, and that not all eggs that ripen are necessarily spawned (i.e. many mature eggs can undergo atresia prior to release). So the question arises as to which eggs should be counted; not all adults spawn every year in some longer-lived species, and fecundity can vary as a result of food supply. Moreover, recruitment variability generally increases at low population sizes (for high fecundity species), for populations at the edge of their range and in regions with less oceanographic stability. Other confounding factors with the S–R relationship are variable survivorship from egg to recruitment, compensatory responses and variable environmental conditions. All of these factors can contribute to substantial year-to-year variations in recruitment strength and a resulting wide variation around the average S–R curve in many species. This should not deter managers from attempting to determine the nature of the S–R relationship, especially in relation to determining a productive target biomass for spawners and the lower limits to be avoided.

recruits produced per spawner each year (i.e. maximum annual reproduction rate as indicated by the slope at the origin of the S–R function; see Figure 2.5) at low population sizes is relatively constant, both within and across species. Exceptions have been found only among highly productive species, such as herring. This rate does not differ substantially from a range of 1 to 7 replacement spawners per spawner per year and suggests a limited population growth potential in most species under such conditions and irrespective of fecundity (Myers *et al.*, 1999).

An approach complementary to S–R relationships in determining targets and lower acceptable limits for spawner biomass is the spawning potential ratio (SPR). This ratio examines the proportion of recruited stock likely to survive to spawn at different levels of fishing mortality (F): as F increases, SPR decreases because of loss of spawning stock to fishing. SPR thresholds are expressed as a percentage SPR of the maximum SPR (i.e. when F 5 0) of the virgin biomass. They can be used to indicate the thresholds below which the spawning potential should not be allowed to drop. From a series of analyses, SPR targets of around 30% are recommended as a default level (i.e. spawners should not be allowed to drop below 30% compared to the unfished stock) but can vary widely with species, and the appropriate literature should be consulted (Musick, 1999).

Age, growth and mortality

Other biological parameters are needed for developing species-specific fishery models and for understanding stock performance, including age, growth and natural mortality. These are commonly used in the better-known dynamic pool models, yield-per-recruit (YPR) and

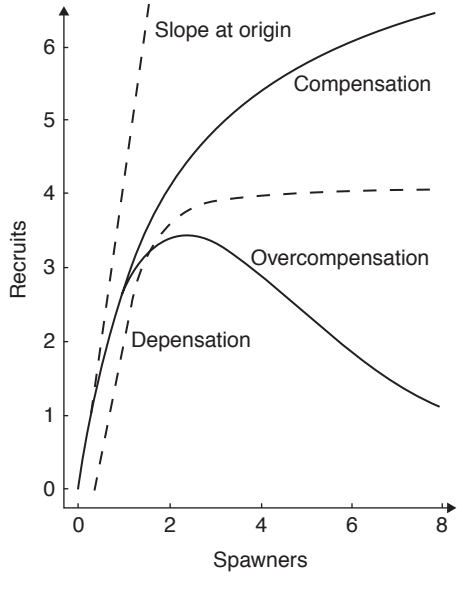


Figure 2.5 Curves showing different possible relationships of spawners to recruits. The overcompensation curve is the Ricker model and the depensation curve is a modified Ricker model; in the original form of the Ricker model the lower left of the curve reaches the origin rather than sitting to the right-hand side. The modified form in this figure depicts a possible situation whereby very low numbers of spawners may not produce recruits because mating does not occur at low population numbers or densities. The slope at the origin is the maximum reproductive rate. Adapted from Myers, R.A. (2001).

spawning-stock-biomass-per-recruit (SSBR) as well as most other fishery models. These models are expressed on a per-recruit (into the fishery) basis because of the problems of estimating absolute fish abundance.

As animals grow in length, their weight increases disproportionately in concert with their volume and both length and weight provide important information for managers. Length–weight relationships, or curves are readily generated by sampling a large size range and number of fish allowing for conversion between the two measures when only one or the other is available, as is often the case in practice. Although many such curves are available in the published literature, local conditions could substantially affect the relationships and these should be generated for the fishery of interest. Note that the unit of measurement should always be indicated for such data as well as the length type (fork, total, standard fish length, total weight, gutted weight, etc.). It is surprising how often this simple but critical information is not made clearly available in published reports and papers.

The relationship between length and age can vary markedly according to conditions, such as food availability, population density and temperature, and research has revealed that some exploited species can be surprisingly long lived. The relationship between age and length is non-linear, with growth rate slowing after sexual maturation as the organism starts to divert energy into reproduction and away from growth. Estimating growth rates and establishing ages in fishes and invertebrates are achieved using a range of methods from tagging work in captivity and in the field to analysis of hard body parts such as vertebrae, ear stones (otoliths), etc., depending on the species. Methodologies are well described in the literature.

The typical growth curve that is widely applied for fish, and has also been applied to some invertebrates, is the von Bertalanffy growth function, the parameters ($L_{infinity}$ = asymptotic or mean maximum length; K = rate at which $L_{infinity}$ is attained) of which are widely used in stock assessment. Studies over the last few decades have shown that longevity can range from less than a year to well over 100 years in exploited species. Long-lived species include certain elasmobranchs (sharks and rays) and a range of demersal species including some reef, estuarine and deepwater fishes and certain groups such as rockfishes and bivalves. Most fishes and some invertebrates continue to grow throughout their lives, albeit at reduced rates in the adult phase, unlike humans who stop growing, at least in length, once they reach adulthood.

In addition to growth and recruitment, an estimate of natural mortality (M) is needed for stock assessments (Box 2.3). Ideally this is determined prior to the commencement of fishing in which case, because F = 0, the total mortality should be equivalent to M. If a fishery is

Box 2.3 Natural Mortality

Animals of exploited species are lost from populations through fishing mortality (F) emigration and by natural mortality (M), mainly from disease and predation. Fishing mortality is controllable through management, and emigration is unlikely to be a major factor in most stocks if managed as a whole, so it is the relationship between natural and fishing mortality in fished stocks that is most important in relation to their sustainable use. The level and pattern of natural mortality throughout the life of a species varies enormously depending on the species or taxonomic group and the age and life history phase of the species. In a typical marine pelagic-spawning species with a bipartite life cycle and a benthic

adult phase, by the time the larvae settle into the juvenile or adult habitat almost all of the propagules released at the spawning episode that produced them have perished.

At settlement, as the organism leaves its pelagic phase and enters its (most typically) demersal phase, natural mortality is high because settling animals are very vulnerable to predation as they seek new shelter, change their diet and undergo morphological changes. Hence the high mortality indicated at time '0' to the left of the curve (Figure 2.6). After settlement, the organism becomes established and natural mortality declines markedly, mostly within the first few weeks or months following settlement. Early natural mortality would be substantially different in live-bearers or where some form of egg-care is involved in which the survivorship of each young animal is much higher than each larva produced by pelagic spawners.

The importance of the form of this curve is that the impact of removing an animal by fishing will depend on where it is on the mortality curve (i.e. along the x-axis in Fig. 2.6) at the time of removal and the corresponding level of fishing intensity; a species with a low natural mortality (M) in the adult phase would be more susceptible to depletion under a given level of fishing mortality (F) than one with high natural mortality. This is an important consideration in multi-species fisheries because at a given level of fishing pressure species vary in their natural susceptibility to depletion. When F is greater than M over the long term, there are possible implications for fishing acting as a major selective force (see Section Genetic effects of fishing, restocking and mariculture).

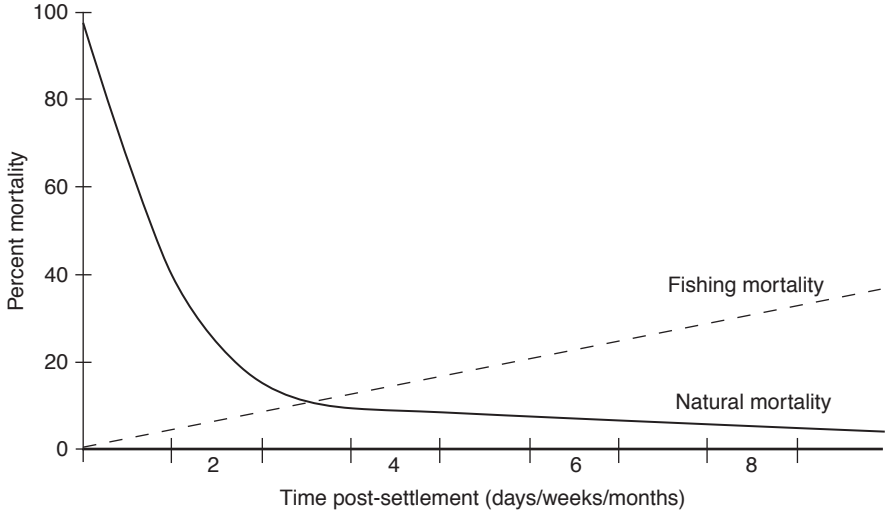


Figure 2.6

already exposed to fishing, as in most cases, the total mortality (Z = M + F) can sometimes be determined using a 'catch curve' analysis if a representative sample of age class data is available. Catch curves can be used to produce a regression across age classes of recruited fish, providing an estimate of the rate of decline in numbers of fish with increasing age. With

the assumption of constant recruitment, this rate of decline produces an estimate of Z. Natural mortality, M, is then estimated by subtracting F from Z.

Given the difficulties and uncertainties in deriving M, alternative means have been developed using parameters that are easier to measure. One widely used equation is that of Daniel Pauly, which provides an estimate of M on the basis of the growth rate of the species and the mean temperature of its environment (Pauly, 1980). Use of this method requires growth and temperature data. There are also other methods and equations available. However, given the challenges in estimating M and the importance of this parameter, good stock assessments usually conduct sensitivity analyses by applying a range of M values around the estimate and seeing how these affect the results.

Understanding the pattern and implications of natural mortality levels in relation to age is particularly important in the case of fisheries that focus on several different life history phases of the same stock. Management in such cases needs to consider all sources of F in relation to the levels of M of targeted animals (Box 2.3). As an example, certain stocks may be targeted at both adult and juvenile phases by different fishing sectors focusing on animals from very different parts of the mortality curve (i.e. as both young juveniles and as adults). In such cases, the sum of all fishing mortality should be taken into account when planning management. For example, in Australia, the western rock lobster (Panulirus cygnus) is taken from the wild both at the settling puerulus stage for grow-out in captivity and as adults in a separate fishery sector. Information from the fishery sectors on both life history phases is combined to produce an overall level of mortality and separate management quotas allocated to each fishing sector based on the combined mortality from both sectors. Likewise, stock assessment of the southern bluefin tuna (T. maccoyii) factors in both the fishing mortality associated with on the catch of wild juveniles for ranching (fattening) and for catch of adults destined for immediate sale. Many species included in capture-based aquaculture (CBA), however, are not managed for the fishery on their juvenile phases, with the potential for overexploitation (see Section 2.4.2).

Determination of biological parameters allows for the application of conventional fishery models, such as YPR or SSBR and should be standard practice for all key commercial and vulnerable species, providing valuable information for understanding the status and dynamics of the stocks and for setting target and limit reference points (Chapters 12 and 13). Indicators or reference points should be used to assist managers in preventing stocks from getting too low by, for example, setting targets to be aimed for or thresholds below which biomass should not fall. In addition to the indicators, guidelines or 'rules of thumb' can be applied to make simple or preliminary management decisions in data-poor situations.

Habitat needs and shifts

Important as they are, biological characteristics are only one aspect of the life history of target species, and knowledge of habitat association and ontogenetic changes is necessary for a fuller understanding of species' needs. Over their lifetime, many species exhibit movements in association with increases in body size, dietary shifts and changes in permanent or temporary reproductive requirements, or have very specific habitat requirements (Table 2.3). When settling out of the plankton onto the substrate, young fish often use very different habitats from that occupied by adults to satisfy specific biological and ecological requirements of food and shelter or shield them from predators. Such 'nursery' areas are often found in

Table 2.3 Habitat and behavioural changes after settlement for representative exploited species.

Family/species	Nursery areas/habitats	Ontogenetic movements	Spawning /feeding areas/habitat
Lutjanidae (e.g. certain snapper, *Lutjanus*, species)	Mangroves	From inshore nursery areas to mid and offshore reefs.	Short-term seasonal movements to specific spawning aggregation sites on outer reefs.
Serranidae (e.g. certain grouper, *Epinephelus*, species)	Inshore reefs and macroalgae.	From inshore nursery areas to mid and offshore reefs.	Short to long (i.e. >100 km) seasonal movements to small, well-defined, outer reef aggregation sites, sometimes along regular migration routes.
Gadidae (e.g. Atlantic cod, *Gadhus morhua*)	Younger fish generally occupy waters closer to shore.	Generally demersal but pelagic while feeding or spawning; larger fish found in colder waters. School by day and scatter by night.	Seasonal migrations of tens of kilometres to large spawning and feeding grounds.
Sciaenidae (e.g. Large yellow croaker, *Larimichthyes crocea*)	Inshore areas	Adults and juveniles occupy similar habitats.	Seasonal movements between deepwater feeding area and inshore spawning areas, the latter in or close to estuaries.
Scombridae (e.g. Southern bluefin tuna, *Thunnus maccoyii*)	Young fish occur in coastal waters of southern Australia and migrate between southern Australia and the central Indian Ocean.	Larger fish occur in Atlantic, Indian and Pacific Oceans. Move between deeper colder and surface waters.	Very long-distance migrations of adults to single known spawning ground.
Carcharinidae (e.g. Lemon Shark, *Negaprion brevirostris*)	Young settle and remain in shallow water nurseries for a couple years.	Nocturnal, hunting in shallow waters by day and moving deeper at night in coastal areas. Males are nomadic and females more sedentary.	Mature Lemon sharks have been observed aggregating, probably to breed, in certain locations at specific times. Females may return to their natal areas to mate.
Salmonidae (e.g. Salmon [several species])	Hatch high up in river systems and young phases develop in freshwaters.	Move from rivers into coastal and offshore waters to feed and grow.	Return to rivers to spawn.
Lobster (Panuliridae: [e.g. spiny lobster *Panulirus argus*])	Settle in inshore shallow reefs after many months in plankton.	From nursery areas spread out to extensively occupy reefs.	Seasonal mass migrations to deeper water to reduce exposure to rough weather conditions.

shallow water coastal habitats, including shallow seagrass beds, or mangroves or estuarine waters. Hence, the younger, smaller, fish of many species are particularly susceptible to coastal activities such as mangrove clearance, shoreline construction, water degradation or a range of other activities. As fish grow larger, they often move offshore, where, as adults, they might undertake seasonal migrations for feeding or spawning.

Habitat considerations

It is usually difficult in practice to separate the effects of habitat loss from other effects, such as exploitation when stocks decline, although some negative impacts on fisheries are almost certainly largely driven by habitat degradation (reviewed in Dulvy *et al*., 2003). For example, mangroves are removed for many purposes, such as for fishery production related activities like shrimp aquaculture, at a global rate of at least 1% per year, often much more, affecting local populations of plants or animals. Loss of habitat necessary for certain life history phases is partly responsible for declines in some Pacific salmon stocks, while loss of spawning areas have affected certain sturgeon stocks. Bottom trawling can cause extensive damage in areas of the global continental shelf, thereby altering benthic habitats and species composition and reducing productivity. In coral reef ecosystems, fish abundance and diversity are positively linked to habitat type, abundance, complexity and topography. The need for habitat considerations in resource management is recognised under the CBD, EAF and the FAO Code of Conduct (e.g. Article 6.8), and the notion of 'essential habitat' in US law recognizes the importance of habitat for productivity and substrate necessary for spawning, breeding, feeding or growth to maturity.

Negative impacts on juvenile habitat may ultimately affect adult numbers, so it is important to understand the range of habitats needed throughout the life of species of interest to manage it effectively. Such considerations become particularly critical when the juvenile habitat of one important species is the fishing ground of another important species. One such example is the valuable trawl fishery for shrimp in the Gulf of Mexico that also takes large numbers of juvenile red snapper (*Lutjanus campechanus*) as bycatch in the same habitat; the snapper is itself a valuable commercial species, once adult. Management has to factor in such aspects of the life history of different species and address the biological and economic implications for different fishing sectors while ensuring the sustainability of all affected species.

Some species may have specialized habitat requirements or occupy environments subjected to damaging fishing practices. In some coral reef systems in Southeast Asia, for example, cyanide and explosives are extensively used to catch adult and juvenile fish and can damage the reef habitat on which the fish and invertebrate communities depend. Loss of living coral reef substrate through damage caused by bleaching or climate change, disease or other impacts is expected to reduce abundances of fishes that depend heavily on live coral for shelter and may even result in the disappearance of species that depend on living coral for food. Deepwater seamounts host unique communities, with many species of low resilience to fishing, that are subjected increasingly to unregulated fishing activities.

Temporal and spatial considerations

Once adulthood is attained, most invertebrates and some fishes are somewhat sedentary; others including a range of pelagic, continental shelf and coral reef species undertake seasonal

movements or migrations that might have to be factored into management planning. Such species move to places where they seek mates or locate specific types of spawning or feeding habitat or conditions. For many species, estuaries, the outer reef slope, water of a particular temperature, or specific habitat such as floating substrate for egg deposition, as in the case of flying fish, might be the focus of adult movements. Certain pelagic species, such as some tuna or shark, may migrate for thousands of miles to mating and feeding grounds each year, passing through many national jurisdictions or into the high seas.

Diverse habitat needs help to explain why measures like MPAs or other means of habitat protection or management are particularly and increasingly important for certain fisheries (see Chapter 8). But area protection, if such areas are small which is the most typical case, are unlikely to encompass all the needs of all species. Those that undertake seasonal migrations to spawn or feed, or undergo major ontogenetic movements, will need special attention and additional management measures. Such species illustrate why countries must often work together or cooperate regionally to manage important, and shared, fish stocks and apply the FAO Code of Conduct. Fishery management is not just about numbers and sizes of fish but must encompass other aspects of the biology and ecology of the target species, including spatial and temporal considerations, and the wider ecosystems in which species live.

Ecosystems and interspecific interactions

It is, of course, easiest to think of each fishery species in isolation and, while single-species management approaches that once dominated fishery science inevitably fostered this way of thinking, growing understanding of aquatic systems is changing this narrow approach. Species interact or depend on each other in important, sometimes subtle, ways, as part of the wider acquatic ecosystem. Certain species may be particularly important in the community, as 'keystones', interacting with a range of other species, and fisheries can have substantial direct and indirect impacts on these species. Understanding something of such interdependencies is important for fully appreciating the roles of different organisms and the importance of maintaining intact ecosystems. As a general rule, we cannot view species 'of interest' in isolation from the rest of the biological system in which it lives, any more than we, humans, can hope to flourish in isolation from the living world. Hence the increasing focus on ecosystem considerations in management planning.

To address ecosystem-level management, there is a need to move beyond single species to embrace ecosystem-level thinking through, for example, models that consider ecosystem impacts of fishing and interrelationships between physical conditions and populations (Section 13.4). Ecosystems are complex and modelling their dynamics in any meaningful way requires that reasonable approximations to ecosystem dynamics be made through parameter estimation and a series of assumptions. Models can be used to describe or explore past trends and to predict future possible changes or scenarios under different sets of conditions.

Functional relationships in ecosystems can be described by three types of information: physiological and behavioural parameters such as bioenergetics, ecological parameters defined by interspecific interactions, and ecosystem-level events such as colonization rates or sporadic natural physical occurrences such as El Niño events. Temporal and spatial components also have to be considered along with different scales of interactions and mass-balance data (Walters and Martell, 2004; http://www.seaaroundus.org/). Such models are data-intensive but can produce invaluable insights into how complex systems work and facilitate the

consideration of fishery-induced, as opposed to environmental, effects on exploited populations and ecosystems. Modelling of the potential or actual impacts of climate change would benefit from this level of detail in addition to using other information such as oceanographic and temperature data.

The use of community or system indications for ecosystem-based management is a developing emerging field and includes, for example, the use of community size spectra (species composition and sizes), marine trophic index and the ratio of pelagic to demersal catch as signs of ecosystem condition and function (Chapter 12). In all such modelling exercises, care is needed in the assumptions made and these should be tested whenever possible to minimize the risk of misleading outcomes.

Species interactions

Several classes of direct and indirect species interactions illustrate the importance of maintaining natural ecosystems. Direct relationships are those within and between species in the form of predator/prey relationships, symbioses and competition for similar resources. Indirect relationships can occur when there are knock-on effects on some species within the ecosystem due to large changes in relative numbers of others or from the loss of a 'keystone' species (those that play a pivotal role in the ecosystem). As an example, studies recognize that certain predator and prey species need to be considered together, such as maintaining sufficient capelin (*Mallotus villosus*) to avoid depleting the cod that prey on them within a 'trophic cascade'. The removal of top predators can also influence other species in the ecosystem, with possible short- and long-term effects on fishery production. This important effect is known as 'fishing down the food web' (Pauly *et al*., 1998) and is implicated in multi-species fisheries such as in the Gulf of Thailand where reductions in larger fish appear to be directly and negatively linked with increased abundance of shrimp and cephalopods. In other cases, knock-on effects, as in the loss of herbivores (plant eaters) such as sea urchins (*Diadema antillarum*), through disease or fishery removals, can lead to domination of the reef by certain types of algae (plants) that, in turn, can overgrow and kill living corals (Côté and Reynolds, 2006).

Productivity and biodiversity

An important aspect of ecosystems is that, in general, intact ones may be more productive than compromised or stressed ones. Eutrophication (nutrient enrichment), for example, has bottom-up effects that can change the productivity of pelagic and demersal environments. Polluted or otherwise degraded waters can negatively impact egg and larval survivorship of some fish species with particular concern in the case of estuaries, because they are so important for spawning in many species and so heavily subjected to various anthropogenic impacts. In coral reef systems, there can be positive significant relationships between number of species and biomass per unit area, as demonstrated on Indo-Pacific reefs, highlighting the potential fishery benefit of maintaining species diversity (Kulbicki *et al*., 2004). Substrates damaged by, for example, repeated bottom trawling or dynamite fishing will ultimately be less productive due to loss of, or disturbance to, habitat and associated benthic communities.

Monitoring fisheries

Without basic data on species composition, landings over time and changes in fishing effort, it is not possible to monitor changes in a fishery, undertake adaptive management or identify 'shifting baselines' – an incorrect shift in perceptions of the baseline population size (Pauly, 1995). All of the instruments in Table 2.1 call for monitoring or related activities and much can be determined from well-designed simple and standardized data-collection programmes. Information can be collected in different ways, ranging from simple, regular and standardized sampling of fish markets, landing sites or fishing communities for landings, species and size data, to surveys or focused studies. Studies can be part of in-depth scientific research programmes or seek information from user communities through interviews or focus groups in the form of traditional ecological knowledge (Section 3.6). In a growing number of cases, the systematic collection of anecdotal, qualitative and interview information, such as local or traditional ecological knowledge, has provided important insights into recent changes in little-documented fisheries. Such studies have been very important for providing a perspective of the recent past and often are strongly suggestive of significant changes over a few decades. Such information can help avoid the shifting baseline syndrome.

It is, perhaps, somewhat surprising that there are so few long-term fishery data sets. Indeed, few fisheries other than major single-species operations can boast a long history of data collection. Surprising, because much important information can be collected relatively cheaply and because without information on catch trends, species composition, size information and indications of effort, meaningful management measures may not be adequately developed. Methods of data collection should be kept consistent over time, otherwise comparisons across years can be impossible. Unfortunately, funding for monitoring may be sporadic; personnel changes may lead to changes in data collection methods, and reporting requirements may not encourage comprehensive record-keeping, leading to lack of continuity and loss of detail. The development of long-term monitoring programmes should be a priority of fishery departments, both to understand the fishery and to facilitate adaptive management.

Species composition

For key target fishery and significant bycatch species, species-specific information should be collected rather than information combined (or lumped) across species, because species-specific responses to fishing could be masked. For example, the fact that the output of whaling was reported as tons of oil produced, without indications of species-specific trends in declines, was one of the major contributors to the serial collapse of these resources and their fisheries. More recently, prior to 1982, all groupers were recorded as a single lumped species data category in the United States obscuring some very real differences in susceptibility to fishing by different, closely related, grouper species. Key bycatch species should also be recorded by fleet, location, etc., and species often not conventionally included in fishery monitoring programmes, such as marine aquarium fishes, fishes taken for mariculture feed or bait should, if possible be documented. All significant removals, whether targeted or not, have the potential to affect the fisheries of interest and the marine ecosystem that supports them, and should be recorded (see also Section 13.5).

Size information

Data on size of key target and bycatch species are important for gauging possible changes to exploited populations over time, identifying selectivity issues and for monitoring the outcomes of management interventions in relation to body size. Properly collected, size data can signal important changes that could be fishery induced and may warrant management attention. Examples include declines in mean sizes, truncation of age classes (i.e. loss of older, larger, fish) and increasing, or heavy predominance of, juvenile fish in catches. In long-lived large species, loss of larger females may substantially affect egg output and may need management action.

Landings and catch-per-unit-effort

Estimating fish abundance reliably, most typically using a proxy measure for abundance such as catch-per-unit-effort (CPUE), is an essential part of monitoring and can allow for a preliminary assessment of stock status by examining extent of decline over predetermined time periods and over the short term (Grainger and Garcia, 1996; Garibaldi and Caddy, 2004). However, both catch and CPUE data should be collected judiciously. Care is needed to document factors that could possibly influence catch or CPUE data independently of actual changes in stock size, such as changes in fisher behaviour, including increases or decreases in fishing effort over time, shifts in area fished or changes in fishing gears used. For example, where fishing pressure is heavy or increasing, fishers might progressively increase their effort in ways that may not be recognized or recorded (e.g. through longer periods at sea, travelling further from port, increasing the number of gears set per fishing trip) in order to maintain catch rates. A simple examination of landings data, however, may not reveal such changes and the problems they might signal with the fishery. However, if there is good reason to believe that fishing effort and practices have been constant over time, landings information can be useful for indicating any changes in the overall fishery or in particular species.

Care is also needed to account for possible changes in fish behaviour, such as seasonal migrations to spawning or feeding grounds that could influence catch rates. For example, in the case of species that aggregate to spawn, a focus by fishers on spawning aggregations would show seasonal peaks in landings. If the catch is inspected a focus on spawning fish could be confirmed by the presence of ripe eggs. If much of the annual catch comes from spawning aggregations, stock declines might not become apparent until numbers have declined substantially due to 'hyperstability', whereby the continued aggregation of large numbers of fish obscures declines in the population as a whole until numbers are very low. Hyperstability is also a feature of many small pelagic species that form tight shoals. Changes in either fisher or fish behaviour, therefore, mean that CPUE is not necessarily proportional to fish abundance.

2.4 Emerging issues

Pressures on marine resources are increasing and there is a need to manage them more effectively to improve or sustain yields, avoid the loss of ecosystem function and

biological diversity, and to address emerging issues that could variously improve or challenge our ability to do so. From a biological and ecological perspective, there are several major areas have not conventionally been considered of relevance for the marine resource manager but are increasingly likely to become so. These include MPAs, mariculture, threatened species, genetic effects of fishing and new stresses on marine habitats, including climate change. Being aware of these emerging issues allows for forward thinking and integration into policy, education and management planning. Each is summarized briefly.

2.4.1 Marine protected areas

Interest in the use of spatial protective measures in relation to resource management mainly developed due to marine conservation interests, analogous to area protection on land. However, a growing body of work suggests that some fishery benefits also occur and certain traditional systems, such as in parts of the Pacific, have long used temporary marine area closures for cultural reasons. Examples of possible fishery benefits include larger fish, higher densities and greater biomass and biodiversity within protected areas of sufficient size and where there is no fishing compared to adjacent unprotected areas. There are also indications of benefits occurring outside the protected area boundary through adult and larval movements. However, benefits over large areas or for entire fisheries are as yet unknown. Large-scale benefits from spatial protection will only be possible if MPAs are big enough, suitably placed to encompass key biological processes and if they are properly enforced. Overcapacity, when it exists, should be eliminated from the fishery in addition to spatial protective measures. At present, despite the large number of MPAs declared, very few appear to effectively fulfill their promise and most are considered to be ineffectively implemented.

MPAs should play an important role in ecosystem-based management, in habitat protection from damaging fishing techniques, for seasonal protection of spawning and nursery areas and to ensure sufficient refuges for species that are fished throughout their depth and geographic ranges (Bohnsack, 2003). MPAs and area-based management measures in general are discussed in more detail in Chapter 8 and are one of a suite of management tools available to address fishing effort and impacts and increasingly the subject of research and fishery planning.

2.4.2 Mariculture and restocking

The hatchery production or wild capture of small fish and their subsequent rearing and/or release are widely considered to be promising supplements to capture fisheries, as means of increasing seafood production. As yet they play little role in reducing fishing pressure. Most mariculture focus is on high-priced, luxury species, many of them carnivorous or omnivorous, such as croakers, porgies and shrimps – a change from the past when most culture was in freshwaters based on herbivorous and omnivorous species. Although such activities generate many livelihoods, some of the culture practices can have negative impacts on capture fisheries, while few of the species cultured today represent a cheap source of protein. Examples of problems include extensive removal of mangroves for shrimp farming that can affect nursery areas of commercially important species.

Moreover, for certain cultured species, the majority of individuals entering the grow-out, or fattening, phase in captivity are taken from the wild, rather than originating from hatcheries.

While technically mariculture under the FAO definition, this activity is in reality a form of fishery with a captive phase prior to sale. Examples include many groupers in Southeast Asia, eels in Europe, southern bluefin tuna in Australia and mullet in Egypt, amongst many others. Such 'CBA' can potentially add significantly to pressures on wild stocks by removing large numbers of juveniles, because most such activities are unmanaged and largely overlooked by fisheries management authorities (Ottolenghi *et al*., 2004).

An additional consideration with current mariculture practices in many areas is that the typical species under culture are carnivorous and require substantial volumes of fish feed. Fish feed often comes from small individuals of a range of species taken as bycatch; many 'feed' fish are juveniles of species important as human food. In some cases, their value as fish feed enables otherwise collapsed trawl fisheries to persist (Naylor *et al*., 2000). Since demand for fish feed is high and set to grow as culture operations expand, research is urgently needed to find ways to reduce the proportion of fish in fish feed, or to use alternative species with lower or no demand for fish protein as food. If marine resources decline, managers may have to consider questions such as whether species of food interest to humans, such as croakers, hairtail (Trichiuridae), ponyfish (Leiognathidae), etc., currently taken as bycatch in their juvenile phases to feed high value fish being grown-out in mariculture operations, should instead be left to grow and replenish food fisheries for humans.

Often closely associated with mariculture operations is the practice of restocking as a method of stock replenishment or in association with the introduction of artificial reefs. Surprisingly, despite the widespread interest in restocking and its considerable expense, success stories are few and, in most cases, large numbers of organisms are released with little long-term follow-up or monitoring to assess the success, or otherwise, of restocking programmes. Releases are often conducted with little knowledge of the correct conditions or sizes required to maximize survival. Yet, for restocking to be successful, it is critical to ensure that released fish survive long enough to re-establish spawning stocks or enable a fishery to recover.

If restocking or artificial reefs are going to play major roles in fisheries in the future, their application needs to be carefully planned, researched and conducted (Section Genetic effects of fishing, restocking and mariculture). Restocking initiatives need to consider the possible genetic implications of releases and to assess the outcomes of restocking. Artificial reefs have not been unequivocally shown to restore or enhance fisheries that are overfished, and likely to be recruitment limited and debate continues regarding the extent to which they might actually increase fishing pressure by concentrating fish in known areas (Bohnsack, 1996); fish attracting devices (FADs) after all are designed to help attract fish and improve fishing rather than restore fisheries. The precautionary approach should be applied to the deployment of artificial reefs; their most valuable proven function is probably to control trawling.

2.4.3 Threats to biodiversity

Threatened species

It has long been an assumption by many people that commercial marine species cannot go extinct or that severe depletions are readily reversible by fishery management. Yet, as we are learning from the growing list of threatened marine species, as well as from studies on the likely, and often combined, impacts of overfishing, poor fishing practices and environmental

stresses on ecosystems, managers must question such assumptions. A major challenge is the management of the more vulnerable species within multi-species fisheries. To protect such species, innovative approaches such as developing gear selectivity to allow certain species to escape, or balancing fishing effort across a wide range of species (as were used traditionally in many fishing societies) rather than focusing on just the valuable species present using non-selective fishing gears.

Marine species appear to vary enormously in their susceptibility to extinction, and fishing can threaten those that are particularly vulnerable due to their life history, high market value, and because of the indirect effects of fishing. Examples of targeted species considered to be threatened come from a diverse range of families, including sharks, rays, seahorses (*Hippocampus* spp.), several croakers, reef fishes and queen conch, and the giant clam (*Tridacna gigas*). Threatened bycatch species include the massive barndoor skate (*Dipturus laevis*), taken in Atlantic groundfish trawl fisheries, whereas the giant coral reef wrasse, the Napoleon fish (*Cheilinus undulatus*), is threatened by high demand in the luxury live reef-fish food trade in Southeast Asia. Other species are listed in the various threatened categories of the International Union for Conservation of Nature (IUCN) Red List. The relatively new application of Appendix II of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) to commercially important marine species reflects a growing acknowledgement of the problems faced by certain vulnerable species from direct or indirect effects of fishing.

Invasive species

Marine invasive species can harm native species and natural ecosystems and are often inadvertently introduced into new habitats through shipping or through the farming of non-native fishes and shellfish. Concern is growing over the actual and potential impacts of invasive species in fresh and marine waters although documentation, especially in the marine environment, is in its early stages and the issue clearly needs to receive more attention. Invasive species range from dinoflagellates, through crustaceans and molluscs to fishes. A recent and dramatic example of the speed with which invasions can occur is being documented for the lionfish *Pterois volitans*, a voracious predator with few predators itself, and an aggressive invasive in the Caribbean. A precautionary approach should be taken, especially in the case of culture-related operations in which controls on exotics should be exercised to prevent escapes.

Genetic effects of fishing, restocking and mariculture

Certain traits of some exploited species are at least partially genetically determined, including maximum size and size of sexual maturation, so it is important to examine the extent to which fishing can act as a selective pressure on such traits. Genetic change due to size-selective harvesting can occur over a small number of generations and there is a real risk that certain desirable characteristics, such as large size, could be lost completely from certain stocks. Harvest selection on large Atlantic silverside, *Menidia menidia*, for example, led to reduced growth efficiency, lower egg quality, and less 'aggressive' foraging and reduced consumption rates. Genetic impacts of fishing are possible when there is extreme selectivity for

characters that have a strong genetic basis, and when fishing mortality is very much greater than natural mortality and hence becomes a possible selective force.

In relation to aquaculture and restocking practices, concerns have been expressed over the possible impacts on wild stocks of the escapes of cultured hybrid fish. In the case of the Atlantic salmon (*Salmo salar*), escapees from salmon farms can out-compete fish in native populations, leading to concern for the fitness and productivity of wild salmon populations. Farmed salmon have been under artificial selection for growth and other economically important traits for 30 years and are genetically different at the molecular and quantitative genetic levels. The potential for negative impacts are particularly acute in the case of restocking programmes, where released fish are not taken from local populations. Due to concerns over possible problems, in Australia releases of the Barramundi (*Lates calcarifer*) are conservatively made only back into their respective populations. Many of the actual and possible genetic implications of fishing are little understood calling for the application of the precautionary approach to be applied in cases where impacts are possible or suspected. Measures to reduce escapes are recommended. Relevant instruments are the FAO Code of Conduct (Article 9.3) and CBD.

2.4.4 Stressed habitats and climate change

In addition to long-recognized stresses on marine habitats in proximity to human activities, such as those associated with coastal construction, pollution and runoff from the land, other anthropogenic stressors threaten further impacts. One of these, global climate change, is already having important large-scale systemic effects regarding species bathymetric distribution, with some species moving to deeper waters, and geographical distribution, with some species moving hundreds of kilometres poleward. As a result there is introduction of new species and losses of familiar species in conventional fishing grounds. These changes may open new opportunities for fishing in some areas, but could also cause losses. Moreover, they could introduce considerable confusion in stock assessments, confounding the ability to distinguish between the impact of fishing and that of the environment. For species or populations that cannot move in response to climate change, changes in the population parameters used for stock assessment and management could affect the reliability of assessment made using historical parameter values.

Coral reefs represent an ecosystem most immediately threatened by global warming because corals are increasingly being exposed to their upper limits of thermal tolerance for extended periods. As a result as much as 20% of coral cover may have been destroyed with another 50% under short- to long-term risk of collapse with important implications for coral-dependent organisms (Wilkinson, 2004). In coral reef ecosystems, ecological and productivity distortions are likely to arise from community and biodiversity changes with decreases in fish abundances and other unwanted or unexpected outcomes anticipated on compromised reefs. As just one worrying example, damaged reefs in some areas are associated with increased incidence of ciguatoxic fishes that produce the condition of ciguatera (food poisoning) in humans, compromising sales of fish from impacted areas and potentially affecting food security (Lewis and King, 1996). Such matters need to be factored into marine ecosystem-level planning and integrated into broader planning objectives such as coastal zone management.

2.5 Concluding comments

> Those who forget history are condemned to repeat it
>
> George Santayana

It is critically important that we learn from our mistakes in fishery management and aquatic resource stewardship if we are not to repeat them. Over the last few decades, we have gained many new perspectives and insights and thereby increased our understanding of marine systems and their vulnerabilities and responses to exploitation and perturbation. This newfound knowledge will enable us to better address current and emerging challenges in global fisheries and to ensure that our waters are productive and will remain so in the long term, and that biodiversity is not irresponsibly compromised. Managers can benefit from the guidance and support in the instruments of Table 2.1 developed from a wealth of experiences and study over the last few decades.

It is now clear that fisheries management must first and foremost seek to exploit populations in a way that ensures their reproductive viability and takes into account ecosystem-level effects to avoid the risk of irreversibly affecting the ecosystems and biodiversity which allow marine resources of value to humans to flourish. Where once managers focused on single species and on maximizing yield, nowadays there are many more considerations that form part of the planning process. Managers should also be cautious about activities heralded as 'easy' solutions to overfishing, such as artificial reefs, restocking and mariculture that may supplement or complement management initiatives, but which do not directly or explicitly address biological overfishing. Management objectives must be based on a foundation of contemporary science, data-collection programmes and seek to build on our evolving understanding of the biological and ecological foundations of aquatic ecosystems. Good management will look ahead to the challenges of a world that is changing due to shifting human demographics and environmental conditions and respond appropriately to the growing demands and pressures on marine resources to ensure they continue to supply us with high quality protein in the future.

Acknowledgements

I am grateful to Rachel Wong Pin Pin, William, Cheung Wai Lung, Kevern Cochrane, Serge Garcia and George Mitcheson for support and constructive comments in the preparation of this chapter. Partial financial support comes from the Society for the Conservation of Reef Fish Aggregations, funded by the Packard Foundation.

Sources and recommended reading

Bohnsack, J.A. 1996. Maintenance and recovery of reef fishery productivity. In: *Reef Fisheries*. Polunin, N.V.C. and Roberts, C.M. (eds). pp. 283–313. Chapman and Hall, London.

Bohnsack, J.A. 2003. Shifting baselines, marine reserves, and Leopold's biotic ethic. *Gulf and Caribbean Research*, 14: 1–7.

Conover, D.O. and Munch, S.B. 2002. Sustaining fisheries yields over evolutionary time scales. *Science*, 297(5578): 94–96.

Côté, I.M. and Reynolds, J.D. (eds). 2006. *Coral Reef Conservation*. Conservation Biology 13, Simon Fraser University, Cambridge University Press, U.K. 588p.

Dulvy, N.K., Sadovy, Y. and Reynolds, J.D. 2003. Extinction vulnerability in marine populations. *Fish and Fisheries*, 4: 25–64.

Garibaldi, L. and Caddy, J.F. 2004. *Depleted marine resources: an approach to quantification based on the FAO capture database*. FAO Fisheries Circular No. 1011. Rome, FAO. 32p.

Grainger, R. and Garcia, S.M. 1996. *Chronicles of marine fishery landings (1950–1994)*. FAO Fisheries Technical Paper No. 359. Rome, FAO. 51p.

Hsieh, C.-h., Reiss, C.S., Hunter, J.R., Beddington, J.R., May, R.M. and Sugihara, G. 2006. Fishing elevates variability in the abundance of exploited species. *Nature*, 443: 859–862.

Hutchings, J.A. 2001. Conservation biology of marine fishes: perceptions and caveats regarding assignment of extinction risk. *Canadian Journal of Fisheries and Aquatic Sciences*, 58: 108–121.

Jennings, S., Kaiser, M.J. and Reynolds J.D. 2001. *Marine Fisheries Ecology*. Blackwell Publishing, U.K. 417p.

Kulbicki, M., Labrosse, P. and Ferraris, J. 2004. Basic principles underlying research projects on the links between the ecology and the uses of coral reef fishes in the Pacific. In: *Challenging Coasts. Transdisciplinary Excursions into Integrated Coastal Zone Development*. Visser, G. (ed.), pp. 119–158. Amsterdam University Press, Amsterdam.

Lewis, R.J. and King, G.K. 1996. Ciguatera (fish poisoning). In: *Venomous and Poisonous Marine Animals: A Medical and Biological Handbook*. Williamson, J.A., Fenner, P.J., Burnett, J.W. and Rifkin, J.F. (eds), pp. 346–353. University of New South Wales Press, Sydney, Australia.

Musick, J.A. 1999. Criteria to define extinction risk in marine fishes. *Fisheries*, 24(12): 6–14.

Myers, R.A. 2001. Stock and recruitment: generalizations about maximum reproductive rate, density dependence, and variability using meta-analytic approaches. *ICES Journal of Marine Science*, 58: 937–951.

Myers, R.A., Bowen, K.G. and Barrowman, N.J. 1999. Maximum reproductive rate of fish at low population sizes. *Canadian Journal of Fisheries and Aquatic Sciences*, 50: 1576–1590.

Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. and Troell, M. 2000. Effect of aquaculture on wild fish supplies. *Nature*, 405: 1017–1024.

Ottolenghi, F., Silvestri, C., Giordano, P., Lovatelli, A. and New, M.B. 2004. The fattening of eels, groupers, tunas and yellowtails. In: *Capture-Based Aquaculture*. Ottolenghi, F., Silvestri, C., Giordano, P., Lovatelli, A. and New, M. B. (eds). Rome, FAO. 308p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES International Council for the Exploration of the Sea. *Journal du Conseil*, 1980 39(2): 175–192.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution*, 10(10): 430.

Torres Jr, F. 1998. Fishing down marine food webs. *Science*, 279: 860–863.

Ricker, W. 1975. Computation and interpretation of biological statistics of fish populations. Can. Department of the Environment, Fisheries and Marine Service, Bulletin 191. Ottawa, Canada.

Sadovy de Mitcheson, Y.J., A. Cornish, M. Domeier, P.L. Colin, M. Russell, and K.C. Lindeman. 2008. *A Global Baseline for Spawning Aggregations of Reef Fishes*. Conservation Biology 22(5): 1233–1244.

Walters, C.J. and Martell, S.J.D. 2004. *Fisheries Ecology and Management*. Princeton University Press, New Jersey, U.S.A. 399p.

Wilkinson, C. (ed.). 2004. *Status of Coral Reefs of the World*, Vol. 1 Australian Institute of Marine Science, Townsville, Queensland, Australia. 301p.

Web resources

www.fishbase.org
www.scrfa.org
http://www.iucnredlist.org/
www.CITES.org
http://www.seaaroundus.org/

Chapter 3

Social Aspects of Fisheries Management

Fikret Berkes

3.1 Introduction

Although most conventional fishery management concerns itself mainly with biological or bioeconomic approaches, fishery management is really 'people management'. This chapter is written with the general objective of providing support to managers in dealing with social dimensions of fisheries, consistent with the FAO Code of Conduct. It discusses a selection of issues, most of them interdisciplinary rather than purely social. The chapter is not about social theory, nor is it about established sub-disciplines such as fisheries sociology or fisheries anthropology, even though it includes elements from some of them. Neither does the chapter attempt to provide a comprehensive guide on all social dimensions of fishery management. Rather, it cross-references several other chapters in this book that deal with various relevant topics in more detail. These include institutions (Chapter 6), rights-based management (Chapter 10), partnerships (Chapter 11) and small-scale fisheries (Chapter 15).

Two overarching considerations shape the selection of the particular social and interdisciplinary dimensions considered in this chapter: the need to question and redefine the conventional view of *resources* and *management*, and the necessity of considering natural and social systems together.

- *Re-defining the concepts of resource and management*
  It is becoming clear that single-minded emphasis on production objectives for fish-as-commodity undermines the need to protect habitats, ecosystem processes and the health of the environment that is the basis for the fishery. The resource system needs to be managed, not for products and commodities but for *resilience*, defined as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedback. The argument here is that maximization approaches tend to reduce natural variability, impairing the renewal capacity of ecosystems and the ability to absorb shocks and stresses. As discussed in Chapter 2 this makes them fragile and vulnerable to disturbance. Since systems of humans and nature are characterized by cycles of renewal, their integrity is closely related to their ability for self-organization, renewal, learning and adapting. Hence, we need fisheries management that is resilient: works with the variation found in nature, is consistent with renewal cycles, can learn and adapt, and operates flexibly rather than following blueprint solutions.
- *The necessity of considering natural and social systems together*
  The new generation of fishery managers need to be interdisciplinary, with skills in both natural sciences and social sciences, so they can deal with the fish, the environment and the people together. This is the idea of ecosystem-based management (and of ecosystem

approach to fisheries) that explicitly includes humans in the system, instead of trying to separate them out (Francis *et al.,* 2007). We use the term *social–ecological system* to emphasize that social systems and ecological systems are linked and interdependent. Seen this way, both resilience and adaptive management have ecological and social components. The delineation between the social and the ecological is artificial and arbitrary.

The chapter expands on these two points, following a consideration of the 'tragedy of the commons' as the starting discussion. Fisheries management is a complex and evolving discipline, with a constant search for alternative approaches. In this chapter, these initial two themes provide the context of the search for alternatives, with the vision of an ecologically, socially and economically sustainable fishery. If conventional managerial approaches are falling short of such a vision, what do the alternatives look like? What can we learn from the diversity of emerging ideas? The chapter discusses the relevant issues and explores new approaches under four social dimensions of fishery management that follow from the initial two themes. These are: broadening management objectives; use of fishers' knowledge; institutions; and governance. Each of these is a section of the chapter.

3.2 Dealing with the 'tragedy of the commons'

Paramount among people management problems in fisheries is the 'tragedy of the commons'. This phenomenon, well known to fishers and fishery managers, is about the divergence between individual and collective rationality. Since the resource is fugitive, the fish you do not catch today may be caught by someone else tomorrow. There is little incentive to conserve the resource, as opposed to catching as much as possible as soon as possible. But since each fisher operates with the same rationality, the users are caught in an inevitable process that leads to the destruction of the very resource on which they all depend. Unless the fishers are somehow regulated in the common interest, the long-term outcome will be ecological ruin for all. This is the 'tragedy of the commons' as originally popularized by Hardin in 1968, using the example of a medieval English grazing common. But the earliest theories of the commons were, in fact, based on fisheries. Two fishery economists, Gordon and Scott writing in the 1950s, are usually credited with the first statements of the theory of the commons. Long before Hardin's essay, fishery economists were already modelling how excess labour was attracted into fisheries and the income dissipation and the resource depletion that often followed.

3.2.1 Developing a science of the commons

Most fisheries are commons; but contrary to Hardin, resource destruction is not 'inevitable' and neither is it dependent on external regulation. In the decades since Hardin, commons scholars have examined the conditions under which the 'tragedy' can be averted (Ostrom *et al.*, 1999; Dietz *et al.*, 2003). Commons (or common-pool resources) share two characteristics: (a) exclusion or the control of access of potential users is difficult (the *exclusion problem*), and (b) each user is capable of subtracting from the welfare of all other users (the *subtractability problem*). These two universal characteristics of commons are referred to as the *exclusion problem* and the *subtractability problem*, respectively. Thus, c*ommon-pool resources* (or commons) are those 'in which (i) exclusion of beneficiaries through physical

and institutional means is especially costly, and (ii) exploitation by one user reduces resource availability for others' (Ostrom *et al*., 1999).

Commons may be held in one of four basic property-rights regimes. *Open-access* is the absence of well-defined property rights. Access is free and open to all. *Private property* refers to the situation in which an individual or corporation has the right to exclude others and to regulate the use of a resource. *State property* or *state governance* means that rights to the resource are vested exclusively in government to control access and regulate use. In c*ommunal-property* (*common-property*) regimes, the resource is held by an identifiable community of users who can exclude others and regulate their own use. These four regimes are ideal, analytical types; in practice, resources are usually held in combinations of property-rights regimes.

The evidence accumulating over the last few decades indicates that three of these property-rights regimes (private property, state property and communal property) may, under various circumstances, lead to sustainable resource use. No particular regime is inherently superior to the others, but one may fit a particular circumstance better than the others. No one particular regime guarantees sustainability; there are successes and failures under all three regimes. But it must be emphasized that much of fishery management in the world uses mixes of property regimes and use rights (Chapter 10).

3.2.2 Property-rights regimes in the real world

For example, most aquaculture is managed as private property but comes under various government regulations as well. For capture fisheries, many developed countries use quota management (e.g. individual transferable quotas, ITQs) to privatize commons through the use of market-based approaches (Chapter 4). In developing countries, privatized quotas are not common. In both cases, there are many regulatory measures developed and enforced by governments, and they continue to be important (described in the chapters in Part II). However, pure state property regimes, in which the government makes and enforces *all* the rules and regulations, are rare. More workable are government regulations made with inputs from fisher organizations and enforcement that is aided by community and market processes (Chapter 11 on Partnerships). Similarly, communal-property regimes, in which all fishers have equal rights and equal say, probably exist only in the abstract. Most communal-property regimes depend on government recognition of local rights and may include simultaneous and multilayered sets of rights and authority, both communal and individual, with increasing market influence in the globalized world.

Regarding the open-access regime, however, there is general consensus that long-term sustainability is not possible. Open-access conditions are an historical anomaly; they do not exist for long. In time, property rights become established and authority is exercised on a resource, a process that may or may not involve the government – there often is fishery governance without government (Kooiman *et al*., 2005). That said, however, even short periods of open-access can lead to resource depletion before rights can be established and protected.

Figure 3.1 illustrates a hypothetical coastal area in which several property-rights regimes are found together. On the coast is a private aquaculture area, next to a fishing territory controlled by a village. The coastal fishery within the territorial sea (up to 12 miles) and the offshore fishery in the Exclusive Economic Zone (EEZ usually up to 200 miles) are under state property. Beyond the EEZ there may be an international regime in force on the high seas, but the area may have many of the characteristics of an open-access situation with fishing

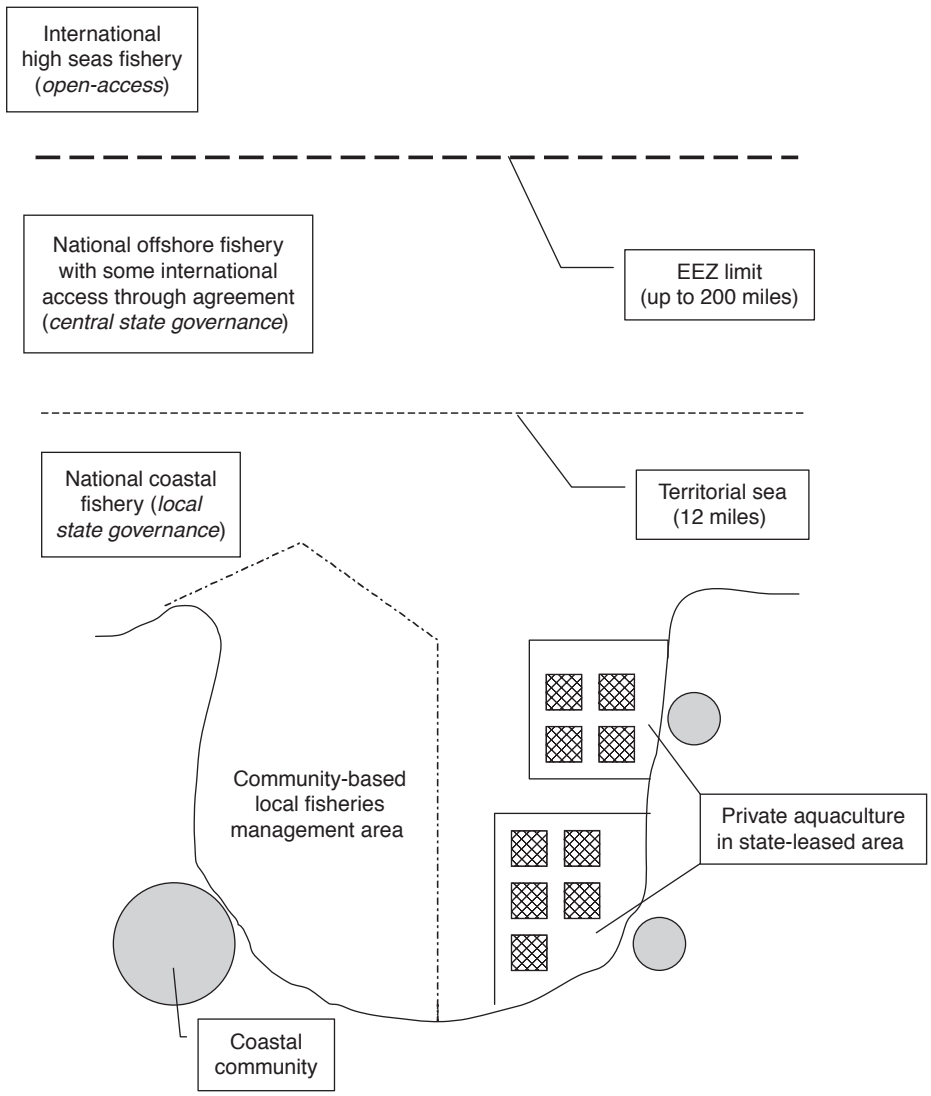


Figure 3.1 Different property-rights regimes in a coastal area. Source: Prepared by P. McConney (Berkes *et al.*, 2001). With permission from International Development Research Centre, Ottawa.

fleets opportunistically targeting resources that acquire high market value. Resources may be effectively open-access within the territorial sea and the EEZ as well, if the state is unable to enforce its regulations, a common situation in many developing countries. The private and the communal areas may both be mixed regimes, as it is the state that normally leases aquaculture areas and enables a community to control its fishing area, as in co-management.

Although the example is hypothetical, many coastal areas in fact have co-existing and overlapping property-rights regimes. Resource managers cannot function effectively unless

they know the property-rights regimes they are dealing with, and the implications of each with respect to dealing with the 'tragedy of the commons' (Section 10.3).

A number of conclusions emerge from the considerations in this section:

- There is nothing inherent in commons that would lead to resource degradation.
- Commons or common property is not the same as open-access.
- Hardin's metaphor is misleading to policy-makers and resource managers because it confuses 'common property' with 'open-access'.
- One fundamental flaw in Hardin's argument is that it ignores social relations among resource users that mediate their activities.
- A second flaw is the assumption that users could freely and openly access a common resource.

The 'tragedy' analysis would have us believe that resource users are self-centered utility maximizers, unrestrained by community and social relations. As anyone who has worked with fishers knows, even the most selfish and individualistic fishers are nevertheless subject to social pressures that shape their behaviour. Fisheries social science literature describes communities as learning systems and networks (Figure 3.2). In this view, communities are not just aggregations of individuals but networks guided by social values and norms, as well as by

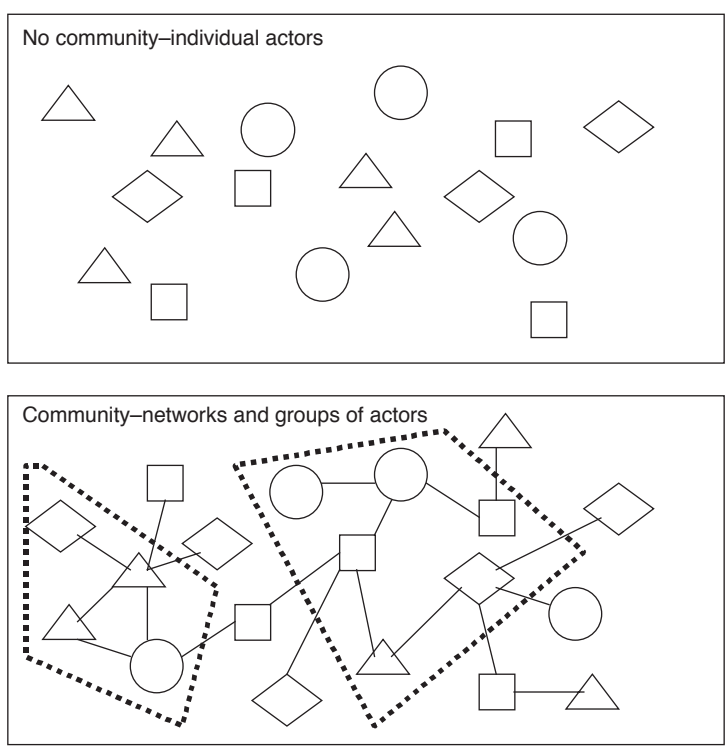


Figure 3.2 Individual actors versus concept of community. Networks may be found both within and across communities. Source: Prepared by P. McConney (Berkes *et al.*, 2001). With permission from International Development Research Centre, Ottawa.

rules that are often made officially or unofficially to express these norms and create explicit mechanisms for the group to control the behaviour of its more individualistic members.

Thus, there are social relations involved in the use of commons, through networks and other associations. These social relations often lead to problem-solving as with the information exchange and mutual assistance networks of longliners in the eastern Caribbean (McConney *et al*., 2007). They can also function in the formulation of practical rules-in-use: institutions in the terminology of Ostrom. In the governance of a given fishery, there often are both formal (i.e. legal, see Chapters 5 and 6) and informal institutions at many levels. Management is often multi-level. This theme is picked up again in Section 3.7.

3.3 Changing perspectives on resource management

The history of 'resource management' is closely associated with the commodification of nature in the service of industrialization. In the early phases of the Industrial Age, the relationship between humans and nature changed. Nature came to be viewed as clockwork and was considered to exist separately from humans. It could be studied by taking it apart and subjecting it to reductionistic analysis. Nature could then be brought under human control and made to yield economic benefits. From this historical perspective, industrial development is seen a consequence of freeing these supposedly limitless resources, and economic growth in general is seen as a process of overcoming environmental constraints. By the 1930s, a more realistic view of limits to production was beginning to appear. Contemporary perspectives in resource management have provided a fundamental modification of the view of an unlimited nature.

The meaning of the term *resource*, which carries implications of creating commodities abstracted from ecosystems, can be revised to include ecosystem products and services used by different groups of people (MA, 2005). The term *management*, which carries implications of domination of nature, can be updated to highlight governance, social relationships, adaptation and the maintenance of the productive potential of the ecosystem. However, it is nevertheless true that the dominant philosophy of resource management has been, and to a large extent is still, based on a tradition of positivistic science which assumes that the world is predictable and controllable. These assumptions do not fit well with the evolving thinking on ecosystem-based management. The ability to actually predict ecosystem behaviour is limited. Ecosystems have thresholds which, when exceeded, can cause major system structuring and such changes can be irreversible.

Furthermore, the science of ecology is abandoning the notion of equilibrium ('balance of nature') and instead adopting the idea that ecosystems are actually or potentially multi-equilibrium systems in which alternate states may exist over time, and an ecosystem may 'flip' from one state to another (Levin, 1999). According to this thinking, we can never possess more than an approximate knowledge of an ecosystem, and our ability to predict the behaviour of multi-equilibrium complex systems, such as marine ecosystems, is limited. Hence, models based on equilibrium thinking often do not work, not only because we lack data but also because ecosystems are intrinsically and fundamentally unpredictable.

This does not mean rejecting science. But it means recognizing the limits of conventional scientific knowledge, and appreciating other kinds of information, including the time-tested knowledge held by fishers and other people who live in and use these ecosystems to make

a livelihood. The idea of embracing complexity and learning to live with uncertainty is slowly replacing the command-and-control approach to management in a number of fields of applied ecology. Such adaptive management, combined with participatory approaches has been referred to as adaptive co-management.

In the field of fisheries, Charles (2001) refers to the 'illusion of certainty' and the 'fallacy of controllability.' Recent thinking in fisheries reflects the growing importance of recognizing complex adaptive systems thinking, and the necessity of moving away from single-species stock assessment models to protecting the productive potential of the ecosystem as a whole. Once we put aside the idea of controlling nature, then we can come to terms with the idea of dealing with resources through a learning-by-doing approach. Adaptive management is the contemporary scientific version of the age-old, trial-and-error learning of traditional societies. Adaptive management (Section 13.8) starts with the assumption of incomplete information and relies on repeated feedback learning in which policies are treated as experiments from which to learn.

One approach to deal with uncertainty and complexity is to build local institutions that can learn from crises, respond to change, nurture ecological memory, monitor the environment, self-organize and manage conflicts. A complementary approach is to build working partnerships between managers and resource users (Chapter 11). The use of imperfect information for management necessitates a close cooperation and risk-sharing between the management agency and fishers. Such a process requires collaboration, transparency and accountability, so that a learning environment can be created and management practice builds on experience. To take the argument one step further, we need to look at the implications of dealing with people issues as part of complex systems.

3.4 Fisheries as linked social–ecological systems

As with many resource systems, fisheries are not purely ecological systems isolated from human influence, nor are they purely social systems that function independently of the ecosystems that provide the resource. Rather, fisheries are linked social–ecological systems in which human activity modifies the ecological part of the system, and the nature of resources and their availability in turn modifies the social subsystem. A number of non-fishing considerations that did not concern previous generations of managers now have a strong influence on fisheries management throughout the world. In addition to the provisions of the FAO Code of Conduct, the fishery manager can no longer ignore such drivers as:

- United Nations Millennium Development Goals that bring in new national and international policies for such issues as poverty alleviation and sustainability.
- Environmental movements which can influence the activities of fishing fleets, as in tuna-dolphin controversies.
- Biodiversity issues, involving such matters as bycatch, habitat loss, species introductions, invasive species.
- Eco-labelling and certification that can shape fisheries practices, marketing structures and the species and
- The rapid development and invasiveness of international markets in shaping fisheries management at the local, national and regional levels.

The vulnerability of local fisheries to international markets emphasizes the interconnected nature of the world; globalization effects illustrate the futility of separating the social from the ecological. Specialty markets in far away places for new aquatic products can open up faster than local controls can develop, leading to the emergence of 'roving bandits' as seen in the globalized exploitation of sea-urchins (Berkes et al. 2006).

Fishery management is more than stock assessment; fisheries are complex systems of humans and nature. Addressing such complexity means paying attention to drivers and dealing with a number of issues ignored by conventional resource management. A complex adaptive system has a number of attributes not observed in simple systems, including greater uncertainty, non-linearity, scale and self-organization. These characteristics of complex systems have a number of important implications for resource management.

- *Uncertainty*
  Given ecosystem complexity and uncertainty, it has been generally known for some time that the maximum sustainable yield (MSY), as defined by stock assessment models, is in fact a meaningless target (Charles, 2001). More generally, target reference points are difficult to negotiate because of lack of data as well as uncertainty. As an alternative approach, some fishery managers are experimenting with the use of reference directions (e.g. to increase the proportion of valuable species in the catch) instead of target reference points (e.g. a catch of 1000 tons of a particular species) (see also Chapter 12). Using reference *directions*, rather than targets, still requires quantitative data, but the choice of the management direction itself is a qualitative decision. This approach shifts the focus of management action from the exacting and difficult question, 'where exactly do we want to be?' to the simpler and more manageable, 'how do we move from here in the desired direction?'
- *Non-linearity*
  The consideration of non-linearity raises other questions. Ecosystem change triggered by exploitation or other causes do not occur smoothly but often lead to ecosystem flips or phase shifts. Ecosystem processes seem to have thresholds. For example, on many coral reefs the depletion of herbivorous parrotfish, beyond a certain point, can result in macroalgae blooms that replace corals. The depletion of fish and lobsters in kelp beds has led to explosions of sea urchins in various parts of the world, promoting phase shifts to overgrazed urchin barrens (Hughes *et al*., 2005). Resource management that uses linear thinking performs poorly in a world characterized by non-linear processes and phase shifts. Emphasis on centralized institutions and command-and-control resource management, stemming in part from linear thinking and mechanistic views of nature, often aims to reduce natural variation in an effort to make the ecosystem more productive, predictable, economically efficient and controllable. But the reduction of the range of natural variation is the very process that may lead to a loss of resilience in a system, leaving it more susceptible to crises and less able to renew and self-organize.
- *Scale*
  The scale issue raises yet other questions. A given stock may be used by coastal and offshore fisheries and more than one nation. How does the fishery manager choose the spatial and temporal scale of management? Can a fishery be managed by one centralized agency, or are there more appropriate structures of governance in which the scale of management institution is matched to the scale of the ecosystem? Often, 'one size fits all' kind of management ignores scale issues and is one of the key reasons for the failure of many resource management regimes. Management occurs at multiple levels but

not all levels are equally important. The relevant principle is: as much local management as possible, and only so much government management as necessary. Sometimes called the *subsidiarity principle*, the idea has been adopted, among others, by the Maastricht Treaty that lays out the framework for establishing the European Community: 'decisions [should be] taken as closely as possible to the citizen'. It articulates the objective that decisions affecting peoples' lives should be made by the lowest capable level of social organization.

One of the insights from complexity thinking is that multiplicity of scales means, there is no one 'correct' perspective in a complex system. A fishing community may focus on their livelihoods, regional managers on user-group conflicts and the central government on export earnings. The perspective depends on the interest of the observer and their reading of the history and context of the fishery. A complex social–ecological system cannot be captured using a single perspective. It can be best understood by the use of a multiplicity of perspectives.

- *Self-organization*
  Finally, self-organization is considered by some to be the key attribute of complex adaptive systems, with emphasis on the word *adaptive*, as related to feedback. Complexity emerges out of the self-organization of complex systems. Fishing communities have long been used as 'laboratories' for investigating self-organization and self-governance. Commons research over the last 30 years or so has documented in considerable detail the self-organization and self-regulation capability of communities to solve the commons problem. Relevant to fisheries management, understanding how complexity arises has led to work on the evolution of cooperation (e.g. among fishers; among nations) and the development of social norms and culture. The notion of self-organization has precautionary lessons as well. If patterns we see in ecosystems are a result of processes of self-organization, this has serious implications for management. It means that the patterns we observe in nature perhaps do not represent unique and robust assemblages, suggesting that larger and larger perturbations that humans impose on nature may in turn result in larger and larger system flips.

  Treating fisheries as complex systems does not necessarily complicate the role of the manager. There is evidence that simple rules may be appropriate to deal with complexity. The sockeye salmon fishery of Bristol Bay, Alaska, provides an example. The Bristol Bay sockeye have been managed for decades by two simple rules: (1) a minimum number of salmon should be allowed to escape to any given watershed before fishing is allowed and (2) within any watershed, escapement should be distributed over time in a natural pattern. Hilborn *et al*. (2003) showed how these rules have conserved the biocomplexity of stocks that in turn has enabled the resource as a whole to maintain its resilience to environmental change.

3.5 Why broaden management objectives?

There is general agreement on the larger goals of management: preventing biological and commercial extinction of resources and promoting their sustainable use. But the specific goals are more controversial and elusive. In the history of fisheries management, objectives have changed over time; from the MSY approach to maximum economic yield (MEY) to optimum sustainable yield (OSY). Benefits from a fishery can be measured in different ways, as

the quantity of fish harvested (biological), or as revenue from the fishery (economic) or as a composite benefit to society, including sustainable livelihoods and sustainable communities.

The idea of optimal yields emerged, as it became evident that the benefits from a fishery could be measured in many other ways than simply the weight or the landed value of the catch. The problem, however, is that multiple objectives are messy. Maximization of a single objective is much easier than optimization that must address trade-offs and compromises. Nevertheless, the OSY approach is useful because it necessitates a process of reaching consensus on the most appropriate objectives, hence bringing people into the decision-making model more explicitly than is the case with MSY and MEY.

Most of the objectives commonly stated for fisheries management fall into three categories (Clark, 1985). One set relates to resource sustainability, ensuring that the biological productive capacity of the resource is maintained. The other two sets are social and economic, and relate either to the optimization of returns from the fishery (efficiency) or to the fair distribution of those returns among stakeholders (equity). Clark recognized some 22 fishery objectives (Table 3.1) relating to sustainability (six of them), efficiency (twelve) and equity (eight). Any of these objectives may be a valid goal for a fishery, but it is not possible to achieve them all for a single fishery. Some of the objectives are incompatible with one another. For example, management can aim to maximize the biological yield or the economic yield but not both.

3.5.1 Equity objectives and livelihoods

One of the contributions of fisheries social science has been to point out the importance of the social context of the fishery, such as kinship and other social relations. In fishing communities, norms, networks and trust relationships (so-called social capital) tend to be important as are reciprocal relations, values and local institutions. Fishing is not merely a job but a way of life; not merely a source of employment but also a livelihood that produces income and food for the household and the community. In developing countries as well as in the small-scale fisheries of countries such as the United States and Canada, fishing is often part of a complex of livelihood activities, which may include agriculture and other part-time occupations in which, for example, women may play a major role.

Fishing may be a seasonal activity that is part of livelihoods of households and communities. Flexibility in fishing requires access to a range of resources. The viability of many fisheries, both small-scale and large-scale, depends on having access to a number of stocks to fill the seasonal cycle and to compensate for year-to-year fluctuations in abundance. In particular, small-scale fishers tend to be dependent on a diversity of species and habitats for their livelihoods. The ability to follow a seasonal round of activities and the ability to switch fishing grounds and species (fishing more when a particular resource is abundant; moving on when it is not) allows them the flexibility to change and adapt as conditions dictate.

According to a commonly used definition, a livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities, assets and entitlements, while not undermining the natural resource base. As the notion of coping with and recovering from stresses and shocks lies at the heart of this definition, resilience of livelihoods is the basis of sustainability. Therefore, the ability to follow a seasonal round of activities and switch gears, fishing grounds and target species are necessary for livelihood resilience, providing options and flexibility. At the same time, switching species helps maintain biodiversity and prevent system flips by limiting heavy exploitation on any one species.

Table 3.1 Some objectives of fishery management.

Objective	Main purpose		
	Sustainability	Efficiency	Equity
1. Maximize catches		☐	
2. Maximize profit		☐	
3. Conserve fish stocks	☐		
4. Stabilize stock levels	☐		
5. Stabilize catch rates		☐	
6. Maintain healthy ecosystem	☐		
7. Provide employment			☐
8. Increase fisher's incomes			☐
9. Reduce conflicts among fisher groups or with non-fishery stakeholders			☐
10. Protect sports fisheries		☐	☐
11. Improve quality of fish			
12. Prevent waste of fish	☐	☐	
13. Maintain low consumer prices			☐
14. Increase cost-effectiveness		☐	
15. Increase women's participation			☐
16. Reserve resource for local fishers			☐
17. Reduce overcapacity	☐	☐	
18. Exploit under-utilized stocks	☐	☐	
19. Increase fish exports		☐	
20. Improve foreign relations		☐	☐
21. Increase foreign exchange		☐	
22. Provide government revenue		☐	

Source: Adapted from Clark (1985)

3.5.2 Poverty and resource access

The overexploitation of stocks, degradation of marine and coastal habitats and the increase in coastal populations in many parts of the world make it difficult for fishers to fulfil their livelihood needs. Hence, fishers and poverty often go together. Or at least, this is the conventional view of poverty in fishing communities, especially those of small-scale fisheries in the developing world. Béné (2003) has challenged this conventional view. He argues that two common perceptions ('they are fishermen because they are poor' and 'they are poor because they are fishermen') are in fact two sides of the same coin, and there is not much empirical evidence in support of either. The two perceptions form the circular logic of the old paradigm, equating fisheries with poverty. Béné (2003) argues that this old paradigm is neither helpful from a policy perspective nor correct in view of the findings of research on the causes of poverty. This body of work indicates that several mechanisms (economic exclusion, social marginalization, class exploitation and political disempowerment) governing people's *access* to resources – rather than the resources themselves – play a critical role in vulnerability to poverty.

The issue is far from being resolved. But the controversy underlines the importance of equity-related objectives (Table 3.1) especially for small-scale fishers who constitute the vast

majority of fishers of the world (Section 15.1). These objectives need to be balanced against other objectives. For example, when economically efficient large-scale fishers get quota allocations of groundfish resources in the Canadian Maritimes, small-scale fishers are excluded and marginalized. Their loss of livelihood is not because of their numbers or lack of groundfish but because of lack of access to the available groundfish (Wiber *et al*., 2004).

The task of dealing with multiple objectives and their trade-offs is one of the most difficult jobs of the resource manager, keeping in mind that equity and efficiency objectives, in turn, need to be underpinned by resource sustainability objectives. The task is full of pitfalls. The conventional objective of maximizing biological yields or economic returns often ignores the larger question of the ecological and social costs of maximization. A broader view of fishery objectives recognizes that a sustainable fishery exists only in the context of an ecosystem that supports it. Given that the social and ecological aspects of the fishery system make up one integrated whole, the manager has to keep in mind the overall health of this integrated social–ecological system.

3.6 Is fishers' knowledge relevant to management?

Despite the accumulation of a great deal of scientific data, there often is insufficient information to manage fish stocks, not only in multispecies fisheries of tropical waters but also elsewhere. Our education tells us that fisheries management requires extensive research, sophisticated models, large amounts of data and highly trained experts. However, we now know that these ingredients are not always sufficient. There are practical and cost-efficient approaches to use non-conventional sources of information. Especially in small-scale fisheries, management can work by supplementing scientific data with qualitative indicators and local and traditional knowledge as means of evaluating the status of the resource and determining future directions (Johannes, 1998).

Fisher knowledge has been receiving much attention as a source of management information (Haggan *et al*., 2006). There are a number of strengths and limitations to using fisher knowledge or traditional ecological knowledge.

3.6.1 Strengths and advantages of using local and traditional knowledge

- Good management requires mobilizing as wide a range of information as possible, broadening the knowledge base necessary for sustainable resource use.
- People who live and work in an area develop a detailed knowledge of that area, in some cases, *traditional ecological knowledge* – a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission. Such knowledge is an attribute of societies with historical continuity in resource use in a particular area.
- In many cases, fisher knowledge does not have such historical and multigenerational character. Such practical knowledge can be called local knowledge, also relevant to management and used in many geographical contexts.
- 'Data-less management' has been proposed by Johannes (1998) as a way of dealing with fisheries in data-poor Oceania. It does not mean management without information but rather emphasizes the importance of supplementing traditional knowledge with the use of

studies on similar fisheries in other locations, including the use of marine protected areas as source of baseline data.

- Local knowledge can provide direct input for management. The ability to take the steps needed to improve a fishery will be strengthened considerably when the stakeholders can agree on the measures used. The key element is agreement or consensus. Given the various uncertainties, management using consensus and measures that can be understood by all is a risk-reduction strategy.
- The use of local and traditional knowledge is a part of the trend towards stronger civil society involvement in decision-making. Information produced by specialists is no longer confined to specific groups but becomes widely available for citizen action and civic science. As the barriers between the scientist/manager and the resource user/citizen break down, local and traditional knowledge also starts to play a role in resource management.

3.6.2 Limitations and pitfalls of using local and traditional knowledge

- Traditional ecological knowledge does have a belief component, and this feature often clashes with science or results in the erection of barriers between the two kinds of knowledge.
- Extracting only the empirical knowledge part out of traditional ecological knowledge is possible. But to do so creates an 'intellectual property rights' issue. Perhaps more importantly, it also leads to using that knowledge out of its unique cultural context.
- In the case of local knowledge, or where the cultural distance between fishers and managers is relatively small, the use of empirical knowledge is often not problematic. Nevertheless, using the empirical local knowledge of fishers has to be carried out in a socially sensitive way.
- Methodologically, accessing local and traditional knowledge is not easy. For example, knowledge is not distributed evenly among a group of fishers and this creates a sampling problem. Finding the 'right' fishers as informants for local knowledge is difficult as these are often the busier and the less available people. There is an art and a science to local knowledge research (but it is not the monopoly of social science – for example, Bob (R.) Johannes was a biologist).
- There often is specialized knowledge by social group and gender. Accessing this knowledge does require knowing the different social and cultural groups in an area. In many cases, there is gendered knowledge that the manager needs to access, for example, women's knowledge of lagoon fish and invertebrate resources in the Asia-Pacific region.

3.6.3 Knowledge and scale

In Section 3.4 discussing scale, the observation was made that the multiplicity of scales means a multiplicity of perspectives (rather than one 'correct' one). Such pluralism in perspectives is often mirrored in pluralism in knowledge. In fishery management disputes, local knowledge may sometimes appear at odds with science. But in many cases, the differences in knowledge have to do with differences in the level at which information is obtained. Since understanding the resource system requires the input and knowledge of actors at the various levels of the system, local and traditional knowledge can complement science not only in terms of adding to the range of information available but also in terms of scale. This gives a more complete accounting of the various levels of analysis from local to global (Reid *et al.*, 2006).

Not all fisher knowledge is relevant to management, but the use of local and traditional knowledge creates opportunities for supplementing scientific information, especially in data-poor fisheries. Rather than extracting and using fisher knowledge, an approach that is becoming increasingly common is the *co-production of knowledge*, a process by which managers and fishers interact to define important questions and relevant evidence, sometimes carry out participatory research, and engage in a joint deliberation to make sense of the observations. Using fishers' knowledge, or co-producing knowledge, helps widen the range of information available for decision-making. This is particularly important for complex, multi-scale systems. Such a wider range of more inclusive information is in many cases necessary for decision-making.

3.7 Why are institutions important?

The participatory style of management requires collaboration between managers and resource users. However, building such partnerships is never easy (cf. Chapter 11); it requires fishers who are sufficiently well-organized to carry out such a partnership, and appropriate community-based and stakeholder-based institutions. Further, it requires a favourable policy environment and government's willingness to engage in participatory management. It also requires the presence of appropriate government institutions to interact with fisher organizations – because it 'takes two to tango' (Pomeroy and Berkes, 1997).

Until the 1980s, the question of fisheries co-management through the collaboration of government agencies and community-based institutions would not even have come up for discussion. The prevailing management thinking was that fishers could not self-regulate. Fisheries were used as the classical example of the 'tragedy of the commons' and it was widely believed that government management agencies had to enforce various regulations on fishers as the only way to avoid the 'tragedy'. Yet, many examples from throughout the world show that fishing communities do not require central government regulations to make and enforce simple and practical systems of resource use. In many cases, resource managers have been dealing with users as part of the solution, rather than as part of the problem. This does not mean that the role of the manager has ended; it means that the role of the manager has changed in nature.

3.7.1 Developing a vocabulary on participation and institutions

To fulfil this new role, the fishery manager needs to know about participatory processes and institutions, on which there is an ever-increasing vocabulary.

- *Stakeholders*
  Stakeholders are individuals or groups (including governmental and non-governmental organizations or NGOs, traditional communities, universities, research institutions, development agencies and banks, donors, etc.) with an interest in the fishery management process or a claim on the resource.
- *Stakeholder analysis*
  Stakeholder analysis is a process that seeks to identify and to describe the interests of all of the stakeholders in a fishery. It is considered to be a necessary stage to carry out participatory management.

- *Capacity-building*
  Capacity-building is the sum of efforts needed to nurture, enhance and utilize the skills and capabilities of people and institutions at all levels, towards a particular goal, for example participatory management. The logic of capacity-building is simple: involving fishers in the management process depends on their ability to self-organize to help in the making and enforcing of rules.
- *Empowerment*
  Empowerment is having the power and responsibility to do something; the ability of a person or a group of people to control or to have an input into decisions that affect their livelihoods. Effective participation, after appropriate capacity-building, can bring about empowerment.
- *Multi-stakeholder process*
  Multi-stakeholder bodies bring together stakeholders, including government agencies, for consultation and assessment. The distinction between multi-stakeholder processes and co-management is not always clear. Such processes are often used as a tool for public participation in consultations, and they may or may not involve the devolution of real power (empowerment).
- *Co-management*
  Co-management is a partnership arrangement in which government, the community of local resource users (fishers), external agents (non-governmental organizations, research institutions) and other fisheries and coastal resource stakeholders (boat owners, fish traders, credit agencies or moneylenders, tourism industry, etc.) share the responsibility and authority for decision-making over the management of a fishery. However, all these parties do not have a stake equal to fishers, and the sharing of responsibility and authority is not likely to be equal.
- *Institutions*
  Institutions are socially constructed codes of conduct (rules and norms) that define practices, assign roles and guide interactions. This definition of institutions, as the set of rules actually used, is different from the common use of the term generally to mean agencies.
- *Institutional interplay, horizontal and vertical*
  Institutional interplay is about linkages among institutions, at both the same level of social and political organization and across levels. Institutional interplay can involve the linkage of institutions *horizontally* (across the same level of organization or across geographical space) and *vertically* (across levels of organization). The simplest kind of vertical institutional linkage is a two-party co-management arrangement between a resource user group and the government. A multi-stakeholder process usually creates horizontal linkages among the players.

3.7.2 Institutions in a multi-level world

Some fishing communities have traditions of social organization and autonomous decision-making for resource management. They may have their own resource use areas and a system for making rules of conduct. However, in other cases, community self-organization does not come easily. Not all fishing communities have the experience or capability to regulate themselves or to participate in co-management. It may take effort to organize and

build institutions, often with the help of NGOs. Such institutional capacity-building (or *institution-building*) is widely recognized as a vital component of participatory management. It is not a rapid process. Case studies in the development literature indicate a time frame of the order of 10 years.

There have been many studies to define the conditions under which community-based management institutions or co-management arrangements can work (see Chapter 11). These studies have identified many important factors, but they are not likely to provide a blueprint or a formula for institutional success. This is because context (history, politics, culture) is important in each particular co-management situation. This is not to say that institutional development is not possible; rules and practices change all the time through adaptation and learning. Rather, the point is that each situation is conditioned by the context and the trajectory of its development, and therefore a solution developed in one case cannot readily be transferred to another. For example, the community-based marine protected area approach, developed in one area of the Philippines and replicated throughout the country with little attention to local context, resulted in a high rate of failure (White *et al*., 2002).

In any case, institutional development at any one level of political organization can never be sufficient for management success if it ignores the necessity of managing commons at multiple levels. The increasingly globalized world of the 21st century requires institutions that link the local level to the various higher levels of social and political organization. Any one management institution, or level of political organization, is insufficient by itself to deal with, for example, problems of migratory marine resources. Scale issues are pervasive in commons management, and the understanding of vertical institutional linkages (as in co-management) is particularly important because these arrangements provide a means to bridge the divide between different levels of organization. In effect, they provide ways to deal with linkages in complex adaptive systems and help understand the nature and dynamics of the multi-level world in which fishery management operates.

The consideration of complexity makes the task of the fishery manager more complicated in some ways but simpler in other ways. Learning and adaptive management are facilitated by linking different levels of organization locally and nationally, and creating problem-solving networks with a diverse participation of stakeholders. At the level of national and international policy-making, political scientists have been interested in *policy networks* and *epistemic communities* of managers and scientists that similarly function as problem-solving networks.

Institutional linkages help build capacity for learning and adapting. Adaptive management and co-management can be combined into *adaptive co-management*, a collaborative process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of trial and error. The knowledge component of this adaptive co-management process is significant. As noted in Section 3.6, institutional interplay has the additional advantage of bridging scales in terms of knowledge. If brought into play, fishers' knowledge can complement science by helping provide a more complete information base from local to global.

3.8 The broader issues of fisheries governance

There is international interest in a civil society in which the citizens are no longer treated as subjects but participants in governance. It is part of a trend emphasizing horizontal processes

such as collaboration, partnership and community empowerment in all areas of resource management from fisheries to protected areas. Governance has become a catchword in the social sciences as well as in the various fields of resource and environmental management. The literature on governance only developed in the 1990s with emphasis on problem-solving and opportunity creation as a joint and interactive responsibility of all parties–state, market and civil society. Governance is not considered to be the natural prerogative of governments but rather a broad responsibility to be shared (hence the expression 'governance without government'). As such, governance theory opened up the field to non-state actors.

3.8.1 Common features of governance perspectives

Governance perspectives have three common features:

1. Governing is no longer considered only a task of government managers, as many governments are formally recognizing that public and private actors should also be involved.
2. Governance approaches emphasize that the dividing lines between public and private sectors is blurred (as in the phrase, 'public–private partnerships').
3. Governance has a basis in societal developments and is a reflection of interdependencies in a globalized world.

Governance has been defined in many different ways. According to Kooiman, governance is the whole of public as well as private interactions taken to solve societal problems and create societal opportunities. It includes the formulation and application of principles guiding those interactions and care for institutions that enable them. Hence governance is the broader arena in which institutions operate, and the various processes outlined in the previous section take place. Governance covers some of the area previously captured by the terms policy and management. The trend is to use governance as the more inclusive term, followed by policy and finally by management. Management is about action; governance is about politics – sharing of responsibility and power, and setting the policy agenda and objectives.

Much of the governance literature discusses *good governance*, a norm introduced by the World Bank in the early 1990s. As the United Nations Development Programme (UNDP) puts it, good governance is, among other things, participatory, transparent and accountable. Here transparency refers to openness, the free availability of information, decisions and plans, and the use of language that stakeholders can understand. Accountability means that people who make the decisions should be available to answer to the people who are affected by the decisions. To this list, other criteria may be added, such as legitimacy and authority based on a democratic mandate. For example, do the stakeholders accept that rule-making and enforcement are being carried out by people and groups who should have the authority to do so?

Another major segment of the governance literature is concerned with decentralization that has become pervasive in many resource fields in many parts of the world. As a kind of governance reform, Kooiman *et al*. (2005) and Béné and Neiland (2006) consider that decentralization has a number of strengths and a number of limitations. However, many of these strengths and limitations have not in fact been documented satisfactorily and will not necessarily hold in a particular case.

3.8.2 Strengths and advantages of decentralization

- Decentralization addresses the limited effectiveness of government agencies in resource management, especially at the local level.
- Decentralization helps empower stakeholders.
- Decentralization is seen as a precondition for rural development.
- Decentralization is seen as a precondition for the development of good governance.
- Decentralization is seen as a tool for poverty reduction.
- Decentralization enables user participation in management and problem-solving at the lowest possible level of organization, consistent with the subsidiarity principle.
- Decentralization is a cost-effective way to provide some public services by removing cumbersome government hierarchies.
- Decentralization may stimulate institutional reform and/or the creation of new legislation.

3.8.3 Limitations and pitfalls of decentralization

- Decentralization may result in loss of public services and increased inequity.
- Decentralization may result in 'elite capture' of resources, as local and customary authorities are not always democratic.
- Lack of representativeness of decentralized bodies.
- The determination of 'the lowest possible level of organization' in decentralization is difficult; in some instances the subsidiarity principle may require centralization, rather than decentralization.
- Ecosystems (such as a mangrove area) rarely fall within a single local administrative jurisdiction.
- Decentralization may result in the creation of more local conflicts and social tensions, leading to resource overexploitation.
- Local jurisdictions rarely receive the fiscal support necessary to carry out their new responsibilities in the process of decentralization (the phenomenon of 'off-loading').

In conclusion, decentralization has the potential to create opportunities for local control and management of resources and for empowerment. However, the experience with decentralization in recent years also indicates a number of potential problems, including elite capture and increased resource conflicts. As Béné and Neiland (2006) put it, unless a number of stringent conditions are met, decentralization reforms in natural resource management are likely to fail. Examining decentralization in fisheries and focusing on co-management as a mechanism for governance reform, they raise a number of questions. In the case of artisanal fisheries in developing countries, the authors contend that the co-management literature has focused on the level of participation as the key explanatory element of success or failure. In the process, the literature has not done a good job of addressing the question of whether or not co-management, as a way of carrying out decentralization reform, effectively delivers positive impacts in terms of poverty alleviation.

3.9 Synthesis and outlook

This chapter focused on some social dimensions of fisheries management consistent with modern practices and norms such as the FAO Code of Conduct. The aim is to move from a management

approach that focuses only on target resources, to one that takes a wider ecosystem view. An important part of this more comprehensive approach is the need to address fisheries as an integrated social–ecological system, including the social context of the fishery, participation and governance issues, and the benefits and costs of management actions, for example, in the choice of management objectives. These costs and benefits impact not just individual fishing boats and fleets but fishing communities as well. Such management requires a broader understanding of human behaviour and how people use and misuse fishery commons.

In recent decades, a number of attempts have been made to identify principles to guide the development of a broader concept of fishery management. One such approach, the Lisbon Principles for sustainable governance, provides a useful synthesis by integrating many of the ecological, economic and social dimensions of fishery management discussed in this chapter and elsewhere in the volume (Table 3.2). The six principles cover responsibility for ecologically sustainable, economically efficient and socially just (equitable) management; scale matching; use of the precautionary principle (Sections 9.6.5 and 13.3); adaptive management; full-cost accounting (Chapter 4); and participation. These principles help respond to a number of emerging issues that have been identified in this chapter. Some of these are related to the changing perspectives in resource management and the need to incorporate them into fishery planning:

- Dealing with resources, not as commodities, but as ecosystem products and services used by different groups of people.
- Dealing with management, not as the domination and control of nature, but as governance, social relationships, adaptation and the maintenance of the productive potential of the ecosystem.
- Developing adaptive management further and applying management practices that do not rely on equilibrium-based models.

Table 3.2 The Lisbon Principles to promote sustainable governance of the oceans and coastal areas.

Responsibility principle	Responsibility to use resources in an ecologically sustainable, economically efficient and socially just manner
Scale-matching principle	Decision-making at the scale of governance which has the most relevant ecological information, which considers actors, and which internalizes costs and benefits
Precautionary principle	The need to take uncertainty about potentially irreversible impacts into account by erring on the side of caution
Adaptive management principle	Monitoring social, economic and ecological systems because they are dynamic and have some level of uncertainty; learning-by-doing
Full-cost allocation principle	The need to identify and allocate all internal and external costs and benefits (social and ecological) of alternative uses of resources
Participation principle	The importance of full stakeholder participation in the formulation and implementation of decisions about environment and resources

Source: Adapted from Costanza *et al.* (1999)

- Managing for resilience, maintaining natural variation and capacity of the system to absorb disturbance and reorganize.
- Noting that the notion of resilience applies to livelihoods as well as to ecosystems: coping with and recovering from stresses and shocks requires the maintenance of diversity, options and flexibility.

Some of the emerging issues identified in this chapter are related to our increased understanding to deal with complexity:

- Dealing with fisheries as linked social–ecological systems in which fishers and their ecosystem have a two-way feedback relationship.
- Addressing complexity, including uncertainty (e.g. adaptive management), non-linearity (e.g. recognizing thresholds and system flips), scale (e.g. space and time scale for which to manage) and self-organization.
- Developing ways to use information at different scales, including fisher knowledge.
- Broadening management goals to include livelihood and equity objectives, in addition to biological and economic objectives.

Some of the emerging issues identified in this chapter are related to our increased appreciation of governance issues:

- Avoiding the 'tragedy of the commons' mindset and dealing with fishers as part of the solution, rather than the problem, with due recognition of their institutions.
- Recognizing different kinds of commons regimes and the appropriate roles of each.
- Looking for a mix-and-match, using the relative strengths of community-based, market-based and regulatory measures for a given fishery situation, rather than looking for panaceas or formula-based solutions.
- Developing multi-stakeholder and co-management arrangements as appropriate.
- Combining the elements of user participation and adaptive management, to develop adaptive co-management.
- Recognizing that capacity-building is a slow process but will pay dividends for better long-term management.
- Making decentralization work as governance reform by paying attention to a number of conditions that have to be met.

The fishery manager has some control over many of the problems mentioned earlier. However, other emerging issues are largely beyond the control of the fishery manager who can recognize them in a precautionary way, even though they cannot easily be incorporated into management plans:

- Taking notice of global environmental change that includes climate change as well as other global environmental phenomena (e.g. biodiversity loss) and social and economic changes.
- Taking notice of external drivers resulting from *globalization* in general, sometimes defined as the compression of space and time scales, with regard to flows of information, people, goods and services.

- Taking notice of 'roving bandits' who operate by taking advantage of specialty markets in far away places for new aquatic products that can open up faster than local controls can develop.
- Taking notice that eco-labelling, green products and certification have potential long-term influences on the way fisheries are carried out throughout the world.
- Taking notice of UN Millennium Development Goals, target date of 2015, which will result in new resource policies related to poverty alleviation, sustainability, food security, equity and livelihoods.

Expanding on some of the afore mentioned, the consideration of resilience is shaping up as one of the more important emerging issues. Resilience is a complex systems property, and refers to the dynamics of systems by highlighting their ability to absorb shocks, self-organize, learn and adapt in dealing with change. These considerations will become more important as global change becomes more prominent; for example climate change impacts are not so much about mean change but about increased variability, increased frequency of extreme weather events and reduced predictability. Current research has dealt with slow and fast variables of change, and how different kinds of institutions may be needed to deal with slow-onset global problems (e.g. biodiversity erosion) as opposed to fast-onset ones (e.g. hurricanes and other extreme weather events). Ecological and social aspects of resilience are closely connected. Sustainable livelihoods are those that are resilient to stresses, can cope with crises and are capable of absorbing environmental and economic perturbations.

The related area of complexity is another important emerging issue. Conventional fishery management science does not have the methods in its toolkit to deal with complexity. What is needed is a different kind of management regime that goes beyond command-and-control measures, empowering fishers to self-organize and self-manage, so they can learn, adapt and respond to change, such as those driven by globalization. However, communities cannot do this in isolation. They need networks and partnerships involving various levels of government and support organizations such as NGOs. Partnerships, co-management and other participatory approaches are also essential for an ecosystem approach in management that is shaping up as the major approach to deal with complexity.

Many fishery managers resist dealing with additional complexity as conventional management is complex enough. The implication is that the more complex the system being managed, the more complex the measures of management. But this is not necessarily true. Rather than complex systems problems requiring increasingly complex solutions, in some cases the counter-intuitive solution may be true: simple rules may be more appropriate than complex ones, as seen in the case of Bristol Bay salmon.

Taken together, these approaches are consistent with modern practices and norms such as the FAO Code of Conduct, and turn the older managerial approach on its head. Instead of reductionism and positivism, there are complex system approaches; instead of control-of-nature utilitarianism, there is emphasis on humans-in-ecosystem management; instead of sole reliance on expert-knows-best science, local and traditional knowledge are also used; instead of top-down decision-making, there is participatory management; and instead of fishing-as-business, there is focus on sustainable livelihoods.

These approaches are not 'management' in the conventional sense because they effectively re-define the troublesome terms, *resource* and *management*. As re-defined, resources are no longer merely commodities but elements of an ecosystem that supports ecological services as well as human well-being. Such management is not control-oriented but is about governance, learning and adaptive management. It serves to maintain the productive capacity and resilience of linked social–ecological systems.

Acknowledgements

Many of the ideas in this chapter originated with the book project, *Managing Small-Scale Fisheries*, supported by the International Development Research Centre (IDRC). I thank project colleagues, Robin Mahon, Patrick McConney, Richard Pollnac and Robert Pomeroy, as well as Brian Davy. My work on social–ecological systems and community-based fisheries has been supported by the SSHRC and the Canada Research Chairs (http://www.chairs.gc.ca) programme.

Sources and recommended reading

Allison, E.H. and Horemans, B. 2006. Putting the principles of sustainable livelihoods approach into fisheries development policy and practice. *Marine Policy*, 30: 757–766.

Armitage, D., Berkes, F. and Doubleday, N. (eds). 2007. *Adaptive Co-Management: Collaboration, Learning, and Multi-Level Governance*. University of British Columbia Press, Vancouver.

Béné, C. 2003. When fishery rhymes with poverty: A first step beyond the old paradigm on poverty in small-scale fisheries. *World Development*, 31: 949–975.

Béné, C. and Neiland, A.E. 2006. *From Participation to Governance*. WorldFish Center, Penang and CGIAR Challenge Program on Water and Food, Colombo.

Berkes, F. and Folke, C. (eds). 1998. *Linking Social and Ecological Systems*. Cambridge University Press, Cambridge.

Berkes, F., Hughes, T.P., Steneck, R.S., Wilson, J.A., Bellwood, D.R., Crona, B., Folke, C., Gunderson, L.H., Leslie, H.M., Norberg, J., Nystrom, M., Olsson, P., Osterblom, H., Scheffer, M. and Worm, B. 2006. Globalization, roving bandits and marine resources. *Science*, 311: 1557–1558.

Charles, A.T. 2001. *Sustainable Fishery Systems*. Fishing News Books, Blackwell Science, Oxford.

Chuenpagdee, R. and Jentoft, S. 2007. Step zero for fisheries co-management: What precedes implementation? *Marine Policy*, 31: 657–668.

Clark, C.W. 1985. *Bioeconomic Modelling and Fisheries Management*. Wiley, New York.

Costanza, R., Andrade, F., Antunes, P., van den Belt, M., Boesch, D., Boersma, D., Catarino, F., Hanna, S., Limburg, K. and Low, B. 1999. Ecological economics and the sustainable governance of the oceans. *Ecological Economics*, 31: 171–187.

Dietz, T., Ostrom, E. and Stern, P. 2003. The struggle to govern the commons. *Science*, 302: 1907–1912.

FAO. 1995. Code of Conduct for Responsible Fisheries. FAO, Rome.

Francis, R.C., Hixon, M., Clark, E., Murawski, S. and Ralston, S. 2007. Ten commandments for ecosystem-based fishery scientists. *Fisheries*, 32(5): 217–233.

Haggan, N., Neis, B. and Baird, I.G. (eds). 2006. *Fishers' Knowledge in Fisheries Science and Management*. UNESCO Publishing, Paris.

Hardin, G. 1968. The Tragedy of the Commons. *Science*, 162: 1243–1248.

Hilborn, R., Quinn, T.P., Schindler, D.E. and Rogers, D.E. 2003. Biocomplexity and fisheries sustainability. *Proceedings of the National Academy of Sciences*, 100: 6564–6568.

Holling, C.S. and Meffe, G.K. 1996. Command and control and the pathology of natural resource management. *Conservation Biology*, 10: 328–337.

Hughes, T.R., Bellwood, D.R., Folke, C., Steneck, R.S. and Wilson, J. 2005. New paradigm for supporting the resilience of marine ecosystems. *Trends in Ecology and Evolution*, 20: 380–386.

Jentoft, S. 2000. The community: A missing link of fisheries management. *Marine Policy*, 24: 53–59.

Johannes, R.E. 1998. The case for data-less marine resource management: Examples from tropical nearshore fisheries. *Trends in Ecology and Evolution*, 13: 243–246.

Kooiman, J., Bavinck, M., Jentoft, S. and Pulin, R. (eds). 2005. *Fish for Life: Interactive Governance for Fisheries*. Amsterdam University Press, Amsterdam.

Levin, S.A. 1999. *Fragile Dominion: Complexity and the Commons*. Perseus Books, Reading, MA.

Mahon, R. 1997. Does fisheries science serve the needs of managers of small stocks in developing countries? *Canadian Journal of Fisheries and Aquatic Sciences*, 54: 2207–2213.

McCay, B. and Jentoft, S. 1996. From the bottom up: Participatory issues in fisheries management. *Society and Natural Resources*, 9: 237–250.

McConney, P., Oxenford, H.A. and Haughton, M. 2007. Management in the Gulf and Caribbean: Mosaic or melting pot? *Gulf and Caribbean Research*, 19: 103–112.

Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B. and Policansky, D. 1999. Revisiting the commons: Local lessons, global challenges. *Science*, 284: 278–282.

Pomeroy, R.S. and Berkes, F. 1997. Two to tango: The role of government in fisheries co-management. *Marine Policy*, 21: 465–480.

Pomeroy, R.S. and Rivera-Guieb, R. 2005. *Fishery Co-management: A Practical Handbook*. IDRC and CABI Publishing, Ottawa.

Ruddle, K. 2007. Wronging rights and righting wrongs. In: *Globalization: Effects on Fishery Resources*. Taylor, W., Schechter, M. and Wolfson, L. (eds). Cambridge University Press, Cambridge.

White, A.T., Courtney, C.A. and Salamanca, A. 2002. Experience with marine protected area planning and management in the Philippines. *Coastal Management*, 30: 1–26.

Wiber, M., Berkes, F., Charles, A. and Kearney, J. 2004. Participatory research supporting community-based fishery management. *Marine Policy*, 28: 459–468.

Web resources

Berkes, F., Mahon, R., McConney, P., Pollnac, R.C. and Pomeroy, R.S. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods*. International Development Research Centre, Ottawa. Online http://www.idrc.ca/books/

Fisheries Governance Network 2008. Online http://www.fishgovnet.org

Folke, C., Pritchard, L. Jr., Berkes, F., Colding, J. and Svedin, U. 2007. The problem of fit between ecosystems and institutions: ten years later. *Ecology and Society*, 12(1): 30. Online http://www.ecologyandsociety.org/vol12/iss1/art30/

IASC International Association for the Study of the Commons, Digital Library of the Commons, Indiana University. Online http://dlc.dlib.indiana.edu/

ICSF International Collective in Support of Fishworkers. *Samudra* Online http://www.icsf.net/icsf2006/jspFiles/icsfMain/

MA. 2005. *Ecosystems and Human Well-Being. General Synthesis*. Millennium Ecosystem Assessment. Island Press, Chicago. Online http://www.millenniumassessment.org/en/Synthesis.aspx

Macfadyen, G., Cacaud, P. and Kuemlangan, B. 2005. Policy and legislative frameworks for co-management. FAO/Fishcode Review No. 17 Online http://www.fao.org/fi/fishcode.htm

Reid, W.V., Berkes, F., Wilbanks, T. and Capistrano, D. (eds). 2006. *Bridging Scales and Knowledge Systems*. Millennium Ecosystem Assessment and Island Press, Washington DC. Online http://www.millenniumassessment.org/en/Bridging.aspx

South Pacific Community, Traditional Marine resource Management and Knowledge Information Bulletin. Online http://www.spc.int/coastfish/News/Trad/trad.htm

UNDP United Nations Development Programme. Millennium Development Goals 2008. Online http://www.undp.org/mdg/

UNDP United Nations Development Programme. Governance for Sustainable Human Development 2008. Online http://mirror.undp.org/magnet/policy/default.htm

WorldFish Center http://www.worldfishcenter.org and *Naga*, *the WorldFish Center Quarterly*. Online http://www.worldfishcenter.org/Naga/nagainfo.htm

Chapter 4

Economic Principles: An Economic Perspective on Fishing

Arne Eide

4.1 An economic approach to fisheries

Fishing is an economic activity based on available fish stock resources. The properties of the biological resource and market characteristics determine the economic performance of the fishery. The aim of fishing may be to obtain food for one's own consumption, to bring fish products to market or to gain recreational value. Fishing can be unrestricted but is now more often regulated. Modern fisheries regulation focuses on resource conservation and sustaining exploitable fish stocks, but aquatic ecosystems are dynamic and the state of a system is hard to measure and forecast. The economic activity of fishing interacts directly with the natural resources, and previous fishing activity is one of the several factors influencing future stock situations.

Open access to common-pool stock resources is known to involve severe market failures, causing overcapacity of fishing effort and loss of resource rent (the concept of resource rent is explained later). The core idea of introducing fisheries management is to control fishing activity to increase the probability of achieving desirable future stock development and to promote a sustainable fishery. Essentially, the management problem is to reduce or control growth of fishing effort. The choices of proper management means and levels of fishing effort are, however, not trivial problems. Fish stock resources as well as fishing fleets are highly dynamic, non-transparent systems.

Old-established fisheries regulation systems, such as the Norwegian Lofoten Act of 1816, targeting the problem of gear collisions due to high fleet densities on local fishing grounds in the Norwegian cod fishery, were aimed at solving social and economic problems caused by unregulated fishing. Other regulations with a long-standing tradition focus on market and trade issues, controlling landings and production facilities.

When classical economics emerged as a discipline in the 18th century, it was on the basis of studies on the use of scarce natural resources versus the seemingly exponential growth of the human population. Adam Smith, professor in moral philosophy at the time, was studying such problems and became one of the founders of modern economics. The following quote from his main work, *Wealth of Nations* (Smith, 1904), demonstrates a profound understanding of the role of natural resources in different markets, pointing to management challenges yet to come.

> Hunting and fishing, the most important employments of mankind in the rude state of society, become in its advanced state their most agreeable amusements, and they pursue for pleasure what they once followed from necessity. In the advanced state of society, therefore, they are all very poor people who follow as a trade, what other people pursue as a pastime. Fishermen

have been so since the time of Theocritus. A poacher is everywhere a very poor man in Great Britain. In countries where the rigour of the law suffers no poachers, the licenced hunter is not in a much better condition. The natural taste for those employments makes more people follow them than can live comfortably by them, and the produce of their labour, in proportion to its quantity, comes always too cheap to market to afford anything but the most scanty subsistence to the labourers.

Adam Smith (1776), An Inquiry into the Nature and Causes of the Wealth of Nations. Book I, Ch.10 (I.10.6): Of Wages and Profit in the Different Employments of Labour and Stock in paragraph 3.

4.1.1 Different components of a fishery

As mentioned earlier, fishing is an economic activity where the dynamics of the economy interact with the dynamics of an ecosystem. The resource base (the ecosystem) is, of course, the essential part of any fishery. The fishing activity may target different trophic levels of the ecosystem, ranging from the lowest level prey species to the top predators. The fishery may target several species at the same time, including species from different trophic levels (multi-species fishery) or specifically one species or one specific part of this species. Species which could possibly be targeted by fisheries are determined by ecosystem properties, available technology and market conditions. Fishing technologies (vessel and fishing gear) typically have different properties of selecting between and within species, reflected in different catch compositions of different gears utilised in the same fishing area (see Chapter 7).

Fisheries are normally classified by a set of criteria:

- Economic category (industrial, artisanal, subsistence)
- Spatial dimension (freshwater: lake, river; marine: coastal, oceanic, foreign waters)
- Seasonal profile (may involve dynamic adaptations to natural variations)
- Home port (the origin of the vessel)
- Landing port (from which the fleet operates)
- Fishing gears (alternating seasons)
- Vessel size (vessel length, tonnage, engine size)
- Targeted species (multispecies fisheries, alternating seasons)
- Product types (fresh, frozen, preserved, salted, etc.)
- Markets (auction, traders, vertical integration, sales organisations, processing industries, etc.).

Several of the criteria are interrelated and the list demonstrates the multidimensional environment in which a single decision maker in fisheries is operating. Some of the criteria are the result of decisions made in the short run, while others are determined by long-term investments. Several of the criteria are targets of management decisions, effectively reducing the fisher's multidimensional space of possible decisions.

Within the multidimensional space, the fisher is expected to make decisions aimed at maximising the profit earned from the fishing activity. As the constraints vary by natural fluctuations, the activity of other fishers and changes in management decisions, the fisher faces uncertainty at many levels. Attitude towards risk, ability to adapt to changes, market information, assets, skills and experience constitute the background of the decisions by the fisher. The manager faces the same types of uncertainty, including the uncertainty related to the

future decisions by the fisher. The introduction of the precautionary approach (Section 13.3) and ecosystem approach to fisheries (EAF) management (Section 1.2; Garcia and Cochrane, 2005) opens the way for procedures capable of handling uncertainty at different levels.

The fisher's choice of vessel type relates to the choice of fishing gear. Some vessels may have the capacity to operate several different gears, making it possible to participate in different fisheries over the year (adapting to seasonal variations). Other vessels are more specialised in respect of fishing gears and targeted species. Fishing may also take place without any vessel (e.g. beach seining) and in some cases also without any specific fishing gear (e.g. diving for mussels). Catch production is discussed further in Section 4.1.6.

For the profit-maximising fisher, the choice of which fishing gear to use involves a number of considerations, including: knowledge of market price for fish products (market information), capacity to operate and utilise the potential of different gears (skills in handling equipment), the cost of gears and gear operations (investments and running costs) and knowledge of the stock situation and prospects (stock estimates and future expectations).

For the manager, the fishers' choice of which gear to use is equally important, as different gears have different impacts on the ecosystem (see Chapter 7 for details). It is also important for the manager to have knowledge of fleet-economy and technological and economic differences between vessel groups. If a management system is put in place, the fishers may be obliged to provide governmental institutions with such information as a part of the legal system of allocating fishing rights (e.g. licensing agreement).

Elements of fleet economics are reflected in markets where fish products are landed and traded. Quantities and prices are important factors to monitor, first as a part of the ordinary catch monitoring and control, but also, when separated into different markets, for identifying market mechanisms. Some fish products are traded in local markets where the fishers may have some degree of market power (influencing the prices), while other products are priced according to world-market prices, not providing the single fisher with any market power (as they are price takers). By monitoring catch quantities and market prices over time in different markets, information on the relation between quantity and price may be obtained. This information could prove to be useful in predicting the impacts of changes in catch quantities on fishers' revenues.

Essential cost information is, however, not equally easy to monitor. If management measures have less impact on fleet dynamics, some rough cost information may be found by utilising bioeconomic reasoning as explained in Section 4.2.1, while more accurate information has to be based on sampling economic data. The quality of collected data may, however, also be tested against bioeconomic theory, as some development patterns over time may be more likely than others. Increasing stock size (reflected in e.g. increased catch per unit of effort [CPUE]) is, for example, more likely to be the consequence of decreased fishing effort over time, than the opposite. If information provided by the fishing fleet is inconsistent with what is expected from a theoretical point of view, further investigations may be needed to confirm the data.

Cost data can be separated into three cost components:

1. Fixed costs (long-term investments and costs not related to level of activity, in principle including opportunity costs)
2. Effort-dependent costs (running costs directly related to the amount of fishing effort produced)
3. Costs varying with catch quantities (costs of handling, transporting and preserving catch)

Opportunity costs represent a theoretical concept which is discussed further in Section 4.1.2. Operational costs are easier to identify, given that the annual accounts are accessible. Separating variable costs into different types of costs (as the second and third point in the previous list) makes it possible to make a cost prognosis on the basis of different levels of effort and catch, as well as calculating possible effects of changes in costs, for example, by different taxation levels.

Fish products may pass through several markets before being consumed. As the primary target of management decisions is the fishing fleet and its activity, the manager should place most emphasis on landed value when predicting immediate effects of management decisions. Vertically integrated companies, operating through several markets between fisher and consumer, may represent a problem for the manager regarding obtaining accurate information in this respect, since obtained price on landings may include market imperfections.

Market regulations may be appropriate and required at all levels, but in this context we only consider the primary market, trading between fisher and fish buyer, reflecting landed value. Value landed gives income for the fisher and within the framework given by the authorities, is one of the core inputs in the decision-making by the fisher regarding his or her future fishing activities.

Some fish products go directly to the consumer market, from fisher to consumer. Given price negotiation between the two is not distorted by market imperfections, the fisher – and monitoring manager – gets information immediately through the negotiated price that reflects the social benefits of the fishery. In principle, this is the same for fish products passing though several markets before final consumption. If all markets in the market chain were perfect, effective regulation (reducing fishing effort from the open access level) should, in principle, provide the fisher with all the resource rent that could be obtained from the fishing activity, unless the management includes means of effectively increasing costs of fishing (e.g. taxation, and prohibiting effective gear use).

4.1.2 What are opportunity costs of fishing?

Cost of fishing is the value spent on the two input factors, labour and capital, to produce fishing effort and catch handling. The costs include investments (sunk costs) and running (variable) costs, as described in Section 4.1.4. The opportunities forgone by not utilising this labour and capital elsewhere also represent a cost, known as the opportunity cost. Opportunity costs are, therefore, normally not found by examining annual accounts.

The opportunity cost of labour is the highest return which could be obtained by utilising the labour resource elsewhere. This cost may be estimated on the basis of average ordinary salaries of similar labour groups within the region, assuming this to reflect the best alternative salaries for the fishers.

Similarly, the opportunity cost of capital is the highest return which could be obtained by investing the capital elsewhere. If this is higher than the return earned in fisheries, in the long run, the capital is expected to move from fisheries to be invested where it gives higher return. In the opposite case, the capital is expected to move from other sources into fisheries. Therefore, in a perfect market, the return on capital should be levelled between all possible placements and this return defines the *normal profit* on capital investments, in the long run. This applies to all input factors in production, not only capital. Normal profit is the profit needed to cover all opportunity costs of production, basically the opportunity costs of labour

and capital. If the profit exceeds the normal level (abnormal profit), economists characterise the additional profit as *economic rent*. Before discussing economic rent further, let us look more at the role of opportunity costs.

Opportunity costs are not constant. As the economy develops, opportunity costs change and even though markets may be imperfect, in the long term changes in profitability within one sector influence other sectors within the same economy. The following example may illustrate the impact that economic development has on all sectors, including fisheries.

Assume the opportunity cost of labour to be close to zero in a fishing village where virtually the whole population depends on fishing activities for food supply and no labour is demanded by labour markets outside the fishing sector. Assume further that a labour-intensive industry is to be established in the village. The industry offers low salaries, but still more than zero. This new demand for labour affects fishing activities. Fishers will look at the new industry for jobs which offer higher salaries than those received from fishing. If the supply of labour exceeds the number of jobs offered by the industry, the latter may reduce salaries, substituting capital by labour until the salary of an industrial worker equals (or corresponds to) the income of a fisher. The reduction in number of fishers available affects the profitability in the fishery and hence the return to labour employed in fishing. The increased total income in the community affects the price setting on fish products (increased price of fish is expected) and the reduced number of fishers may have an immediate positive effect on the stock (increasing availability), thereby reducing unit cost of harvest. This may attract industrial workers back to the fisheries until labour market equilibrium is reached and the industry salaries equal the return to labour in the fishery, at a level which is higher than the initial return per fisher (before the new industry developed). The unit cost of effort has therefore increased as a consequence of the installation of the new industry. The unit cost of harvest may be less than before, if the impact of reduced effort on the stock more than compensates for the increase in unit cost of effort. The economic development described may later result in additional increases in the market price of fish products, causing the fishing effort to increase, possibly also beyond the initial level.[1]

This hypothetical example also describes the dynamics of an economic system interacting with a natural resource. In the example, perfect markets are assumed and the profits earned at all levels are normal profits. Profits exceeding normal levels (abnormal profits) could only be obtained when the markets are not perfect. The economic rent obtained is often categorised according to its origin. *Monopoly rent* originates from a market distortion caused by the hold on market power by sellers or buyers in a market, while *intra-marginal rent* originates from differences in technology or unit cost of effort among the producers. *Resource rent* is yet another type of economic rent, originating from the properties of the exploited biological resource. If not paid for (as in the case of free access to a common-pool resource), the economic value of the resource (reflected in the primary market) constitutes a rent which is a profit beyond the normal level defined by the opportunity costs.

The following section provides an explanation on why resource rent may occur in fisheries. It may be reflected (at least in the short run) in the payment to input factors in fishing. Labour

[1] This example does not include the effect of external markets. External markets interfere with the local factor markets (labour and capital) as well as with the local fish product market. Increased product quality may open high price markets outside the community, while increased fuel price (within the capital factor market) is an external factor changing the substitution rate of labour and capital, normally reducing the overall fishing effort.

costs reflected in wages and salaries paid to fishers may be regarded as shares of profits for the fishers, rather than payment of input factors in production (Turvey, 1964). This distinction clarifies the reason why resource rent also may be found in wages. The labour market is affected as fishing becomes more attractive and other employers have to pay more to keep their labourers. In the long run, the picture may, however, be the opposite, as the resource rent may be lost and both labour markets pay a lower price than the initial.

4.1.3 Basic market failures in fisheries

Economists often argue that the market should take care of efficient allocation of goods and commodities, since social welfare is efficiently maximised in perfect markets according to standard economic theory ('the invisible hand' of Adam Smith). Market imperfections always exist to some extent but, normally, markets show amazing ability to find solutions close to social optimums. There are, however, some markets that systematically fail to reflect true social values, because of severe market failures. Free access to the exploitation of common-pool fish stock resources is such a case.

From an economic point of view, management is motivated by the political wish to impose market failures where, before, there was more or less a perfect market situation (e.g. licensing taxi drivers) or to resolve existing market failures (e.g. in the case of public goods which are not produced by market mechanisms). Political reasons may therefore exist for both introducing and eliminating barriers to free market, creating or removing market failures. Exploitation of common-pool stock resources normally includes market failures which need to be corrected through management measures.

In short, market failures in fishing have two causes:

1. The discrepancy between real value (reflecting relative scarcity) and zero payment from the resource users (in case of free access to the resource).
2. The long-term interrelation between the two essential input factors of fish harvest production: fishing effort and stock biomass.

According to standard textbook production theory, efficient production is obtained by using less fishing effort and more fish stock biomass, since access to stock biomass is free while effort production is costly. However, the stock biomass is either given (in the short term) or partly determined by biological growth and previous fishing efforts (in the long term). As a consequence, the basic conditions for normal substitution are not met and the presence of the free factor (stock biomass) leads to increasing use of the other factor (fishing effort). The opposite should be expected if both factors were independent of each other.

Together, the two causes mentioned earlier constitute the situation referred to as the market failure of open access fishery; the first of them originates from a value not reflected in the market (the economic aspect) and the other originates from the stock response to harvest, simply the fact that the natural level of equilibrium of the stock declines as mortality increases (the biological aspect).

The first market failure (the economic aspect) underscores the potential for gaining economic rent (resource rent), while the second (the biological aspect) is the reason why the rent is wasted. Management is needed if the market failures are to be corrected and resource rent collected. The resource value increases as the resource becomes scarcer, making potential

gain by proper management even greater. Fisheries management, therefore, is not equally relevant in all fisheries at all times.

Hardin titled his famous science paper in 1968 'The tragedy of the commons'[2], referring to how open access to common-pool resources leads to over-exploitation (Hardin, 1968; see also Section 4.3.2). Fisheries are often used as a case illustrating Hardin's point. Similar reasoning was presented in the seminal works of Gordon (1954) and Scott (1955). Hardin also refers to much older works expressing the same ideas regarding open access to the common-pool resources in ancient literature (e.g. Aristotle). From an economic perspective the only tragedy is, however, that the benefits of the first market failure (to get the resource free of charge) are wasted by building up overcapacity (because of open access to the resource value). Without proper management, the value of the scarce resource is lost, as the unit cost of harvest increases with the decline in stock biomass.

4.1.4 Fleet diversity, costs, markets and stock fluctuations

Bioeconomic theory provides the manager with an insight into how the two dynamic systems (i.e. the resource and the fishery) interact. Open access fleet dynamics (see Section 4.2.1) illustrate the consequences of the fishers' economic rational behaviour. Assuming economic rational behaviour is useful when aiming to predict fishers' response to management decisions. The manager's problem is, however, that he or she does not have all the information on cost and harvest production of the fisher. Cost of fishing and change in cost by management decisions and stock fluctuations are known (within limits) by the single fisher but are to a large degree hidden to the manager.

Systematic studies of costs and earnings of different vessel groups are useful to control the achievement of management goals, predict the performance of the fleet and foresee the behavioural reaction on future management means. As described in Section 4.1.1, obtaining accurate data may be demanding and the monitoring cost should be in balance with the expected benefits. The fleet itself should preferably cover the monitoring cost or a part of it.

Most fisheries are characterised by a highly diverse fleet structure. The fleet diversity has to be understood on the basis of the fluctuations caused by the dynamic systems (ecological and economic dynamics), constantly changing the conditions of the economic activities. Equilibrium theory predicts that the single most cost-efficient vessel type in the long run will be totally dominant, as no other types of fishing will be economically viable (bioeconomic equilibrium is discussed in Section 4.2.1). Fleet diversity, therefore, could be regarded as reflecting a rational economic response to stock variability, changes in demand for fish products and changes of costs on input factors in effort production.

Differences in catch pattern between vessels and fishing gears and in technological efficiency contribute to extending the range of cost-efficiency of the total fleet. These differences include, for example, differences in stock-output elasticities (as explained in Section 4.1.6),

[2] Unfortunately, in this paper, Hardin introduced confusion between common property and open access corrected only 30 years after when Hardin published a paper about the tragedy of **unmanaged** commons (emphasis added). Hardin, G. 1998. Essays on science and society: extensions of the 'tragedy of the commons'. *Science*, 280(5364): 682–683.

cost composition (between the three types of cost elements listed in Section 4.1.1) and price of fish products (which may have different seasonal profiles). One vessel type being the most cost-efficient during one period at a certain market situation and stock biomass composition and size may be less cost-efficient than others during another period. Higher diversity is an economic response to increased fluctuations, both in the ecosystem and in the economy of the fleet, including the fish markets. This should be recognised by managers and policy-makers when they establish policies and regulations.

4.1.5 Fish stock resources as the basis of economic development

Fishing has been and still is the employer of last resort for many people without land, money and a job (see also Section 3.5.2). Free and open access to fish stock resources is access to instant food which can be obtained by manual power or simple technology involving almost no cost other than the labour of the fisher. In such cases, 'the fisher is not poor because he is fishing; he is fishing because he is poor', as expressed by MacKenzie (1979).

Free access to common-pool resources is essential for the survival of many poor fishers and their families (e.g. for subsistence fishing). If a demand for fish products exists in accessible markets for the fishers, excess catches may bring income as well as food to the poor fishers and their families. Given necessary public goods (first of all infrastructures) and stability over time, the exchange of goods and services in a community develops markets. As the economy develops, these market places become more important in defining the value of the resource. In a subsistence fishery, the market does not play an essential role. Similarly, lack of access to markets becomes a critical constraint on further economic development. Lack of necessary infrastructure is usually the most important constraint in market development, as public goods such as roads, electric power and water supply are not usually produced through standard market mechanisms. The development mechanisms are further discussed in Section 4.4.

4.1.6 The economics of harvest production

Economically, fishing is a production process where the input factors are fishing activity (often referred to as fishing effort) and the fish stock resource, while the output is fish harvest. The two input factors are equally essential, as no catch could be produced without the presence of both factors. As discussed earlier, harvest production interlinks two dynamic systems, ecosystem dynamics and economics (reflected in fleet dynamics) and the harvest influences the dynamics of both systems. Management measures aiming at control of inputs as well as output in harvest production, therefore, also have the potential to affect the dynamics of both systems.

A simple bi-linear relationship between output and input factors is commonly assumed in fisheries models. This implies that a 1% change in stock size (up- or downwards) gives a corresponding 1% change in catch if fishing effort remains unchanged (in technical terms *stock-output elasticity* equals one and implies that CPUE is linearly related to stock abundance). Almost all studies on this matter (e.g. Hannesson, 1983, and Eide *et al*., 2003) conclude, however, that usually *stock-output elasticity* is less than one, indicating that the change in catch is less than the corresponding change in stock biomass and, therefore, that the

relative efficiency of fishing increases as the stock goes down[3]. In the case of typically schooling species, the stock-output elasticity may even approach zero indicating that the catch is almost independent of stock biomass, given that the stock is not extinct. This point becomes essential, when aiming to control a fishery through effort regulation as well as when interpreting information available from catch and effort data. Information on CPUE becomes less useful as a stock biomass indicator when stock-output elasticity is very different from one.

Fishing effort is an input factor in harvest production, but it could also be regarded as an output from another production process involving the use of labour and capital. Labour and capital are substitutes in the production of fishing effort. A certain amount of fishing effort could, for example, be made by a large number of fishers (high labour) fishing with hand line from dugout canoes (low capital). The same amount of fishing effort could be made by a few fishers (low labour) on a trawler with more advanced fishing gear and fish finding equipment (high capital). As fishing effort is the same in the two cases, the harvest produced by the effort also will be the same, given equal selective properties and stock biomass.

Economic development normally leads to labour being substituted by capital, as labour over time becomes relatively more expensive than capital. This also has several consequences from a management perspective. First of all, since labour in the short run normally is easier than capital to move between sectors, economic development may affect the entry/exit dynamics in harvest production. In the long run, both a labour-intensive and a capital-intensive fishery need to cover their total cost of fishing. In the short run, they need at least to cover their running costs (e.g. having a positive contribution margin). Since a capital-intensive fishery normally has higher sunk cost while the input factors of a labour-intensive fishery are easier to move to other places, the first is expected to change more slowly than the latter. Fixed costs constitute most likely a larger share of the total costs in a capital-intensive fishery than in a labour-intensive fishery. As a positive contribution margin is needed also in the short run, to stay in a fishery, this factor also leads to higher entry/exit rates in labour-intensive, usually less developed, fisheries.

4.2 Bioeconomic reasoning and reference equilibriums

In 1954 an economic theory of fishing based on open access to a common-pool fish stock resource was published by the Canadian economist H. Scott Gordon (Gordon, 1954). The economic reasoning behind his paper was not new (some elements are represented already in the early quote by Adam Smith cited in the introduction to this chapter), but the mathematical formulation of the problem, including natural growth of the fish stock, was new and groundbreaking. The actions of rational, profit-maximising fishers were shown to affect

[3] Fishing efficiency can increase with time through fishers' learning or adoption of better fishing gear and practices, but also as a function of input variables in fishing, due to the properties of the stock or the gear technology. Gill net fishing on homogeneously distributed fish species is normally expected to result in catches linear in stock biomass (random fishing and stock-output elasticity equal one), while fishing gears luring fish (e.g. by bait) or approaching fish (e.g. trawl) typically have stock-output elasticities below one. Similarly, shoaling species also affect the relative efficiency, as changes in total fish stock biomasses is not correspondingly reflected in fish densities within the shoal.

future profits of all fishers. All fishers exploiting the same stock are affected by the market failure described in the previous section, as the availability of one input factor (the fish stock) depends on previous fishing activities. Gordon presented a comparative static analysis of a fishery, focusing on two reference points: bioeconomic equilibrium (open access solution) and resource rent maximisation (maximum economic yield [MEY]). Short descriptions of these reference points and two more (the equilibriums of MSY and social-economic optimal solution) are provided in the following section.

4.2.1 Bioeconomic equilibrium – the consequence of an unregulated fishery

As all fishers within a fishery harvest the same stock resource, the state of the resource affects the catch of all fishers. Assuming a homogeneous fishing fleet in terms of harvest efficiency, vessel revenue equals the average revenue of the whole fleet, given the same fishing effort of each vessel. Each vessel may, however, differ in terms of effort costs. Let us, for the sake of the argument, assume equal unit cost of effort throughout the fleet. If opportunity costs are included in the cost, the net revenue of each vessel equals the resource rent obtained by the vessel. The resource rent derives from the fact that the access to the valuable natural resource (the fish stock biomass) is free.

If the resource rent is positive, this will attract more vessels or increase the effort of the vessels participating in the fishery. Since there is free access to the fishery, fishing pressure will increase, stock will decline and so will the revenue per unit of effort (average revenue). Since effort will increase until net vessel revenue becomes non-positive, in the long run the resource rent is lost, that is, the fishery will develop to the point where the benefit achieved by the last unit of effort recruited to the fishery (marginal revenue) equals the cost of this effort (marginal costs). This is shown graphically in Figure 4.1. The resource rent is actually lost by being converted into excess effort (overcapacity). In an open access fishery, therefore, resource rent is wasted, in effect subsidising fishing activities beyond the levels by which abnormal profits (positive rent) could be obtained.

It is easy to understand the new recruitment of fishers to a fishery where labour and capital earn more than elsewhere. But why should the fishers already inside the fishery spoil their future chance of obtaining resource rent by increasing their fishing effort of today? The economic keyword in this context is *externalities*. The negative long-term effect caused by the increased effort production of one fisher is shared with all fishers within the fishery, while the immediate gain is individual and not shared with any. Therefore, all fishers have incentive to increase their fishing effort until the individual gain is non-positive (no economic rent).

Given a stable situation (with no change in stock and fishing effort) and no regulations, a fishery is in the long run expected to approach bioeconomic equilibrium. Based on this reasoning, assuming it is not too far from equilibrium, time series of catch and fishing effort (if available) may be utilised to calculate rough estimates on growth properties, biomass history of the stock and also cost/price ratios for the fishery. If a time series of catch and effort also covers a wide range in effort and calculated CPUE, valuable information may be obtained even from relatively short time series and highly aggregated data. The boxed example illustrates one

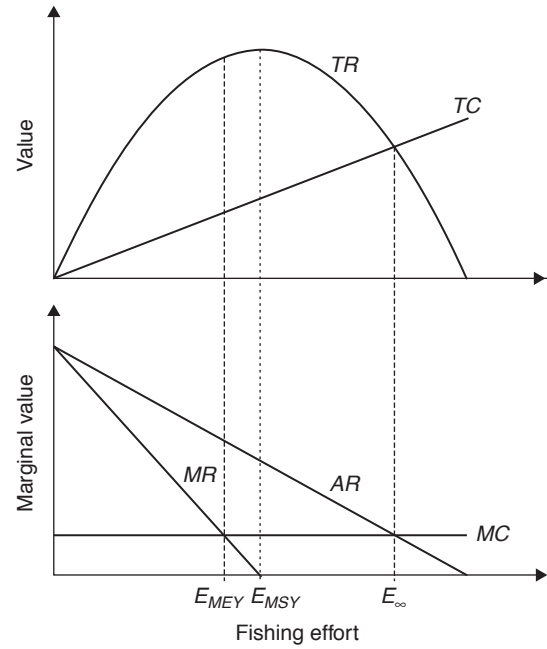


Figure 4.1 The standard textbook bioeconomic model (the Gordon–Schaefer model). The figure presents the three first reference equilibriums: open access equilibrium effort (E_{∞}), maximum sustainable yield (corresponding to the equilibrium effort E_{MSY}) and MEY (corresponding to the equilibrium effort E_{MEY}). TR and TC in the upper panel represent total revenue and total cost respectively, both as functions of fishing effort. The cost includes opportunity costs of labour and capital. The lower panel shows the situation per unit of effort, MR being the marginal revenue, AR the average revenue (per unit of effort) and MC the marginal cost with respect to effort (explained in the text). Resource rent is maximised when MR = MC, while bioeconomic equilibrium occurs when AR = MC. MSY is equivalent to maximising revenue (MR = 0), assuming constant unit price of catch.

possible rough approach to obtain some immediate ideas of the state of the stock and the fishery and how essential economic information connects to this.

4.2.2 The economics of Maximum Sustainable Yield (MSY)

The bioeconomic equilibrium of a fishery (open access equilibrium) includes the biological equilibrium (sustainable catch: biological net growth in stock equals harvest) in coexistence with an economic equilibrium (constant effort; since a normal profit – see Section 4.1.2 – is obtained in the fishery). This theoretical concept is a useful reference point, similar to the better-known reference point of MSY, which is presented below.

MSY refers to a theoretical long-term biological equilibrium (as indicated by the term *sustainable*), but it is not likely to represent the economic equilibrium (providing participating fishers with a normal profit). The bioeconomic equilibrium depends on the cost of fishing per unit of effort and the productivity of the stock and may be at lower or higher biomasses than

Box 4.1 Brief Look at Aggregated Data, Establishing Useful Reference Points: An Example

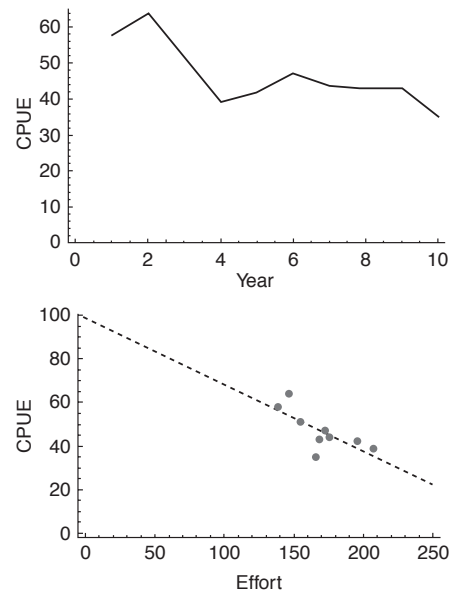
In this example, 10 years' catch (Y) and effort (E) information is available, as shown in the table below. It is always useful to take a thorough look at the data from different angles. Graphical plots are useful tools for comparing different data series and testing hypotheses. The common assumption of a linear relationship between catch and catch per unit of effort (CPUE) provides us with a simple but powerful method of calculating indicators reflecting the state of the stock. In this example, a logistic model for growth of biomass and a linear relationship between CPUE and biomass are assumed; CPUE is then proportional to the stock biomass.

Measured effort and catch over a period of 10 years.

Year	Effort (1000 vessel hours)	Catch (tonnes)
1	138.05	8007
2	146.52	9377
3	155.06	7908
4	207.72	8101
5	195.36	8205
6	172.40	8128
7	175.46	7720
8	167.58	7206
9	169.54	7290
10	165.91	5807

A linear regression of CPUE (catch/effort) versus. effort gives expected CPUE – CPUE(E) as a function of effort (lower graph on right), Fitting a regression line gives the equation: CPUE(E) = 98.387 − 0.306 E. CPUE is defined by Y/E. Multiplying both sides of the equation by E gives the following expected catch function:

$$Y(E) = 98.387\,E - 0.306\,E^2.$$



Graphical presentation of the tabled data.

An estimate of MSY is easily obtained by maximising the Y(E) function: MSY = 7916 at a fishing effort E = 161. The effort of today (year 10 in the table) should in the long run result in an annual harvest more than 1000 tonnes above today's harvest. The dramatic drop in catch from year 9 to 10 may indicate that there are other explanations than those included in the model.

Since this is an open access fishery, equilibrium effort is in the long run expected to provide the fishers with a normal profit. The effort over the last 3 years seems to stabilise around 165–170 thousand vessel hours, which may indicate a situation close to that open access equilibrium. The cost/price ratio of the fishery should then be close to the open access catch/effort ratio, in this case about 40 (from the figures in the table). Given a market price for fish product of $ 2, unit cost of effort should be close to $ 80 per vessel hour. This may, however, be an overestimate, since the recent catches have been very low. This illustrates how a time series on effort and catch data (together with some market observation) may contribute to providing the manager with some rough information on harvest potential, including cost estimates

that corresponding to MSY. Only by coincidence may it occur at the MSY biomass level. If the open access bioeconomic equilibrium occurs at a stock biomass above that of MSY, the latter could not be achieved without subsidising the fleet, since the high cost of effort would keep the effort below the level necessary to obtain MSY.

A situation which is probably more often found in open access fisheries is the bioeconomic equilibrium in a region in which biological overfishing of the stock would be taking place, at a stock level below which would produce MSY. MSY could then not be obtained without reducing fishing effort, for example by the use of fisheries management. The MSY reference point therefore has no general economic interpretation. In developed commercial fisheries, overfishing is however most likely to be the consequence of open access to the resource and effort reduction is needed if aiming to harvest a maximum yield on a sustainable basis.

The arguments given above (and the fact that the exact levels of effort and yield corresponding to MSY are usually known only approximately and too late) highlight the problem of selecting MSY as a development target. The conclusions of the 1995 UN Fish Stock Agreement, therefore, were to refer to MSY as a *limit* to be avoided, rather than a target to be reached. MSY is, however, still a useful reference point, as it provides a basis for the term *biological overfishing* and by that defines the ultimate limit of biologically sound exploitation levels of a fish resource.

4.2.3 What is resource rent maximisation?

If the management objective is to maximise the sustainable profit from the fishery in the long term, the effort always needs to be below the effort of MSY, moving closer to this as the unit cost of effort is reduced (as seen from Figure 4.1).

Resource rent is the profit beyond the normal profits (see the description given in Section 4.1.2) and is maximised when marginal revenue equals marginal cost (including opportunity cost). Resource rent maximisation always represents a more conservative approach in relation to the state of the stock than maximising sustainable yield does. As explained in Section 4.1.3, the equilibrium of MEY (the point where the rent is maximised) could not be obtained without controlling the access to a common-pool resource. Different types of control are discussed in the subsequent sections.

The MEY reference point is shown graphically in Figure 4.1 in a model often referred to as the Gordon–Schaeffer model. The work of Schaffer which Gordon (1954) utilised in the

development of his model is also presented in other chapters of this book (Sections 2.3.1 and 13.4.4).

4.2.4 A capital theoretic approach

Fish stock resources are a natural renewable capital which can be utilised in different ways. Renewable natural capital may also be exploited to an extent where it is totally depleted and renewing becomes impossible. The other extreme is not to utilise the capital at all, as in cases where the cost of harvest exceeds potential revenue. Ongoing fisheries are somewhere between the two extremes.

The biological properties and the natural environment of the stock determine how the stock grows, that is, how the natural capital changes. From an economic perspective, the biological growth rate corresponds to an interest rate on natural capital, the value of which is added to the stored capital or withdrawn from the stock through harvest in a fishery. The comparison with an ordinary bank is, however, not perfectly valid, as the natural capital (e.g. the fish stock in the ecosystem) offers an interest rate that increases (up to the biomass at which MSY occurs) as the natural capital (the stock biomass) decreases. Normally, monetary banks practise the opposite principle. This phenomenon is illustrated by the downwards-sloping average revenue (AR) curve in the lower panel of Figure 4.1, corresponding to the average interest earned at different biomass (natural capital) levels. As the natural capital increases, the capital increment per unit of time declines and the other way around.

In an unexploited stock, the biomass in natural equilibrium reflects the environmental saturation level or carrying capacity of the ecosystem. This carrying capacity varies naturally from year-to-year. However, assuming that this carrying capacity is constant (at equilibrium) on average, there will be no net growth in the natural capital at that level. As the natural capital (stock biomass) is reduced, the stock compensates for the reduction by growing at a faster and faster rate (increased growth per unit of biomass). Stock biomass and the increase in interest rate work in different directions (are inversely related), giving rise to a point at which maximum sustainable production occurs – the MSY reference limit.

When stock biomass is considered as a capital deposit, the time perspective becomes important. Gordon's model represents a comparative static approach to fisheries but a dynamic approach was later introduced by several authors, for example Smith (1968). A comprehensive review with several examples is given by Clark (1990).

The dynamic approach brings back the time dimension, making it relevant to give a value to time. With the consideration of time, the concept of discounting is essential for understanding economic adaptation to fishing activities as a dynamic process. It is therefore reasonable to refer to the dynamic view as a capital theoretic approach, where resource value is not only related to availability, markets and biological growth, but also to time. The value, or benefit to be collected in the future, is less than that which can be obtained today, due to the fact that it is not presently available and that there is a cost associated with the delay in time. The present value of the catch is more than the nominal value collected in future. The difference between the values at the two different times reflects the degree of impatience of waiting for the benefit to be available and is measured in terms of interest or discount rate.

The long-term social-economic optimum for a fishery is found by maximising the present value of all future flows of resource rent from the fishery. The control variable for maximising this criterion is the input (fishing effort) or output (harvest) of the fishery. In the case

of an over-exploited fishery, since today's resource rent per unit of harvest is valued higher than tomorrow's, there is a trade-off between the long-term benefit of building the stock up to a level where the annual resource rent is increased and the short-term benefits of not making such an investment, which would produce a reduced profit today. This dynamic problem reaches an equilibrium solution if and when the immediate gain of fishing one unit more today equals the long-term discounted reduction in profit caused by the last unit caught today. As long as the immediate gain exceeds the long-term losses, the present value of all future profits increases while fishing more today, and vice versa. The equilibrium is often referred to as the Golden Rule of optimal economic harvest. It says that the present value of profits of future fishing could not be increased by fishing less or more today. The discount rate represents the potential growth of the natural capital if it was placed elsewhere (the opportunity cost of the capital). The growth in value of this natural capital is determined by the natural growth of the stock and the change in cost/price ratio as a function of stock size. The biological effect from natural growth is shown above to increase as the biomass decreases, while the economic effect due to changes in harvest cost as stock density changes, works in the opposite direction. The stock growth per unit biomass increases as stock biomass declines, whereas the cost of harvest declines as the stock biomass increases.

In the light of the reasoning above, the properties of the open access bioeconomic equilibrium and MEY reference points are also better understood, as the two may be regarded as special cases of maximising present value of the resource rent of the fishery. The MEY-solution actually corresponds to the optimal solution of maximising present value of all future resource rent, given a zero discount rate, while the open access solution maximises the present value in the case of an infinitely high discount rate. For the owner, if the discount rate equals zero today, the value of the income a thousand years from now would be regarded as equal to the nominal value of the present income. In contrast, with an infinitely high discount rate the value of all future incomes would equal zero.

4.2.5 Including more dimensions

The presentation in the previous section has been dealing strictly with an idealised situation of one targeted species and a homogeneous fleet assuming equilibrium and reversibility. The purpose has been to present useful reference equilibriums (note, however, that the capital theoretic approach describes a dynamic process towards a stable equilibrium) related to some basic management principles. The reference equilibriums represent different concepts and may prove to be useful also when considering situations not corresponding to these idealised situations, even when no stable equilibriums exist. Following are other dimensions which may be included:

- Selection – the inclusion of year classes (or cohorts) in management considerations
- By-catch regulation and ecosystem considerations
- Multispecies fishery
- Seasonal changes in targeted species and gear use
- Fleet diversity (see Section 4.1.2).

Theoretical stable equilibriums may still exist when including some of these additional dimensions (as shown in Figure 4.2), but their existence is not critical for the usefulness of

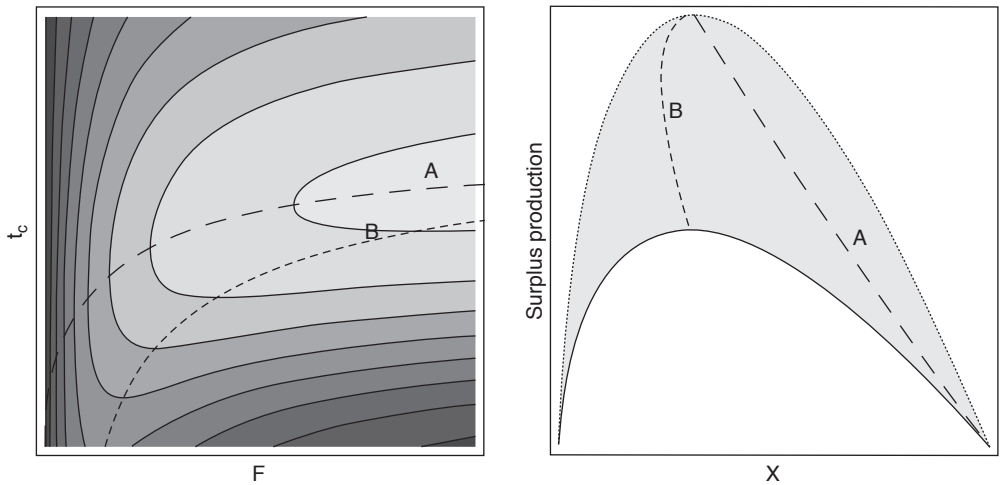


Figure 4.2 Relations between fishing mortality (F), age at first catch (t_c) and yield (X). The left panel shows the well known yield-per-recruit contour map (Adapted from Beverton and Holt [1957]) as function of fishing mortality (F, horizontal axis) and age of fish at first catch (t_c vertical axis). Yield-per-recruit decreases as the shading gets darker. The dashed lines A join maximum yields obtained by changing t_c for given Fs. The dashed lines B join maximum yields obtained by changing Fs for a given t_c. The shaded area in the right panel shows the same range of yield, here presented as a surplus production model with equilibrium stock size (X) as the variable. Each point found in the shaded area is defined by a unique pair of (F, t_c)-values.

the related economic theory. It may, however, be a problem if reference equilibriums are employed as realistic goals of management actions.

Fisheries management has to be multidimensional, as are the economic activities utilising fish stock resources. In the next section, the economics of practical management options are discussed, given that the basic management objectives are identified. Even in the case of varying objectives and uncertainty, the basic principles of the economic reasoning will be the same.

4.3 An economic perspective on fisheries regulations

This section should be read in connection with Part III on Management Measures and Tools (Chapters 7–11). The basic principles of management are described in detail in these chapters, while this section adds a few economic considerations to the use of some of the management measures discussed. Firstly a short note on the relation between economics and politics, before pointing at economic issues related to different types of management.

4.3.1 How do politics interfere with economics?

From an economic perspective, management can be considered as the regulation of markets based on political priorities. The approach may be to correct for market failures or to create market failures with the intention of reaching a political objective. The aim of fisheries

management is usually to remove the effect of the market failures described in the section 4.1.3. To achieve this, governmental interventions are normally needed. The political objectives of the regulation may, however, vary.

Fisheries are complex societal constructions involving traditional rights, community characteristics, economic values, environmental considerations, cultural habits and life style properties. Political documents therefore often address several of these issues without establishing clear priorities. Typically, at the same time, the political objectives may be to increase economic benefits, secure employment and conserve the resource. The risk of arriving at situations of conflicting objectives is high and management may not be able to solve all issues at the same time.

Fisheries management needs to be based on expressed political objectives, preferably with clear priorities. Bioeconomic theory is a useful tool for the analyses of the biological and economic effects of different exploitation levels and of the possible management means needed to obtain these effects. But there is, in principle, no built-in normative theory which makes it possible to omit the basic political decision on how to utilise the natural value of a fish resource. The following discussion, related to the use of different management means, therefore presumes a clearly expressed political objective for the utilisation of the fish resource. For simplicity, in the following discussion, it is assumed that resource rent maximisation is the political goal. This should, however, not be interpreted as a normative statement, since an infinite number of other objectives are possible.

Economists like to express political goals in terms of object functions which should be maximised under given constraints. An objective might be to maximise resource rent, present value, employment, food supply, marine mammal biomasses, stable delivery for the processing industry, etc.

If the market is hindering the fulfilling of the political objectives, management measures are needed. Management therefore first involves the political process of identifying goals and thereafter proper means and finally implementation, control and evaluation. As such, it is an iterative process which is open to adaptive implementation mechanisms in which knowledge is gained from previous experiences and new information and, finally, used to improve management. In the same way as other political processes, this is also influenced by the activities of different stakeholders, not only within the industry but now more often also from other groups. Rent-seeking groups within the industry have interests in both the processes of setting political objectives and the management implementation.

4.3.2 The short history of resource conservation

The history of fisheries management developed as adaptation to recurring crises (Sections 1.1 and 17.2). Governmental interventions are meant to solve the existing problems and are consequently more urgent when problems are substantial and new regulations are most needed when a crisis occurs.

When the International Council for the Exploration of the Sea (ICES) was established in 1902, one of the two scientific committees of the council was the Overfishing Committee, reflecting the increasing concern related to the introduction of new efficient steam trawlers in the North European fisheries. One of the results of scientific work carried out within the Overfishing Committee was the groundbreaking work of Beverton and Holt (1957) after the Second World War. Their ideas and modelling approach were, however, not utilised in

fisheries management until crises and collapses of major fisheries asked for some immediate actions in the late 1960s.

The history of resource-based fisheries management is rather short. Until fairly recently, when technological advances led to rapidly escalating fishing effort and more and more cases of over-exploitation, marine biological resources were, to a large degree, treated as being immense and effectively impossible to deplete. Crises in large fisheries and collapses of major stocks after the Second World War laid the ground for the widespread use of management measures to protect resources in order to secure the possibility of future resource use.

The immediate objective throughout such periods of crisis is usually to reduce fishing effort. The concern is not so much to prevent biological extinction, as in most cases the cost of fishing out a stock to extinction will be astronomic. The main concern of the manager is usually to keep the stock at an exploitable level and to avoid the loss of long stock recovery periods with low or no catch after overfishing. In this way, the resource conservation perspective can be seen, first of all, as an economic concern in order to secure future economic activities related to the fish resource.

Still, there exist a number of fisheries where a biological concern is not dominant or non-existent. Such fisheries may be characterised by a high biological turnover rate, extreme costs or other reasons why a sound, exploitable stock may exist and be used without management. The following example illustrates the point. The Mozambican kapenta fishery in the Cahora Bassa dam is the largest fishery of Mozambique in terms of quantity caught. The stock (*Limnothrissa miodon*) originates from the Tanganyika sardine which was introduced in Lake Kariba (higher up in the river), floating down to the later constructed Cahora Bassa dam. After a few years, a significant fishery developed. The biological concern is insignificant or non-existent because if the kapenta stock went extinct, it could, in principle, be reconstituted from the Tanganyika sardine stock, soon bringing back a viable fishery.

Even when there are no biological reasons for managing the fishery, there may be economic reasons to do so. There might be good reasons to manage the kapenta fishery if the aim is to retrieve resource rent from the fishery. There are political and economic reasons for managing, even though biological reasons are hard to find. It all depends on the fisheries objectives (policy) and how these objectives can be best met.

If the fisheries policy requires the use of management means in order to reduce fishing effort, a set of possible measures is available (see Chapters 7–11). The economic consequences of major management categories are discussed in the following sections.

4.3.3 Technical measures

Gear regulations (Chapter 7) are probably the first type of regulation systems aimed at protecting the biological resource. From an economic point of view, the reason, or almost inevitable consequence, of these regulations is to make the fishing gear less efficient, which is equivalent to increasing the cost of standardised effort. Usually, the idea is to develop a more selective fishing gear aimed at certain targeted species or year classes. There might be an economic gain related to this, if the handling costs are reduced (by a cleaner catch) and higher valued products are retained. The cost of implementing the technical measures is paid by the fisher, except for the control cost which in some cases could be substantial. This, combined with the effect of an improved exploitation pattern and increased cost of effort, makes technical measures an efficient economic regulation tool. In most cases, however, technical measures alone have been shown to be insufficient on their own to approach common

management goals, and other measures need to be added. This management measure does not have the property of retrieving resource rent, although it may have the effect of increasing the production of the fishing gear industries.

4.3.4 Taxation

Gordon (1954) proposed the use of effort (input) taxation or harvest (output) taxation to reduce effort and retrieve rent. The attractive property of taxation is that, in principle, the open access solution could remain as a stable solution, since, following ordinary market mechanisms, the increase in cost or reduced revenue (due to taxation) would automatically lead to reduced effort. The equilibrium profit of the fishers left in the industry will still be normal and the regulation will not distort labour and capital markets, though excess labour and capital will be available for other use. The economic reasoning behind the measure is based on comparative statics (Section 4.2.4), while there is low or no legitimacy for introducing taxation during periods when the fisheries economy is critical (e.g. after overfishing due to open access and low costs of fishing). Introduction of taxes, including entry fees, therefore is difficult during crises; while it is easier, in sound fisheries, to have good economic performance. In the latter case, however, management issues are usually not at the top of the agenda. Therefore, it seems to be politically easier to introduce negative taxes (subsidies) than taxes aiming to retrieve resource rent from the fishery.

The introduction of management measures during crises, almost always has the objective of reducing effort. In an open access situation, normal profit is obtained in equilibrium. In crises, which could originate from biological or economic causes, profit is more likely to be below normal level. Solving such crises by imposing taxation is not considered to be legitimate in a situation where, in fact, the fishers are worse off than others. Subsidies (which in principle are negative taxes) are more likely to be introduced in such situations. Without legitimacy, the political cost of imposing taxation on fishers would be too high. Most people would argue that fishers in crisis need help rather that increased cost.

On the other hand if fishers earned a resource rent, that is, more than normal profit, imposing taxation would cause fewer protests. If this was done and the levels of profit were reduced to normal, it would contribute to sustaining a situation where resource rent could be obtained and collected by the tax imposing authority. However, due to the fact that new regulations are seldom introduced without crises, subsidies rather than taxation may be the proposed measure.

Taxation is a type of economic incentive working at several levels in the economy, including outside the domain of fisheries management. Purchase taxes, property taxes, taxes on businesses and on factors of production, emission taxes and licences, all represent different types of economic incentives aiming to control the behaviour of the object of taxation. In general, as well as in fisheries management, besides the governmental need for income, the expected effects of the incentives are the justifications of imposing tax. If the taxes were not regarded as justified, there would be a legitimate economic incentive for cheating the taxing authority. Imposed taxes are also incentives for changing behaviour to avoid taxes (e.g. reducing costs by reducing speed, causing lower carbon emissions). Since the changed behavioural pattern is not known, the outcome of indirect measures (incentives) is less predictable than the effect of direct management means. It may be easier to predict the effects of weaker incentives such as indicative measures (information and appealing to responsible behaviour) as they seldom show any significant change in behavioural pattern.

4.3.5 Entry limitation

Indirect management means have often proven to be insufficient to solve management problems of fishery. If the aim is to reduce effort, the straightforward way to do this is to directly control fishing effort, for example through limited entry as discussed in Chapter 9.

Management based on limiting entry to a fishery involves also problems related to the initial conditions of the system to be regulated. Closing the fishing for others than those already inside may be a way to limit entry. Reducing effort by distributing fishing rights to some fishers while excluding others may be controversial. The situation may to some extent be eased by including several fisheries in the limited entry scheme, distributing different fishing rights at the same time. Different concepts of distributing fishing rights, monitoring and enforcement are discussed in detail in Chapter 10.

Let us assume that through a successful limited entry system with effort limitation and control, the effort has been reduced and the fishers earn a profit exceeding normal level (rent). Normally, the additional profit is likely to be invested in making each licensed unit more efficient, within the framework of the existing regulation scheme. This could result in the following two effects: (a) the actual fishing effort produced by the licence owners is increased even if the nominal effort (the magnitude controlled) is kept constant; and (b) the unit cost of the measured effort is increased through new investments (e.g. introduction of new technology). Together this will cause resource rent to vanish and fishing pressure to increase.

Two problems arise from the aforementioned: first, to control the actual (standardised) fishing effort over time is a non-trivial task. This problem also involves the difficulties of measuring product functions of the fishing fleet and how fishing efficiency varies with stock density (as expressed in terms of stock-output elasticities in Section 4.1.6). Second, the success of the management system also represents a threat to the system because profits exceeding normal levels usually find their way back to the industry, increasing the overall capacity of the licensed fleet. Rent may be invested outside the fishing industry, but in most cases the fishing companies seem to believe that they are better off by feeding the rent back into the industry where it was generated. Occasionally, rents from fishing bring substantial investments to other industries, as for example investments in the aquaculture industry from Norwegian purse seiners a few decades ago.

4.3.6 Quota regulations

Quota regulations include a variety of management systems. The basic principle is simple: instead of controlling directly the input (as earlier), the management controls it indirectly by controlling the output. Quota management has many attractive properties and has in many ways been the dominating measure in single-species, commercial fisheries management throughout the world in recent years. Chapters 9 and 10 give comprehensive descriptions of different types of quota management systems.

Quota management interacts nicely with biological models and, since the management organisational structure usually is based on biological advice, output quantities can be convenient regulation measures. The well-known concept of total allowable catch (TAC) fits very well into this picture. In principle, catch outputs are easily measured, by far easier than measuring fishing effort, particularly in well-developed fisheries where comprehensive catch statistics and market information are available.

The simplest form of TAC-based management is to keep a common total quota covering the whole industry without subdividing the quota amongst individual fishers. This, however, creates a 'race for fish' where all the gained resource rent is wasted on investments aiming to increase the capacity of each fishing unit. For example, boat owners invest in larger and more powerful engines so that their vessels reach fishing grounds before the others in order to get a larger share of the TAC. This may result in increased unit cost of effort, reduced price (if the catch quality is reduced by increased competition) and loss of resource rent. These problems exist even when TACs are set at levels where resource rent, in principle, should be obtainable (i.e. at levels below the currently expected catch in an unregulated open access fishery).

In order to avoid these undesirable effects of a race for fish, TAC allocation rules for subdividing the catch into quotas are included in most quota-regulated fisheries. Such allocation rules could be market based or not. Let us first have a look at the latter.

Allocation of TAC is an allocation of fishing rights (Chapter 10). The legitimacy of introducing a TAC system often depends on how previous fishing rights are converted into the new quota system, that is, the quota allocation rule. The discussion on principles of the subdivision rules often overshadows the first TAC calculation procedure, as the conflict in interests is more pronounced on distribution-related issues. There may be a more general acceptance of the TAC than of the quotas because the TAC is basically a biological issue and its value is founded on scientific reasoning, while the subdivision of the TAC is dominated by societal and economic (basically political) conflicts. TAC allocation principles may be agreed and allocation rules may be negotiated as the basis of future allocation, e.g. a certain percentage of the annual TAC to be allocated to each vessel, fisher, community, etc.

Given an allocation rule, the different TAC shares distributed, most probably, will have different values for the different right holders. If the individual quotas are not transferable, there will still be pressure towards trading quota rights and proper control will be needed to counter it. If quotas are transferable, this control is not needed or it could be converted into a market control system to regulate the quota market. This market is often expected to be able to allocate quotas to the most cost-efficient fishers, as they are able to pay the highest quota price. However, as shown in Chapter 10, the ability of individual transferable quota (ITQ) systems to establish efficient quota allocations may not always be that obvious.

The economics of transferable and non-transferable quota systems differ in many respects. Given a successful non-transferable quota system, the resource rent gained is left with the right holder (assuming no taxation). Even when avoiding the most extreme race for fish by using quota allocation rules, the resource rent is expected to find its way back to the industry, increasing the probably already established overcapacity. Eventually the increasing overcapacity will cause a significant political pressure towards increasing the TAC for the fishery. In other words, the resource rent obtained as a result of successful management may very well create even larger fleet capacity than before, effectively threatening the successful management system. Imposing taxation when profits exceed normal level may prevent this from happening.

A transferable system works differently. Here the quota right immediately has a market value which may be traded. The value depends on how successful the management system has been, and successful management tends to increase the quota value. Even if quota rights initially were given for free, they have value in a quota market and therefore represent an opportunity cost for the quota holder which is equal to the best alternative use of the quotas (i.e. the value obtained by selling them in the quota market). The foregone possibility of income by selling the quotas has to be covered by the fishing activities when utilising the quotas for fishing. Those buying quota rights in the quota market, of course, also experience

increased unit cost of effort in comparison to an open access situation. This increase consequently moves the theoretical open access equilibrium to lower levels of total fishing effort. In fact, the increased cost reflects the resource rent or the shadow value of the stock resource. If the TAC setting brings total effort close to the previous open access level, the shadow value of the stock (the rent) approaches zero and so does the value of the quota right.

Transferable quota rights are based on individual quota allocation. Non-transferable individual quota systems should not, in principle, bring any opportunity cost to the quota, as there is no alternative use of it. Such systems may, however, include other regulations giving value to the use of quota rights. Informal and even illegal quota markets may, however, create substantial value to the quotas, depending on differences in efficiency and risks related to disregarding non-transferability.

4.3.7 Future perspectives

Until recently, modern fisheries management in principle was based on the assumption of full knowledge on biological and economic dynamics in the fishery. The new approach is to acknowledge that full knowledge cannot be obtained and the management challenge is to cope with uncertainties. The precautionary approach to fisheries management presented in Section 13.3 represents one possible way to deal with such uncertainties.

This reasoning introduces some quite new ideas to fisheries management. The introduction of indicator-based management rules (Chapter 12) makes it possible to automate quota setting by predefined rules of action. Such rules are now commonly referred to as harvest control rules (HCR). HCR may include a precautionary approach and also corresponding economic reasoning. The learned effect of different previous decisions could be utilised in refining the predefined rules, implementing adaptive management (Section 13.8). In many ways, this idea represents a paradigm shift in fisheries management, as the focus shifts from model-based indicators to indicators based on more performance and feedback observations, which relate to rules of actions. The first is based on known functionalities, the latter on experienced effects.

The new concept of HCR also opens the way to the inclusion of other ecosystem effects, year-to-year and seasonal fluctuations, multispecies relations, the dynamics of ecosystems, economics, fisher behaviour and fleets, as well as differences in skills and technology, etc. Section 13.5.2 discusses management issues from an ecosystem perspective. An EAF may also be implemented through the use of relevant ecological, economic and social indicators in an HCR management scheme. The challenge is to establish and measure relevant indicators and to relate sets of indicator values to rules of actions. A set of rules based on combinations of indicator values could be implemented as fuzzy logic control (Zadeh, 1973). In addition, as in the more conventional system, evaluation of the effects of previous decisions could be utilised in refining the predefined rules, adding a dimension of adaptive management to the rule-based control system.

4.4 Fisheries development

Bioeconomic theory and the economic properties of available management measures provide the manager with a toolbox to apply for performance analyses of different management decisions

and for proposing efficient regulations to achieve given political objectives. For obvious reasons, fisheries management issues are often focussed on the state of the resource base and the measures aim to protect the stock from over-exploitation. The state of the resource is essential and so is the state of the users – the fisher and the community around him.

From an economic point of view, resource-based management could be substantiated by the market failure introduced by an open and free access to a valuable resource – the fish stock. However, under some circumstances, such a resource could serve as a last resort. We have stressed that an open access fishery gives value free of charge to the fishers for whom the opportunity cost of labour is less than or equal to the open access earning. In extreme cases, this earning may only be sufficient to feed themselves and their families, as in subsistence fisheries. In such cases, the open access situation is not removing poverty; it is preventing starvation as long as the resource is maintained. Closing the commons could then take the situation from bad to worse, if no other alternatives are presented.

How can the previous sections be interpreted in a development perspective? We learned in the previous sections that the objective of technical regulation is to reduce gear efficiency and thereby increase the cost of standardised effort. In fisheries development, NGOs and governmental aid agencies often support extension services in fisheries where the idea is the opposite – to develop more efficient gears and harvesting methods. How does this fit into the idea we have on sustainable, economically optimal exploitation of fish resources? In the following section we will try to address some of these questions.

4.4.1 Market failures and poverty

In Section 4.1.3, we discussed some basic market failures in fisheries. Without these failures, the common-pool stock resource would be a pure public good, a rival-free or collective consumption good. If a large common-pool resource is utilised only as food for the few families within a community without any significant effects on the stock resource, it may be regarded as a pure public good and the external cost (market failure) in fishing would be practically non-existent. Without any other active constraints, one should expect this situation to remain unchanged until population growth eventually causes external costs to become visible.

The importance of a common-pool fish stock resource as the employer of last resort has already been discussed. From a food supply perspective, external costs do not represent a problem as long as total fishing effort is at levels less than the effort corresponding to MSY (see Figure 4.1). In fisheries with poor technology and lack of markets, as often found in poor coastal communities of developing countries, this may often be the case. In such cases, external costs are not causing food supply to decrease, but an increase in supply through increased fishing effort may take place at a diminishing rate. Ecosystemic effects such as species replacement may help maintain productivity up to a point. External costs are the loss of resource rent, which is value spent on employing more fishers. If the political objective is to provide the community with seafood, the unregulated fishery producing fishing effort below the MSY level has good properties. If the effort produced reaches levels above this, the community may be better off maximising resource rent, as the abnormal profit could finance food from other sources (given the necessary political decisions regarding allocation of resources). The organisational challenges would, however, be substantial as the potential resource rent may easily be spent on other commodities or wasted, and in any case not used to support those excluded from the fishery.

How can fisheries policy best help the poor? Often there seems to be an assumption that the poor must be helped to become better exploiters of fisheries resources. However, the best way to help the poor may not be to help them to become better fishers, nor to encourage them to become fishers at all, but to use the wealth of the fishery to create alternative employment opportunities for them. In this view, poverty alleviation is considered to be a macroeconomic, and not a sectoral, issue (save in the exceptional case of a very large fishery sector). Attempts to improve the incomes of the poor in the fisheries sector alone seemed doomed to failure because incomes in the fisheries sector are linked to those in the rest of the economy. If a policy successfully improves incomes in the fisheries sector, the relative attractiveness of this sector will increase, attracting more fishers and restoring the equilibrium position where opportunity incomes are earned. The new equilibrium can emerge via a combination of price and quantity effects. The problem is that quantity effects in particular are likely to run counter to conservation goals. Increased numbers of fishers will generally mean lower fish stock sizes.

(Cunningham, 1999)

In the earlier discussion on the capital theoretic approach to fisheries in Section 4.2.4, open access equilibrium was found to coincide with the social optimum with an infinitely high discount rate. In a situation of severe poverty, famine and starvation, the discount rate needs to be very high, reflecting the urgent need and impatience in resolving the immediate situation. Hence, socially optimal solutions move toward open access equilibriums, as a way of immediately releasing food resources for a starving population.

4.4.2 Contextual issues related to fisheries development

The dynamics of technological development is a complex mix of a number of factors. First of all, it needs to be understood in the perspective of market dynamics. The market seeks for the most efficient solutions, unless market failures are hindering this from happening. Market dynamics are constrained by the context in which they exist and first of all by the existing infrastructure.

As discussed in Section 4.1.5, access to central markets represents a major obstacle in many artisanal fisheries. The importance of infrastructure for market development is obvious. Technical inventions such as the mobile phone have also been shown to have great impact, replacing former scarce public goods by normal goods accessible in functioning markets (noting, however, that accessibility to mobile phones depends also on infrastructure not necessarily available without governmental interference).

Figure 4.3 displays the market and effort conditions under which a resource-based management regime is needed. Increments in fishing effort production are a function of market developments. Below a certain technological level A, the resource is never threatened, even if all available capital and labour resources are utilised in this fishery. Below a certain market development level B, the demand for fish products will be too low to support an open access fishery that threatens the resource. Development of markets and technology is interlinked and the development direction (shown by the arrow) reflects the linkage between the two. Beyond the area limited by A and B, fisheries management may be needed.

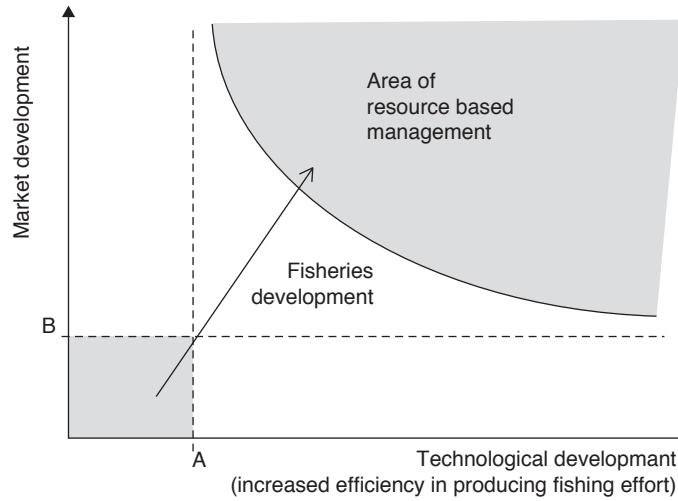


Figure 4.3 Relation between market and fishing development. The figure shows the area of resource-based management defined in the context of development along two dimensions: markets and fishing effort. Development of a fishery over time is shown by the arrow.

4.4.3 Development stages – when is it appropriate to manage?

In an open access fishery, the resource rent is wasted in subsidising fishing effort beyond the levels of a positive resource rent. In order to collect resource rent on a sustainable basis, fishing effort needs, therefore, to be reduced below the level of open access. The resource rent collected could potentially be spent more efficiently (e.g. employing more people) by investing in other sectors. Economic development in other sectors could lead to a reduction in fishing activities if the increase in opportunity cost of labour more than compensates for the change in profits of fisheries (caused by increased price and possibly reduced unit cost of effort). Some fishers will be better off moving from fishing to other economic activities.

Poverty alleviation in fisheries, therefore, needs to be discussed in a broader community and society perspective, rather than as a sectoral issue. It is, however, still essential to keep in mind the fisheries dynamics and in particular the dynamics of fisheries development. The latter was for many years regarded as a matter of developing proper fishing technology, increasing catch and reducing post-harvest losses. Considering population increases, this is still important, but for reasons pointed out above, it is not sufficient for poverty alleviation and it may not be enough to secure a sustainable fishery. In recent years, more emphasis has been put on management, different types of co-management regimes have been introduced and the management perspective has entered the fishing communities. But is the idea of management always appropriate?

Table 4.1 shows three development stages of fisheries differing in terms of labour and capital used for effort production, infrastructure and markets available, and risk for the stock. In general, fisheries management becomes an issue at stage 3, possibly also at stage 2, while stage 1 (found for example in remote islands) calls upon other types of governmental interaction, for community development. Stage 1 may correspond to the area in Figure 4.3 constrained by A and B. All three development stages need, however, to be monitored to ensure that the biological resource is utilised according to given political objectives.

Table 4.1 Properties of three development stages.

Type of fishery	Use of labour	Use of capital	Infrastructure	Markets	Stock risk
1	High	Low	Poor/No roads, water and electricity supply	No markets, subsistence fisheries	Low
2	Medium	Medium	Roads	Reaching commercial markets by roads	Medium
3	Low	High	Roads, electricity, water	Access to new markets after access to ice and trucks	High

The vision for the future of small-scale fisheries in general, as expressed by the FAO's Advisory Committee on Fishery Research (see also Section 15.3), is that

- they are not marginalised and their contribution to national economies and food security is recognised, valued and enhanced;
- fishers, fish workers and other stakeholders have the ability to participate in decision-making, are empowered to do so, and have increased capability and human capacity, thereby achieving dignity and respect;
- poverty and food insecurity do not persist, and the social, economic and ecological systems are managed in an integrated and sustainable manner, thereby reducing conflict.

This vision represents a guideline for all small-scale fisheries and emphasises the importance of participation, poverty alleviation and food security. How the vision can be realised is, however, a more complex task than expressing it. As indicated in the vision, it involves more than management issues; in fact, it is not obvious that management measures are the answer at all in some cases.

The vision could not be realised without the existence of basic infrastructure for markets to develop. Infrastructure is, however, only a necessary, not a sufficient condition to fulfil the vision. The challenge is of a political nature, as political decisions need to be taken on the basis of relevant biological and economic knowledge, if the main objectives of poverty alleviation and food security are to be achieved. The challenge is essentially the same also in the developed fisheries in rich countries, as expressed objectives (e.g. sustainable use of natural resources in order to maximise welfare and equity) ask for the same type of approach, management measures and distributional problems.

4.5 Synthesis

A fishery is a complex system with numerous interlinked components, a high resource and fleet diversity, operating within strong natural and market fluctuations. Opportunity costs, discount rates and market regulations (mitigating or aggravating market failures) have

potential effects on the economics of harvesting, the fate of the fish stocks and the well-being of the people.

Unregulated fisheries may easily miss the objective of producing maximum food (as biological overfishing follows if the cost of fishing is sufficiently low) or maximum economic rent (as economic overfishing is the consequence of open access fishery). Fisheries regulation is therefore necessary in most cases to achieve long-term social welfare.

In fisheries management, politics interfere constantly with biological or economic rationality, introducing priorities and time constraints as well as distributional objectives that substantially complicate the task of a manager. This task gets more complicated as more dimensions of the fisheries are taken into account, for example, under an ecosystem and precautionary approach to management.

The short story of fisheries regulation during the last half century has illustrated the performance (particularly the economic performance) of the various types of management measures presented in Chapters 7–11. It has shown the usefulness of technical measures and also their cost and their incapacity to deal, alone, with overfishing. It has also shown the complexity of economic measures such as taxation, the perverse effects of some economic incentives (e.g. subsidies), the complexity of the control of inputs (by limited entry) or outputs (through TACs) and the necessity, in many cases, to introduce various forms of fishing rights in the form of quotas.

The close connection between development and management performance is often forgotten. The development objectives of providing growth, employment, food security, and reducing poverty lead to political and economic decisions that determine a large part of the context within which fisheries and the fishery manager operate. Market failures may be introduced or tolerated to mitigate poverty in the short term, aggravating it in the long term. Whether management is necessary or even possible is indeed dependent on the development context.

Sources and recommended reading

Beverton, R.J.H. and Holt, S.J. 1957. *On the Dynamics of Exploited Fish Populations*. Her Majesty's Stationery Office, Ministry of Agriculture, Fisheries and Food. Fishery Investigations, Ser. II, Vol. XIX. London. 533p.

Clark, C.W. 1990. *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, 2nd edition. Wiley-Intersciences, NewYork, U.S.A.

Cunningham, S. 1999. Towards the increased policy relevance of fisheries research. FAO FIPP/C964.

Crutchfield, J.A. 1961. An economic evaluation of alternative methods of fishery regulation. *Journal of Law & Economics*, 4: 131–143.

Eide, A., Skjold, F., Olsen, F. and Flaaten, O. 2003. Harvest functions: the Norwegian bottom trawl cod fisheries, *Marine Resource Economics*, 18: 81–93.

Garcia, S.M. and Cochrane, K.L. 2005. Ecosystem approach to fisheries: A review of implementation guidelines. *ICES Journal of Marine Science: Journal du Conseil*, 62(3): 311–318 (doi: 10.1016/j.icesjms.2004.12.003).

Gordon, H.S. 1954. The economic theory of a common property resource: the fishery. *Journal of Political Economy*, 63: 124–142.

Hannesson, R. 1975. Fishery dynamics: a North Atlantic cod fishery. *The Canadian Journal of Economics*, 8(2): 151–173 (doi: 10.2307/134113).

Hannesson, R. 1983. Bioeconomic production function in fisheries: theoretical and empirical analysis. *Canadian Journal of Fish and Aquatic Science*, 40: 969–982.

Hardin, G. 1968. The tragedy of the commons. The population problem has no technical solution; it requires a fundamental extension in morality. *Science*, 162(3859): 1243–1248 (doi: 10.1126/science.162.3859.1243). (Open source text available at: http://www.sciencemag.org/cgi/content/full/162/3859/1243)

Hilborn, R. 1985. Fleet dynamics and individual variation: why some people catch more fish than others. *Canadian Journal of Fisheries and Aquatic Sciences*, 42: 2–13.

MacKenzie, W. 1979. Rational fishery management in a depressed region: the Atlantic ground fishery. *Journal of the Fisheries Research Board of Canada*, 36: 811–826.

Knut, H.M. and Jentoft, S. 2003. Limits to participation? On the history, structure and reform of Norwegian fisheries management. *Marine Policy*, 27: 397–407.

Pearl, R. and Reed, L.J. 1920. On the rate of growth of the population of the US since 1790 and its mathematical expression. *Proceedings of the National Academy of Sciences of the United States of America*, 6: 275–288.

Ricker, W.E. 1954. Stock and recruitment. *Journal of the Fisheries Research Board of Canada*, 11: 559–623.

Ricker, W.E. 2006. One man's journey through the years when ecology came of age. *Environmental Biology of Fishes*, 75: 7–37.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bulletin of the Inter-American tropical tuna Commission*, 1: 25–56.

Schaefer, M.B. 1957. A Study of the Dynamics of the Fishery for Yellowfin Tuna in the Eastern Tropical Pacific Ocean. *Bulletin of the Inter-American tropical tuna Commission*, 2: 245–285.

Scott, A. 1955. The fishery: the objectives of sole ownership. *Journal of Political Economy*, 63: 116–124.

Smith, A. 1904. *An Inquiry into the Nature and Causes of the Wealth of Nations*, 5th edition. Methuen and Co., Ltd. Ed. Edwin Cannan. Library of Economics and Liberty. 24 March 2008. <http://www.econlib.org/library/Smith/smWN4.html>.

Smith, V.L. 1968. Economics of production from natural resources. *The American Economic Review*, 58(3–1): 409–431.

Turvey, R. 1964. Optimization and suboptimization in fishery regulation. *The American Economic Review*, 54(2.1): 64–76.

Verhulst, P.F. 1838. Notice sur la loi que la population pursuit dans son accroissement. *Correspondance Mathématique et Physique*, 10: 113–121.

Zadeh, L.A. 1973. Outline of a new approach to the analysis of complex systems and decision processes. *IEEE Transactions on Systems, Man, and Cybernetics*, 3: 28–44.

Part II

Legal and Institutional Considerations

Chapter 5

Legal Aspects

Blaise Kuemlangan

5.1 Introduction

5.1.1 The fisheries manager and the law

Fisheries law – the body of law governing fisheries (including aquaculture)[1] is an intrinsic component of the modern fisheries manager's operational portfolio.[2] It facilitates and supports fisheries management by implementing the general fisheries policy, defines the scope of its application and establishes institutional mechanisms for fisheries management. It also defines management responsibilities, recognises and regulates the interests of fishers and other stakeholders and the relationship between them to facilitate the attainment of fisheries management objectives. The ultimate purpose of fisheries law is to guarantee that the terms and conditions under which fisheries are managed and the mechanisms that regulate conflict are enforced.[3] The latter is guaranteed through established processes for compliance and enforcement of assigned rights and duties in a judicial or other forum, for example, courts or administrative enforcement mechanisms or processes.

Matters Typically Addressed by Principal Fisheries Legislation*

(a) **Objectives** – *States general development policies and management objectives of policies and the law.*
(b) **Definitions** – *Defines terms and phrases used to assist in interpretation and application of the law.*
(c) **Scope** – *Defines the extent of application of law [including extraterritorial application],* e.g., *to nationals or persons within the territory, fisheries waters or types of fisheries.*
(d) **Administrative and management institutional framework** – *Establishes or designates the public management authority, executive head and staff, boards, committees, etc. and their powers and functions.*

[1] Aquaculture is often part of the fisheries law but is outside the scope of this chapter.
[2] The Code of Conduct for Responsible Fisheries, FAO (1995), Articles 7.1 and 10.1 underscore the importance of legal frameworks for the long-term conservation and sustainable use of fisheries resources.
[3] FAO (1997a) at page 62.

(e) **Management approaches, principles and planning** – *Stipulates specific management aspirations or management approaches, guidelines, management plans including formulation, content and endorsement. A different or specific fishery that is to be managed and the approach to be used may also be described.*

(f) **Statement of general fishing access and entitlements** – *Sets out the prerequisites for fishing and the persons or groups of persons who can participate in fisheries,* e.g., *nationals, locally based foreign operators/vessels or foreign vessels.*

(g) **Management tools and related processes** – *Establishes and describes the management tools to be utilised for regulating input and output, such as concessions, licences and other authorisations, fishing rights, quotas including individual transferable quotas and spatial and temporal limits.*

(h) **Monitoring, Control and Surveillance (MCS)**† **(Bio-economic and enforcement information requirements)** – *Establishes and defines the MCS schemes and tools including scientific observer programmes and inspection schemes, procedures, powers and rights, for example, rights of observers or inspectors to access all parts of the vessel and stop, board and inspect vessels.*

(i) **Prohibitions, violations and sanctions and enforcement processes** – *Creates or describes prohibitions and violations, the administrative or criminal enforcement process to deal with violations including evidentiary provisions. This part of the law also establishes and describes sanctions for violations.*

(j) **Alternative approaches to management** – *Establishes the ability for the State or management authority to delegate, devolve or enter partnership or cooperative arrangements for management or to engage in other management approaches as appropriate.*

(k) **Regulations** – *Sets out requirements including standards, restrictions, procedures etc. that are too elaborate to be stated in principal legislation but are required for implementation of the principal law.*

*This is a typical outline of matters addressed by the fisheries-specific legislation; however, the style and substance of the fisheries law may vary depending on the legal history, philosophy and practice in a given state.

†See Section 5.5. infra for MCS powers, responsibilities and activities that are governed by legislative provisions relating to MCS.

In order to operate assertively and expeditiously, the fisheries manager, while not expected to grasp the intricacies of the law, should develop sufficient familiarity with it by developing, among other things, a basic understanding of the fisheries law, its relationship with other laws including the international legal framework and its operational environment at the national, regional and global levels. In developing a familiarity with the law and administering it, the fisheries manager should know when and how to seek appropriate legal guidance.

In the context of this chapter, it is impossible to use a single country's fisheries legal framework to define all particulars of the fisheries law and the specific circumstances under which its requirements apply. This chapter assists the manager in developing familiarity with fisheries legal frameworks by setting out the prevailing characteristics and trends, together with the factors that shape them. The discussions will, through a comparative approach, focus

on issues such as identifying or describing the principal sources of fisheries law, and how that framework elaborates administrative and management mechanisms and the powers, rights and functions in these respects. The powers and functions relating to monitoring, control and surveillance (MCS) including enforcement will also be discussed.

The latter parts of the chapter examine the significant issues and trends in fisheries and their legal aspects. These parts address the subject of law review and development to assure currency of the fisheries law and conclude with a synthesis and outlook section.

5.2 Fisheries law

5.2.1 National fisheries and related legislation

Fisheries law, primarily as a body of national or domestic laws, is unique to the country or territorial subdivision (a federated authority, e.g. a state, region or province) within which the law applies. The manner in which the law is elaborated, interpreted and applied is subject to the country's legal and judicial system (e.g. civil or common law) as shaped by the governance framework and the country's legal history, philosophy, case law and customs.

Generally, the fisheries law does not have extraterritorial application unless this attribute is stipulated in provisions concerning its scope. It is vital to ensure that fisheries legislation of the Flag State has extraterritorial application in order to regulate high seas fishing by its nationals and vessels flying its flag.[4] Examples of fisheries legislation with extraterritorial scope are found in Antigua and Barbuda, Nauru, New Zealand and Papua New Guinea.

Managers should be familiar with the principal sources of law they administer and where their management powers and functions come from. As a minimum, managers should know the fundamental elements of the principal fisheries legislation and appreciate that other laws that govern other sectors, to the extent that they operationally impact on any aspect of fisheries, are also considered part of the fisheries legal framework. Managers must then work within the ambit of that framework.

Fisheries law is not necessarily found in one piece of legislation bearing the title 'fisheries law', but for many jurisdictions there is an identifiable principal or overarching national legal instrument (principal fisheries legislation) in the form of an 'act' or 'code' that governs fisheries. Examples of such legislation are Australia's Fisheries Management Act, Barbados Fisheries Act, Cambodia's Fisheries Management and Administration Law, Japan's The Fisheries Law, Latvia's Fishery Law, Mauritania's Fisheries Code, Namibia's Marine Resources Act, Norway's Act Relating to Sea-Water Fisheries, Philippines' Fisheries Code, Senegal's Marine Fisheries Code, Vietnam's Fisheries Law, Yemen's Fisheries Law and Zambia's Fisheries Act. Under principal fisheries legislation, there is typically a host of implementing or subsidiary legislations with varying names such as regulations, decrees, *arrêtés*, by-laws or administrative orders. Legislation with a direct application to fisheries can be referred to as 'principal' or 'fisheries-specific' laws.

A country's principal fisheries legislation may have a defined spatial range of application. In a federated government system, for example, the legal framework of direct application would

[4] The FAO Legal Office's model high seas fishing law developed for the Organization of Eastern Caribbean States has a useful sample provision that gives legislation extraterritorial scope (See FAO 1997b).

be the provincial, regional or state's law which could be supplemented by the national law (e.g. India) or could operate under the framework of, or concurrently with, the national law (e.g. State of New South Wales, Australia and Province of Manitoba, Canada). Where the latter situation exists, and depending on the federated structure in question, the national or federal law may prevail to the extent of any inconsistency or conflict between the federated authority-level law and national law.

Fisheries managers should be aware of a 'non-fisheries-specific' category of laws that govern other sectors but indirectly impact on fisheries such as fundamental laws (e.g. the Constitution) and laws on local government or decentralisation, shipping, veterinary, customs and excise, environment and conservation, health (food safety and quality), trade and commerce. A basic awareness of these laws will facilitate the identification of the person or office within the other sector's regulatory authority that should be consulted on operational matters. In some instances, the manager is clearly instructed by the primary fisheries law to ensure that certain management interventions are consistent with other laws (e.g. the US Magnuson-Stevens Fishery Conservation and Management Act 16 *USCA* 1853(b)(5)).

5.2.2 International instruments

A plethora of international instruments in capture fisheries addressing various fisheries management issues have emerged in the last two decades. Many of these are listed in Table 5.1, Section A. The principal binding instrument among them is the United Nations Convention on the Law of the Sea of 10 December 1982 (the LOS Convention). The LOS Convention, often referred to as the constitution for the oceans, codifies customary international law of the sea and lays the foundation for all subsequent international arrangements and agreements relating to the use of the oceans and seas. Arising directly from the LOS Convention and designed to strengthen its provisions on high seas fisheries and transboundary stocks is the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN Fish Stocks Agreement) and the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (Compliance Agreement).

The influence exerted by binding fisheries instruments on national policies and legislation is remarkably visible. For example, in anticipation of entry into force of the LOS Convention, many coastal states enacted national legislation claiming 200 nautical miles exclusive economic zones (EEZs). As a consequence of Article 73 of the LOS Convention, there is a growing trend to limit sanctions against the crew of foreign fishing vessels found in contravention of the coastal state's fisheries-specific laws in the EEZ to monetary and non-custodial sanctions in the absence of an agreement to the contrary between the states concerned.[5] Coastal states now require vessels flying their flags, including those operating on the high seas, to be licensed and subjected to conditions set out in the Compliance Agreement[6] and the UN Fish Stocks Agreement.[7]

[5] Non-fisheries laws such as laws for the protection of endangered species are not subject to this requirement.
[6] Article III.
[7] Article 18.

Table 5.1 Selected fisheries-related international instruments.

SECTION A: FISHERIES INSTRUMENTS
Binding instruments (a) United Nations Convention on the Law of the Sea of 10 December 1982 (b) Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessel on the High Seas (c) Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks
Non-binding instruments (a) Model Scheme on Port State Measures to Combat Illegal, Unreported and Unregulated Fishing (b) Declaration on the International Conference of Responsible Fishing, Cancun, Mexico, 6–8 May 1992 (c) United Nations Conference on Environmental Development 1992: Chapter 17 of Agenda 21: Protection of the Oceans, All Kinds of Seas, Including Enclosed and Semi-Enclosed Seas, and Coastal Areas and the Protection, Rational Use and Development of Their Living Resources (d) 1995 Code of Conduct for Responsible Fisheries[a] (e) The 2005 Rome Declaration on Illegal, Unreported and Unregulated Fishing (f) FAO/ILO/IMO Code of Safety for Fishermen and Fishing Vessels, 2005 (g) FAO/ILO/IMO Voluntary Guidelines for the Design, Construction and Equipment of Small Fishing Vessels (h) Proposed System for the Marking of Fishing Gear in FAO Technical Guidelines for Responsible Fisheries: Fishing Operations, No. 1. Rome, FAO. 1996. 26p. 6 annexes (i) Proposals for the Application of a Standard System of Lights and Shapes for the Identification and Location of Fishing Gear *in* FAO Technical Guidelines for Responsible Fisheries: Fishing Operations, No. 1. Rome, FAO. 1996. 26p. 6 annexes (j) IPOA for Reducing Incidental Catch of Seabirds in Longline Fisheries (k) IPOA for the Management of Fishing Capacity (l) IPOA for the Conservation and Management of Sharks (m) IPOA to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (n) A/RES/61/105 – Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments (UNGA Resolution 61/105)[b] (o) A/RES/60/31 – Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments (UNGA Resolution 60/31)

[a]FAO has produced numerous Technical Guidelines and supplements to these Guidelines to support the Implementation of the FAO Code of Conduct. These Guidelines can be accessed at the FAO Fisheries and Aquaculture Department Internet site: www.fao.org/fishery. Technical Guidelines and supplements have been published on Fishing Operations; Precautionary approach to capture fisheries and species introduction; Integration of fisheries into coastal area management; Fisheries management; Aquaculture development; Inland fisheries; Responsible Fish Utilisation; Indicators for sustainable development of marine capture fisheries; Implementation of the International Plan of Action to deter, prevent, and eliminate illegal, unreported and unregulated fishing; Increasing the contribution of small-scale fisheries to poverty alleviation and food security; Aquaculture development. 2. Health management for responsible movement of live aquatic animals. Supplement 1 to Fishing Operations – Vessel monitoring systems; Supplement 1 to Fisheries management – Conservation and management of sharks; Supplement 1 to Aquaculture Development – Good Aquaculture Feed management practice; Supplement 2 to Fisheries management – The ecosystem approach to fisheries; Supplement 2 to Aquaculture development – Health management for responsible movement of live aquatic animals; Supplement 1 to Inland Fisheries – Rehabilitation of inland waters for fisheries; Supplement 3 to Fisheries management – Managing fishing capacity; Supplement 2, add. 1 to Fisheries management – The ecosystem approach to fisheries. Best practices in ecosystem modelling for informing an ecosystem approach to fisheries; and Supplement 3 to Aquaculture development – Genetic resource management.

[b]The UN General Assembly has issued follow-up resolutions with the same title every year since UNGA Resolution 59/25 in 2003. The most recent resolutions with the same title are A/RES/62/177 and A/RES/63/112 adopted in 2007 and 2008 respectively.

(Continued)

Table 5.1 (*Continued*)

(p) A/RES/59/25 – Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments (UNGA Resolution 59/25) (q) A/RES/24/225 – Large-Scale Pelagic Driftnet Fishing and its impact on the Living Marine Resources of the World's Oceans and Seas (UNGA Resolution 44/225) (r) Unauthorized Fishing Zones of National Jurisdiction and its Impact on the Living Marine Resources of the World's Oceans and Seas (UNGA Resolution 49/116) (s) A/RES/49/118 – Fisheries By-catch and Discards and Their Impact on the Sustainable Use of the World's Living Marine Resources (UNGA Resolution 49/118) (t) A/RES/52/29 – Large-Scale Pelagic Driftnet Fishing: Unauthorized Fishing in Zones of National Jurisdiction and on the High Seas, Fisheries By-catch and Discards; and other developments (UNGA Resolution 52/29)
SECTION B: NON-FISHERIES-SPECIFIC INSTRUMENTS
Binding instruments (a) Convention on Biological Diversity (b) Convention on International Trade in Endangered Species of Wild Fauna and Flora (c) United Nations Framework Convention on Climate Change (d) Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982 (e) Convention on the Conservation of Migratory Species of Wild Animals (f) Convention concerning the Protection of the World Cultural and Natural Heritage (g) Convention on the International Regulations for Preventing Collisions at Sea, 1972 (h) The Torremolinos International Convention for the Safety of Fishing Vessels and the Torremolinos Protocol of 1993 relating thereto. (i) International Convention for the Safety of Life at Sea (SOLAS), 1974, its Amendments and Protocols. (j) International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel, 1995 (k) Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter, 1972 (l) International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (m) International Convention for the Control and Management of Ships' Ballast Water and Sediments (n) Convention concerning Minimum Age for Admission to Employment, 1973 (o) Convention concerning the Minimum Age of Admission to Employment as Fishermen (p) Convention Concerning the Medical Examination of Fishermen (q) Convention Concerning the Fishermen's Articles of Agreement (r) Convention Concerning Fishermen's Certificate of Competency (s) Convention Concerning Accommodation on Board Fishing Vessels
Non-binding instruments (a) United Nations Millennium Declaration, UNGA Resolution 55/2 (A/55/L.2) (b) World Summit on Sustainable Development (WSSD) Declaration (Johannesburg Declaration) (c) WSSD Plan of Implementation (Johannesburg Plan of Implementation) (d) United Nations Conference on Environment and Development (UNCED) Rio Declaration on Environment and Development, 1992 (e) UNCED. 1992: Agenda 21 (f) Global Conference on the Sustainable Development of Small Island Developing States (g) Programme of Action for the Sustainable Development of Small Islands (h) United Nations Conference on the Human Environment

A non-binding fisheries instrument of global significance is the FAO Code of Conduct. Although a voluntary instrument, the FAO Code of Conduct is of high value. It is implemented in numerous policy documents and national legislation. The FAO Code of Conduct, in issuing guidelines on areas where legislation is required for promoting responsible fisheries, is useful in policy and legislative development. The international plans of action (IPOA) developed under the auspices of the Food and Agriculture Organization of the United Nations (FAO) to implement certain aspects of the FAO Code of Conduct are similarly useful. The International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU) warrants special mention. The IPOA-IUU contains valuable guidelines for legislative implementation particularly in MCS. An increasing number of states have adopted National Plans of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated fishing (NPOA-IUU) modelled on the IPOA-IUU. The FAO Technical Guidelines for Responsible Fisheries and related supplements[8] produced to provide advice in support of implementation of the various thematic areas of the FAO Code of Conduct are also worthy references. Resolutions of FAO ministerial-level meetings (e.g. The 2005 Rome Declaration on Fisheries and the Tsunami) and, from time to time, the FAO Committee on Fisheries (COFI) recommendations provide impetus for implementation at the national level.

The non-FAO fisheries instruments of significant value comprise the UN General Assembly (UNGA) resolutions. These include resolution A/RES/22/45 on Large-Scale Pelagic Driftnet Fishing and its Impact on the Living Resources of the World's Oceans and Seas (the Driftnet Resolution) and the recent series of resolutions on fisheries[9] and the yearly resolution on Oceans and the Law of the Sea, the most recent being A/RES/62/215. Many national fisheries legislations now ban driftnet fishing as a consequence of the Driftnet Resolution.

Other binding and non-binding instruments not directly related to fisheries management are also noteworthy. The non-fisheries instruments of relevance are shown in Table 5.1, Section B. Environmental and development instruments like the Convention on Biological Diversity (CBD) and the Plan of Implementation of the World Summit for Sustainable Development, 2002 (WSSD) are influencing fisheries management with respect to issues such as the ecosystem approach to fisheries (EAF), the precautionary approach and sustainable development. The regime of marine protected areas (MPAs) promoted in the domain of environmental protection and port state control – the latter historically linked to ensuring maintenance of standards and safety at sea is increasingly being considered as an effective tool to combat IUU fishing.

The Convention for International Trade in Endangered Species of Wild Fauna and Flora (CITES) is impacting on marine fisheries management in light of growing concerns about some marine species subjected to international trade. The established process which introduces fisheries technical advice through FAO's Expert Advisory Panel into the consideration of proposals for listing fisheries species under CITES is a welcome development. The recently adopted

[8] To date, 15 FAO Technical Guidelines for Responsible Fisheries and supplements have been published. See Table 1 infra.

[9] For example, A/RES/62/112 – Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments.

memorandum of understanding to strengthen cooperation between FAO and the CITES Secretariat[10] has added to the awareness of the need for better fisheries management through cooperative effort and the usefulness of considering CITES listing as a management option.

5.2.3 The relationship between the international and national fisheries legal frameworks

International law and international fisheries instruments are vital to fisheries management as they reflect state commitments to recognised conservation and management doctrines, standards, rights and best practices (Figure 5.1). The manager is required to develop sufficient familiarity with international binding and voluntary instruments concerning fisheries to ensure their effective translation and application at the domestic level.[11] The attention of the manager should eventually focus on how these instruments influence or are reflected in

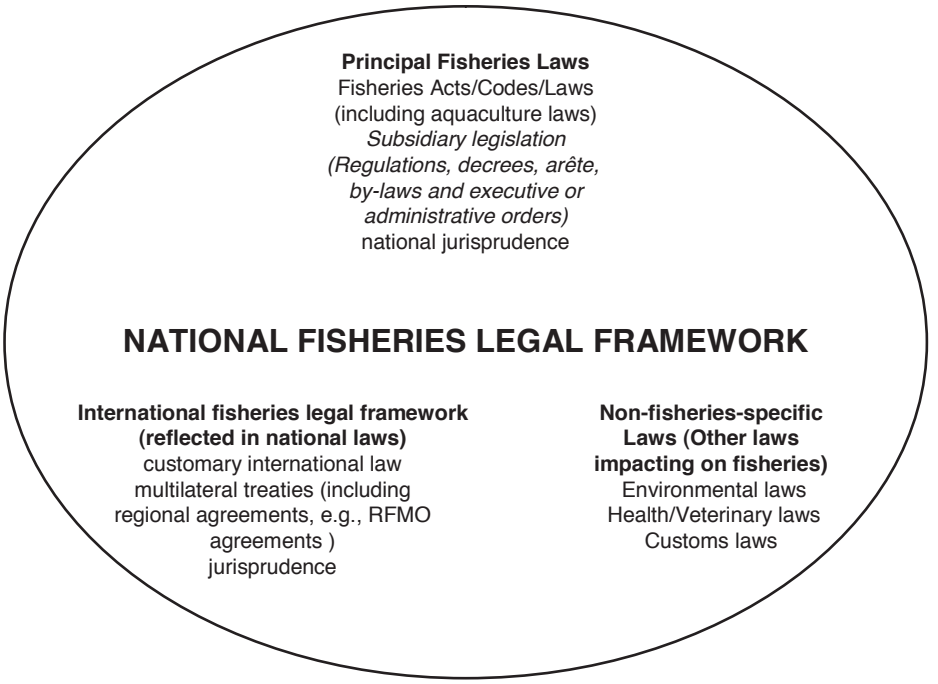


Figure 5.1 Representation of a typical national fisheries legal framework showing the relationship between international, non-fisheries-specific and fisheries-specific law.

[10] Memorandum of Understanding Between the Food and Agriculture Organization of the United Nations (FAO) and the Secretariat of the Convention on International Trade in Endangered Species (CITES) (2006).

[11] See FAO (2001) for an overview of the dynamics between binding international fisheries instruments, namely the Compliance Agreement and the UN Fish Stocks Agreement and implementation at the national, sub-regional and regional levels.

national fisheries legal frameworks. This is necessitated by the often overlooked fact that international law and commitments by states as stipulated in conventions and agreements may bind states, but in many instances they will not be applied or enforced domestically against natural or juridical persons unless they are reflected in 'enabling legislation'.[12] For example, the requirement of a state party to the Compliance Agreement to record and license vessels flying its flag cannot be imposed on the owners or operators of such vessels unless there is in place national legislation that has the same requirement. Domestic enabling legislation is vital for non-binding instruments, such as the FAO Code of Conduct and IPOAs, as national legislation can translate the calls for voluntary action into legal requirements by enforcing rights and responsibilities and sanctioning non-compliance.

The manager in cooperation with appropriate national authorities should ensure that national enabling legislation is in place to implement international instruments before implementation action is pursued at the domestic level. If the manager participates or advises the government in the negotiation of international fisheries instruments, the well-prepared manager would advise on the national implementation and capacity implications of endorsing specific international commitments.

5.2.4 Regional fisheries entities and arrangements

Regional fisheries bodies (RFBs) and regional fisheries management organizations (RFMOs) and arrangements, to the extent allowed by their constitutions, have important institutional, advisory, regulatory and coordinating functions in fisheries management. These entities are the principal medium for multilateral cooperation for the management of shared resources as mandated by the LOS Convention and reinforced in the UN Fish Stocks Agreement, the Compliance Agreement, the FAO Code of Conduct, the IPOA-IUU and other binding and non-binding fisheries instruments.[13] The management, regulatory or coordination regimes of these entities are often pragmatic and are of immediate relevance to state parties in terms of how management advice, measures and regulations are tailored to the region concerned. This in turn often translates into efficient domestic implementation or enforcement of management measures, regulations or advice.[14] The documented growing role of RFBs in preventing, deterring and eliminating IUU fishing clearly underlines the significance of their contribution to global fisheries management.[15]

As a result of the duty for states to cooperate through RFBs, RFMOs and arrangements and the increasing role and involvement of RFBs in combating IUU fishing, more countries than in the past will become members of one or more regional bodies, including RFMOs, such as the various tuna bodies (e.g. the International Convention on the Conservation of Atlantic Tuna (ICCAT), the Indian Ocean Tuna Commission (IOTC)), the Western and Central Pacific Fisheries

[12] The term 'enabling legislation' in this context refers to the kind of legislation that states are required to enact in order to implement obligations under international instruments as part of their domestic ratification process. It does not refer to subsidiary laws such as regulations or rules that implement principal legislation.

[13] See Swan (2004a) for the evolving role of RFBs in implementation in decision-making.

[14] See FAO (2001) for a comparative study of the compliance and enforcement action of the Compliance Agreement and the UN Fish Stocks Agreement at the national, sub-regional and regional levels.

[15] Swan (2004b) provides a useful analysis of the role of RFBs and the measures taken by RFBs to prevent, deter and eliminate IUU fishing.

Commission (WCPFC), the Convention on the Conservation of Antarctic Living Marine Resources (CCAMLR), various FAO RFBs such as the Fishery Committee for the Eastern Central Atlantic (CECAF) and the Asia-Pacific Fishery Commission (APFIC), and others.

Managers must be aware of the RFMOs or RFBs in which their country is involved, and the implications and obligations of membership or in becoming a 'cooperating non-party'[16] particularly where the RFMO or RFB has the competence to adopt binding decisions. In relation to the establishment of new regional fisheries cooperative mechanisms or enhancement of competence of existing RFBs, the manager would do well to monitor or participate in regional and global discussions such as at the UN and FAO as these discussions may indicate the need to establish new regional fisheries entities or enhance or close competence gaps of such mechanisms. It may be imperative for managers to ensure that their countries, whether as a coastal state or a state with fishing interests in the region concerned, are involved in the setting up of a regional organisation if there is the potential that the new organisation may manage fisheries including determining access to the fishing of fish stocks that are transboundary or occur in the high seas.

5.3 Fisheries management regime in the legal framework

5.3.1 The institutional framework in fisheries law

An important feature of the fisheries legal framework is the administrative or institutional mechanism it establishes as elaborated in detail in Chapter 6. It provides the structural and operational basis for the exercise of powers and functions by the manager. For many jurisdictions, this mechanism such as the national fisheries management administration (FMA) is set out in the principal fisheries law, most likely the first sections of the legislation. The administrative or institutional mechanism is closely linked to the fisheries management powers as often the law will state that the power to manage fisheries is vested in a certain ministry or other government entity. It is not uncommon, however, that the institutional structure, particularly for government entities that are given the fisheries management mandate, is set out in some other legislation.

Managers should note where they are placed in the institutional structure, their role within that structure in pursuance of the overall management objectives and the relationship with superiors, persons at the same hierarchical level or subordinates. Managers may be the executive head of the entity charged with general fisheries management or head a division or section charged with managing a specific fishery. In this respect, managers should note their principal management functions, the circumstances in which they are empowered to take initiatives and those where direction, advice or consultation is required before making a management decision. It should be noted that actions taken without legal basis or in excess of specified powers or functions are *ultra vires* (beyond the powers) and could be subject to judicial review and rendered null and void.

In many countries, the principal fisheries legislation creates or designates a fisheries management entity that is responsible, or reports, to a minister. Such entity may comprise a collective decision-making or advisory body (e.g. board of directors, council or committee) with the administrative, technical and operational arm or 'secretariat' of the entity controlled by

[16] A 'cooperating non-party' refers to a state that is not a party to the RFB but has formally indicated its commitment to cooperate with the RFB by, for example, complying with the management measures introduced by the RFB.

an executive head. Within such an institutional framework, managers should be aware of whether they are part of a secretariat or act as secretariat to the collective decision-making body of the entity; make all decisions with the endorsement of such body; or can directly take certain management initiatives.

By legislative prescription or agreement, many countries are utilising partnership or participatory approaches to management such as cooperative management (co-management) as discussed in Chapters 3 and 11 and elsewhere in this book. At the same time, many countries are devolving fisheries management powers to lower or other levels of government. Under these systems, recognised entities or groups are mandated to take certain management interventions within a spatial scope or to manage a certain fishery. These systems expand the broad institutional framework for fisheries management. In this situation, the manager should be aware of the role the FMA plays in managing and supporting the devolved or participatory management approach. This insight will avoid overlapping mandates and duplication in favour of a well-coordinated and therefore efficient operation of the devolved or participatory management system.

Usually lodged in the institutional framework established by the fisheries law is the power vested in the manager or the fisheries management entity to delegate certain management functions. An informed fisheries manager will identify, plan and put these powers to effective use. Such powers of delegation are explicitly stated in the law – their existence is rarely implied. It should be noted that a general rule in many jurisdictions concerning delegation of powers is that, while the management or operational function can be delegated, the power to delegate cannot be further delegated unless it is expressly stated otherwise.

5.3.2 Management powers and functions

The stipulation in the legal framework relating to fisheries management powers and functions is of primary concern to the manager. The relevant part of the legal framework normally designates the entity or person vested with fisheries management powers generally and their decision-making and operational functions.

Statements of resource ownership or access and management rights (Chapter 10), which may be found in the principal fisheries legislation, provide the foundation for management interventions. Normally, the public ownership of or access to fisheries resources or the right of custody, and therefore management mandate of such common property, is vested in the state and exercised by designated government agencies. These statements provide the main objective or general guidance for the management of fisheries in any given jurisdiction. Examples of statements of state or common proprietary rights in fisheries resources can be found in the fisheries laws of Cape Verde, Gabon, Mozambique, Latvia and Canada's Province of Manitoba.

For most jurisdictions, the principal management powers and functions emanate from the provisions of primary fisheries legislation with the heading 'Fisheries Management' or 'Management of Marine Living Resources', but they can also be part of a section that sets out the institutional structure of the FMA or scattered throughout the legislation under specific headings such as the power to elaborate fishery plans, determine or consider co-management arrangements, require registration of vessels, fishers or gear, consider and grant fishing rights, quotas, licences or other rights and authorisations.

The statement of ownership of fisheries resources can also be stated in fundamental laws such as the constitution. This right is carried over into the operational sphere and elaborated in the principal fisheries legislation. Examples of jurisdictions with this feature are Indonesia, South Africa and Vietnam.

5.3.3 Legislated management policies, principles and guidelines

Certain states incorporate fisheries sector policy statements and their objectives in the principal fisheries legislation. This assures that the policy statement is found in the same place as the operational provisions in legislation which can be of great assistance in establishing the intent of legislators and guiding implementation. Examples of this practice can be found in the fisheries legislation of Palau, the Philippines and the United States. Other jurisdictions, such as Namibia and Tanzania, simply empower the minister to formulate the fisheries policy.

State practice shows a trend towards the elaboration of principles for management in the primary fisheries legislation. The principles are inspired by or drawn from international instruments such as the FAO Code of Conduct and the principle of sustainable development found in the United Nations Conference on Environment and Development (UNCED), Rio Declaration on Environment and Development (Rio Declaration) and Agenda 21. Often, these guiding principles are located in the preamble or initial sections of the principal fisheries legislation relating to management. These legislated guidelines should be a handy manual for the manager in exercising management functions. Countries that have incorporated management guidelines provisions in their primary fisheries law include Angola, Canada, Gabon, Lithuania, Namibia, New Zealand, the Philippines, Solomon Islands, South Africa and Tonga.

While many of the management guidelines by their nature are not enforceable, this does not mean that the guidelines should be ignored. They can be significant tools for the courts in interpretation or in constructing the intent of legislators on how specific management functions should be implemented. For example, legislation might enable the FMA to permit fishing by licensing without setting a cap on the number of licenses to be issued. If a guiding principle enshrined in legislation states that fishing shall be carried out in a sustainable manner, the provision would most likely be interpreted to mean that the power of licensing is not without limits and licences issued should be proportionate to the productivity of the resource. The manager might therefore be prompted to ensure that such considerations are built into, for example, the fishery management plans or fishing licences policy.

5.3.4 Fisheries management approaches and tools

Typically, the approaches or tools that can be used to manage fisheries (see Chapters 7–11) are determined or restricted to those set out in the fisheries legislation. Precedence and long-standing practice may provide guidance for what approaches or tools have been effective and therefore can be used, but the only sure way to know is to see these stipulated in law.

A majority of fishing nations' fisheries laws avail the manager with a broad range of fisheries management approaches and measures but leave it to the manager to determine which management approach or measure or combinations thereof will best achieve the management objectives of a fishery. It is not uncommon however that the law will specify in mandatory terms the management approach or measure to be used for a specified fishery. A selection of the main approaches and tools are discussed below but they do not reflect the full range of options stated in the principal fisheries legislation of all jurisdictions.

Fishery plans

Many countries have embraced the management planning approach in regulating and managing fisheries by requiring the development of fishery plans in fisheries legislation. The

manager should determine whether the law requires general (national) plans or specific fishery plans to be developed. For example, the Antigua and Barbuda Fisheries Act calls on the Chief Fisheries Officer to prepare and keep under review a national plan (rather than a single fishery plan) for responsible management and sustainable development of fisheries. In contrast, the Barbados Fisheries Act requires the Chief Fisheries Officer to develop schemes (i.e., more than one plan) for the management and development of fisheries.

The manager should also be familiar with the process for development and promulgation of the fishery plan, any mandatory elements of the plan, the legal status of such plans and their implementation, enforcement and review requirements. The principal fisheries law will normally specify the person who initiates the development of the plan, who should be consulted or provide counsel, what information should be considered, whose endorsement is necessary and the mode of publication of the plan (e.g. in a government gazette).

Chapter 16 describes the standard structure and components of a fishery plan. If the law prescribes the form and essential components of the plan (e.g. description of the fishery, management objectives, how objectives should be met or what management measures will be used and the review mechanism), the manager should ensure that these requirements are satisfied. Jurisdictions that set out mandatory elements of a fishery plan in their fisheries legislation include Antigua and Barbuda, Barbados, Ghana, Marshall Islands and Tonga.

The development process and substance requirements of the plan are crucial if the plan is considered to be a regulatory instrument or has binding character and therefore enforceable.

Effort and catch management

Chapter 9 notes that effort and catch management by their nature span the whole fishery. In the same vein, the requirement for use of conventional fisheries management measures in regulating effort and catch is typically stated in the fisheries law and permeates the management framework established under the law.

The regulation of effort would most likely be achieved through the implementation of an authorisation (licensing or permitting) system. Many jurisdictions require in their fisheries laws that no person shall engage in fishing without a concession or an authorisation in a form of licence or permit issued in accordance with the fisheries law.

The fisheries law may require or, more importantly, leave it open for the authorisation system to be integrated with the management planning system or to be used in combination with other effort-reducing or regulating measures. Unless the law requires that specific limits be employed (e.g. the maximum number of licences to be issued in a fishery), the manager could, based on appropriate information and advice, utilise the opportunities for combining the authorisation system with other effort control measures such as gear restrictions, fishing day limits and spatial restrictions in order to achieve better results in managing effort.

The typical catch management measure, the total allowable catch (TAC), is often prescribed in the fisheries law. For certain stocks, such as highly migratory tuna stocks, the requirement to specify the TAC is required by the LOS Convention[17] and is restated in the national fisheries law as a matter of course. The only difference between the broad international commitment for setting the TAC stated in the LOS Convention and the requirements

[17] Article 61.

relating to TAC in national legislation is that the latter would normally elaborate how the TAC would be determined and allocated as fishing entitlements by the state.

At the multilateral and regional level, the RFMO that has been accorded the appropriate competencies by its members would be the authority that determines and allocates TAC entitlements.

Many jurisdictions, particularly those employing quota management systems, would naturally have a requirement in the law for setting the TAC for a fishery.

Fishing rights

Legally, a 'right' is the ability of the claimants to call upon others without such claims to acknowledge their duty to honour the claim, with any violation of such a duty sanctioned by the state or by an authority. It is 'a capacity . . . of controlling, with the assent and assistance of the State, the actions of the others.'[18] From this basis, and placed in the fisheries context in relation to fishing rights, it can be seen that the licence or permit to fish is one form of right while a TAC allocation as a quota is another form with the latter possessing more in the bundle of rights or valuable characteristics added which can be sanctioned. In this context an individual transferable quota (ITQ) is at the end of the spectrum which has more rights or valuable characteristics often referred to as 'property rights' as it possesses the elements of exclusivity – the ability to hold and manage the right without outside interference; duration, from long term to perpetuity as appropriate; security of tenure – the ability to withstand challenges of others to the title; and transferability, with varying degrees of restriction on transferees.[19]

The various forms and categorisation of fishing rights that can be used are specified in the law. ITQ systems by their exclusive and property nature have to be established by the fisheries law in order to ensure, among other things, the extent of the owners', rights and the protection and enforcement of those rights. These systems can have specific parts of the principal fisheries legislation or regulations dedicated to them.

Communal and other rights allocation in the context of a participatory or partnership management system as discussed in Chapters 10 and 11 is better elaborated in legislation to ensure clarity and enforceability of such rights.

Use of technical measures

The prescription in many fisheries laws concerning technical measures (for regulating effort) can be put into two broad categories. The first, for reasons of the high level of risk it poses to the health and safety of persons and the extent of damage it can cause to species and the environment, falls into the 'prohibitions' category. The second, owing to its technically elaborate nature, can be labelled 'regulated measures' as the detailed specifications for the use of those measures are normally found in subsidiary regulations. Typically, the first group is explicitly prohibited in the fisheries law. For example, the use of explosives or toxic substances to

[18] Black's Law Dictionary.
[19] FAO (2004) at page 11.

take fish or the taking of fish using spear guns and electric shocks, or the taking of protected species are prohibited. Non-fisheries-specific laws relating to species and environmental protection may contain these prohibitions (e.g. Title 24 of Palau National Code – Environmental Protection, Chapter 13 – Illegal methods of capture). Contraventions of these prohibitions are criminal offences and can attract custodial sentences (imprisonment). It is possible that the principal fisheries law will also empower the FMA or other named persons to establish and publish prohibitions from time to time so that emerging destructive fishing methods can be prohibited or vulnerable species can be protected.

With respect to the second group of technical measures, the principal fisheries law typically empowers the management authority through subsidiary legislation (regulations, decrees, by-laws or administrative orders) to regulate the use of, for example, fishing gear such as nets and vessels and their specifications including the requirements or conditions relating to the taking of certain species and temporal and spatial closures and conditions that apply to these closures. Often temporal and spatial closures associated with rights issued within the framework of a participatory or partnership management system are elaborated in legislation.

Examples of Matters That Can Be Regulated*

(a) measures for the conservation, management, development, licensing and regulation of fisheries or any particular fishery, including total allowable catch and quota system as appropriate
(b) licensing any vessel or class or category of vessels to be used for fishing and related activities or any other purpose
(c) licensing or registration of fishing gear and other equipment or devices used for fishing
(d) types and sizes of fishing gears and other fishing devices including the sizes of fishing nets that may be used for fishing, where they may be used and prohibited fishing nets
(e) manufacture, importation and sale of fishing nets
(f) landing requirements for any vessel or class or category of vessel or licence
(g) catching, loading, landing, handling, transhipping, transporting, possession and disposal of fish
(h) tuna fishing or fishing for any specified species of fish
(i) importation, export, distribution and marketing of fish and fish products
(j) licensing, control and use of fish aggregating devices, and, the rights to the aggregated fish and prescribing times and the minimum distance from such devices to for fishing
(k) standards and measures for the safety of fishers
(l) matters relating to satellite monitoring of fishing activities
(m) aquaculture
(n) recreational fishing
(o) canoe fishing including markings and identity of canoes
(p) the provision of statistical and other information related to fisheries
(q) control, inspection or operation of fish processing establishments

(r) returns concerning fishing operations required to be submitted to the Commission by licensees
(s) licences and logbooks to be carried on board motor fishing vessels
(t) further conditions for fishing licences
(u) conditions for the approval of charter agreements
(v) general matters for the achievement of the purposes of the principal fisheries legislation

*These examples are drawn from section 139 of Ghana's Fisheries Act 2002 but they should not be considered as a full representation of matters that can be regulated in subsidiary legislation.

As subsidiary legislation does not have to go through the lengthy legislative process to become law, managers should note the full range of technical measures for which such laws could be promulgated and used effectively.

Participatory or partnership management

Chapter 11 laments the low incidence of partnership management in fisheries and provides guidance on the conditions for establishing partnerships. An often subtle but salient factor that contributes to this situation is that fisheries resources being *res communes* (of the public domain) are vested in the state and its agents to be regulated for the public good. Thus law and other institutional structure, for the most part, were not designed historically to support partnerships or co-management.

For this and other reasons to be examined herein, partnerships, co-management arrangements and other forms of participatory management systems must have a legal basis. Co-management must be unhindered, enabled and supported by the fisheries legal framework so that rights and responsibilities, including decision-making for the management of common pool resources, are redistributed, protected and enforced. Where there are plans for introducing and implementing fisheries co-management, the advice in Chapter 11 for the need for the careful design of the partnership system also applies to the design of the supporting legal framework.

The illustration of the levels of co-management by Pomeroy and Berkes (1997), Figure 5.2, shows the varying degrees of partnership arrangements that exist. The legal framework is not likely to expressly label that which is essentially a cooperative arrangement as a 'partnership', particularly where such arrangements do not involve substantive management interventions. An example of this is the requirement for the FMA to consult stakeholders in the community in the development of management plans or for certain stakeholder groups to be represented on a fishery advisory committee.

Evidently, substantive arrangements entailing the designation of resource user groups to take management decisions and to have certain rights and obligations within a geographic region or fishery; a collection of rules indicating actions that subjects are expected to take under various circumstances; and procedures for collective decision-making would normally be provided for by the fisheries legal framework.

With some exceptions (e.g. Japan, the Philippines), the prevailing practice indicates that the legal frameworks for co-management arrangements are largely 'framework' laws

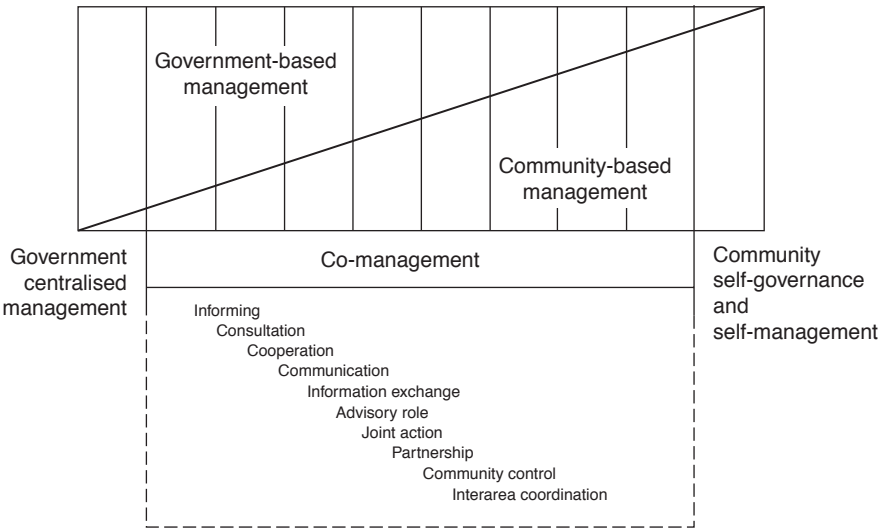


Figure 5.2 From Pomeroy and Berkes, 1997. Levels of partnership arrangements that can be legislated.

(e.g. Cambodia, Tanzania, Tonga, Vietnam) in that they primarily enable the use of co-management by vesting powers in the manager to use co-management where appropriate. These framework laws for co-management set out the basic essentials to provide for

(a) the designation of the co-management unit (e.g. fisher or other stakeholder groups);
(b) choice in demarcation of areas or fisheries for co-management;
(c) allocation of the mandate or such rights and responsibilities as are required for an effective co-management arrangement;
(d) elaborated regulatory framework governing behaviour and relations between various partners in the co-management arrangements and between designated co-management units;
(e) avenues for enforcement of rights and responsibilities and conflict resolution.

Other countries have used existing government structures and laws to establish co-management systems and regulations. This implies using the powers, functions and institutions created or recognised under general governance laws. In Samoa, for example, the village *fono* or Council, recognised as a valid local government institution under the Village Fono Act, issues by-laws that are then endorsed by the national government through the Fisheries Department and Minister for Fisheries as co-management by-laws for the village.

It is worth restating here that the manager should appreciate his or her role in the management or support of the prescribed or designated co-management system to ensure that it is well coordinated and functions in an efficient manner.

5.3.5 Fishing access agreements

Many developing country coastal states with vast EEZs assign, under bilateral or multilateral access agreements, access rights to fish for foreign fishing vessels. This practice peaked

during the advent of the LOS Convention which placed large ocean areas containing most commercially exploited fish stocks under the jurisdiction of coastal states. Such practice was arguably driven by the need to generate revenue, the inability of many coastal developing states to fish surplus stocks and the need to satisfy the obligation in the LOS Convention to assign such surplus stocks to other states for exploitation.[20]

Although the assignment of access rights to fish in the EEZ is a sovereign right exercisable by the coastal state, it is typically reinforced and elaborated in the fisheries legal framework. Unless the law clearly mandates the minister responsible for fisheries or the FMA to directly engage another state in negotiation and adoption of access agreements, the manager is normally expected or required to work with the government ministry or agency responsible for international relations (e.g. Ministry of Foreign Affairs) to undertake these tasks given the international relations and the rights and obligations established under state to state agreements. The principal fisheries legislation might set out who the state will enter access agreements with (usually any foreign fishing state or the agency of that state that is given appropriate competencies to enter into fishing access agreements). It should be noted, however, that certain jurisdictions continue to grant licences outside any access agreement provided the applicant gives satisfactory guarantees.

Some fisheries laws prescribe the essential elements to be incorporated in the access agreement. This requirement has to be complied with in order to avoid the access agreement from being declared invalid. Jurisdictions that have fisheries legislation that require this include Cape Verde, Guinea, Mauritius, Marshall Islands, Seychelles and Vanuatu.

Examples of Essential Elements of Access Agreements*

(a) Provision of fisheries access, related activities and such other matters as are provided for by the fisheries legislation
(b) The granting of preferential access to vessels of certain countries or groups of countries
(c) The requirement that fishery allocations under the agreements do not exceed a level consistent with the conservation and management of fishery resources and the protection of fishing by citizens of the State and must be consistent with all fishery management plans
(d) The requirement to implement minimum terms and conditions of fisheries access as agreed from time to time including:

- establishing the responsibility of the foreign party to take all measures necessary to ensure compliance by its vessels with the terms and conditions of the access agreement and with all applicable laws;
- requiring the operator or any other person responsible for the operation of a licensed vessel not to tranship fish at sea whether or not such transhipment is done within areas under national jurisdiction or on the high seas, and only tranship through designated ports or as provided by the access agreement;

[20] Article 62(2).

- requiring the operator or any other person responsible for the operation of a licensed vessel to ensure compliance with requirements relating to:

  (i) the appointment of a resident local agent;
  (ii) the placement of observers;
  (iii) reporting requirements as to entry into and exit from the State waters;
  (iv) the maintenance of catch figures and log books;
  (v) the provision of data and information;
  (vi) the imposition of any other control required by law or necessary for the proper management or conservation of any fishery.

(e) The issuing of licences for fishing and related activities, and for any matter provided for under the fisheries legislation
(f) Requiring such other matters as may be necessary for the effective implementation of the access agreement

*These examples drawn from the Fisheries Act 2005 of Vanuatu are not an exhaustive representation of what can be required by the provisions of principal fisheries legislation.

5.4 Monitoring, control and surveillance

5.4.1 MCS and the law

Law is central to MCS. The underlying necessity for MCS interventions to be grounded in law is evident from the description and nature of the core elements of MCS set out in Chapter 14, which involve a high degree of command and control intervention by the management authority where the threat of injury to civil liberties is high. It is not uncommon to find non-fisheries-specific laws such as the constitution that pronounce and elaborate civil liberties which will determine the feasibility or otherwise of MCS interventions stipulated in the principal fisheries legislation. It is particularly vital that enforcement actions, especially those that result in criminal proceedings taken against a person for alleged violations, were founded in law. Thus the fisheries law fulfils the following basic functions in relation to MCS:

(a) defines the powers, duties and obligations of the management authority especially in regu-lating entry and the behaviour of persons engaged in the fishery (e.g. prohibiting certain activities, requiring that other activities be undertaken only under the authority of a licence, and prescribing the manner in which fishing and related activities must be conducted);
(b) establishes or designates the competent entity for MCS including the fisheries monitoring centre;
(c) designates or provides a mechanism for the designation of observers and enforcement officers;
(d) provides the basis for developing MCS plans and implementing various MCS tools, for example, vessel monitoring systems (VMS);

(e) protects the interests of fishers (e.g. confidentiality of information);
(f) grants enforcement powers to officials (e.g. to arrest, detain and seize);
(g) safeguards basic civil rights of alleged wrongdoers in enforcement action; and
(h) establishes the judicial or alternative enforcement system for penalising those who violate fisheries rules, the procedures in that enforcement system and the applicable sanctions.

A cursory study of existing national fisheries laws will show that they provide the minimum legal basis required for implementing vital MCS actions. The only remaining question to be asked is whether the law allows the manager to take the full range of MCS interventions considered necessary to ensure a satisfactory level of compliance. The answer to this question naturally varies from jurisdiction to jurisdiction.

The manager is essential to the process of identifying weaknesses or gaps in the management and MCS with a view to rectifying them.

5.4.2 Fisheries management and MCS in the fisheries legal framework

The need to have information on the behaviour and consequences of the behaviour of fishers and other stakeholders in a fishery, so that appropriate management action or the review thereof can be undertaken, is the core incentive for MCS interventions. As can be noted from Chapter 14, the actions to furnish information can be set in motion prior to, during and after fishing operations. This information can be required to be provided by the interested party to enable their entry into a fishery (e.g. by a person or vessel to be registered to qualify for a licence to fish) or it can be collected during fishing and related operations through the manager's direct actions.

The means to procure the kind of information required (e.g. inspections, at-sea monitoring by observers or VMS surveillance) is by and large facilitated by the fisheries law. The manager should be sure to adhere to rules protecting the rights of the person providing information (e.g. ensuring confidentiality). Where enforcement becomes necessary, the fisheries law enables the enforcement authority to utilise available information or gather specific information (e.g. evidence of contraventions) to support enforcement action.

Many jurisdictions use their powers to incorporate requirements for furnishing information into the authorisation or fishing rights regime by making these requirements conditions of the authorisation or right. Breach of a condition conceives an unlawful act subject to enforcement action. This is a convenient way of regulating entrants, as the conditions do not have to be promulgated as a new regulation, thereby enabling the management authority to respond quickly to implement new directives. The manager should note, however, that the convenience of attaching a new regulation as a licence condition may be subject to checks and balances such as ensuring that the condition is lawful and within the ambit of the management powers and objectives. If the condition frustrates the principal right granted, the right holder may challenge the condition or be entitled to compensation.

5.4.3 Participatory management and MCS

Co-management and other participatory management systems could contemplate an MCS role for the co-management unit or participants. For the reasons elaborated above relating

to the nature and implications of MCS interventions, it is vital that any MCS responsibility envisaged for the co-management unit be sanctioned by law. Compliance and enforcement functions for co-management units, particularly those that rely heavily on self-regulation, may not be provided for in the law, as the primary focus of such participatory management systems would be on voluntary compliance, but this is not necessarily true in all cases.

5.4.4 Vessel monitoring systems

VMS (see also Section 14.3.2) like other modern monitoring and near-real-time information systems is a relatively new technology in the MCS toolbox. Although VMS has been around for two decades, many developing coastal states are still testing its viability or considering its use. For these reasons, many FMAs do not have regulatory frameworks to implement VMS although the situation is already changing.

It is advisable that the manager considers a supporting regulatory framework for VMS at the same time when VMS is being considered for use. Among the essential components for the regulatory framework for implementing VMS are

(a) the enabling power of the FMA to introduce and implement VMS as an MCS tool;
(b) the VMS components and technical standards or specifications for the components;
(c) the rights and responsibilities of the FMA in managing the VMS system and the persons required to implement VMS;
(d) the ownership and the primary and secondary uses of VMS information;
(e) the requirements and specifications for ensuring confidentiality and security of information;
(f) the rules for ensuring efficient operation, maintenance and operational performance of VMS components supported by enforcement and sanctions against violations;
(g) the use of VMS information as evidence in a court of law.

The manager could refer to existing laws on VMS[21] like those of the European Community (EC), New Zealand, Mauritius or Palau to develop a VMS regulatory framework. The further use of existing VMS policy or MCS plans which will define how VMS will be used to achieve the objectives set out in such plans, or the formulation of new VMS policies and MCS plans, would greatly assist the development of such a regulatory framework.

5.4.5 Enforcement

The rules governing enforcement for non-compliance or contraventions of fisheries laws are usually precise. Strict adherence by enforcement officers to these rules, which should be broad enough to enable enforcement officers to carry out their duties but sufficiently strict to protect fishers against the abuse of power, is crucial. Initial enforcement actions such as boarding and inspection on suspicion of contraventions, collecting evidentiary material,

[21] See FAOLEX – ftp://ftp.fao.org/FI/DOCUMENT/tc-psm/port_state_biblio.pdf

directing an alleged offending vessel to port and fixing a bond or security for prompt release of a foreign fishing vessel and its crew are typically located in the principal fisheries legislation. In contrast, the rules relating to the cautioning of the alleged offender in an arrest, conducting proper interviews and admissibility of certain hearsay evidence may be found in other laws relating to general law enforcement or in jurisprudence. The manager may not have a direct role in enforcement action, but he has the primary responsibility to ensure that the compliance and enforcement officers receive quality enforcement training and that enforcers act responsibly and in accordance with the rules.

In addition to criminal proceedings, the fisheries law might provide for the use of administrative enforcement processes (e.g. compounding offences or imposing civil penalties).[22] The situations or types of violations that may be subjected to the administrative enforcement process are normally specified in the law. In some jurisdictions, only minor violations attract administrative penalties, while in others the choice may be determined by the need for swift enforcement action or to avoid delays in criminal proceedings due to the heavy workloads of the courts. Jurisdictions that employ administrative sanctions include Angola, Albania, Cambodia, Chile, Ecuador, Guinea, Malta, Marshall Islands, Mexico, Mozambique, Papua New Guinea, Portugal, Senegal, Spain, the United States and Vietnam.

Frequently, fisheries enforcement officers will conduct enforcement action with officers of the regular national law enforcement agencies. To facilitate this, the principal fisheries legislation may provide for the minister or other designated entities to authorise persons to be fisheries enforcement officers. In many developing countries, utilisation of existing enforcement agencies through cross-authorisation to enforce another sector's law and close collaboration between law enforcement agencies ensures sensible utilisation of scarce resources. Ensuring where possible that there is standard or joint training of fisheries and ordinary law enforcement officers, coordinated exercises and cooperation between the management authority and other law enforcement agencies is essential for effective MCS. Managers would do well in appropriately utilising legislative provisions that give them choices in taking enforcement action while ensuring that appropriate capacity-building processes exist to sustain these (see also Section 14.2).

The manager should also note that regional and sub-regional MCS and enforcement schemes exist, such as those of CCAMLR, the European Union, the Pacific Forum Fisheries Agency (FFA), ICCAT, IOTC, North East Atlantic Fisheries Commission (NEAFC), Northwest Atlantic Fisheries Organization (NAFO), the South East Atlantic Fisheries Organization (SEAFO) and WCPFC as described in FAO 2001. These schemes can apply directly in the area of competence of the regional organisation, RFB or RFMO or may require implementation through national legislation. In this regard, the manager should ensure appropriate national facilitation and coordination of implementation of the regional and sub-regional MCS and enforcement arrangements where the manager's state is a party to such regional and sub-regional bodies or arrangements.

5.4.6 IUU fishing

IUU fishing as defined in the IPOA-IUU is essentially a description of the problems that MCS and its supporting legal framework are set up to address. The 'illegal' and 'unreported'

[22] Cacaud, Kuruc and Spreij (2003).

problems are typical aspects of the IUU fishing problem – the terms, fundamentally, refer to situations where regulatory regimes exist and apply to the persons involved in the activities, but the persons who commit the 'unlawful' or 'unreported' acts deliberately choose to ignore the applicable rules. The compliance and enforcement components of MCS deal with these first two aspects of the IUU fishing problem.

The 'unregulated' aspect of IUU fishing basically means that there is no regime governing the fisheries (i.e. there are no conservation or management measures in place) or a specific behaviour and therefore compliance and enforcement rules cannot be invoked. Unregulated fishing can be conducted by vessels without nationality, vessels flying the flag of a country that is not party to the regional organisation governing the particular fishing area or species or any vessel that fishes in an area not covered by an RFMO. The response to the latter problem is to extend the coverage of existing management and regulatory frameworks so that the activity or area in which the activity occurs falls within the scope of the management and regulatory frameworks. The problem of unregulated fishing normally occurs in areas beyond national jurisdiction where RFMOs are either not established or not competent with respect to specific species or states, although this does not mean that weaknesses or gaps in the national MCS framework do not exist. A current 'unregulated' issue is that of deep-sea fisheries. Attention is being drawn by the UNGA and FAO to address this gap in the governance regime.[23] The UNGA Resolutions also express support for the FAO initiatives in developing technical guidelines in this area.[24]

The IPOA-IUU and its related technical guidelines are a manager's essential guidebooks on MCS. They present a wide range of MCS options including legal options to tackle the IUU fishing problem and are indispensable tools to the manager in fulfilling their MCS mandate.

5.4.7 Port States measures

The implementation of Flag State duties to prevent, deter and eliminate IUU fishing in areas beyond national jurisdiction has proven to be insufficient. The failure of Flag States to effectively control the fishing operations of vessels flying their flags has been at the core of this problem. The use of Port State Measures (PSM) to complement other means to fight IUU fishing is becoming increasingly crucial. PSM are considered effective weapons against IUU fishing due to the fact that ports lie wholly within a state's territory and general international law recognises that a state has wide discretion over what happens in its ports. PSM may include denial of access to ports or use of port facilities, refusal of permission to land or tranship catch and inspections to ensure that catches have been taken in accordance with applicable conservation and management measures. States are implementing such schemes largely as members of RFMOs but some jurisdictions (e.g. the EC) have introduced elaborate PSM. The most effective schemes to date belong to RFMOs namely CCAMLR, ICCAT, NAFO and

[23] See UNGA Resolution 59/25.

[24] UNGA Resolution 61/105. In August 2008, the FAO Technical Consultation on International Guidelines for the Management of Deep-Sea Fisheries in the High Seas adopted the International Guidelines for the Management of Deep-sea Fisheries in the High Seas. See FAO, 2008.

[25] See FAO (2001) for an overview of regional and sub-regional MCS and enforcement schemes.

[26] See North East Atlantic Fisheries Commission (2007), Recent results in combating IUU fishing based on the Scheme on http://www.illegal-fishing.org/

NEAFC.[25] The application of the enhanced NEAFC PSM scheme has already achieved practical results.[26]

The non-universal application of PSM helps create the problem of 'ports of convenience' where vessels seek and use ports in states that are unable or unwilling to take adequate enforcement action within their own ports to support conservation and management measures.[27] To help address this problem, FAO has adopted the Model Scheme on Port State Measures to Combat Illegal, Unreported and Unregulated Fishing (Model Scheme) to encourage and assist states in developing their PSM regime. The Model Scheme draws on the principle of international law concerning sovereignty of Port States over their ports reflected in the LOS Convention and as expanded in the UN Fish Stocks Agreement, the FAO Code of Conduct and the IPOA-IUU. The Model Scheme has proven to be a useful guide for developing PSM, although as a voluntary instrument, it cannot oblige the participation of a critical mass of states in order to prevent, *inter alia*, the 'ports of convenience' phenomenon. In recognising this problem, an initiative of states voiced at the UNGA recently called on states to implement the Model Scheme and to adopt under the auspices of FAO a binding instrument on PSM.[28] The COFI has agreed on a process[29] that is implemented by the FAO Secretariat to develop and adopt such binding instrument.

The implementation of nationally and internationally agreed PSM, including those of a RFMO, needs to be authorised by enabling legislation. It is worth noting that the management and control of ports is likely to fall within the purview of another state authority – usually the government ministry or agency responsible for transport or ports. With this in mind, the fisheries manager will need to work closely with the maritime or port authority in implementing fisheries PSM.

5.5 Significant issues and their legal aspects

5.5.1 Sustainable development

Since the Rio United Nations Conference on Environment and Development (UNCED), there has been a marked increase in the effort by states to reflect the paradigm shift from facilitating intensive production to assuring the sustainable utilisation of natural resources and sustainable development.

This trend is also evident in fisheries legislation as observed in the gradual move away from focusing on optimum utilisation to responsible fishing. Whereas in the past the statement of purpose in fisheries legislation might have referred to allocation of a quota levy or the development of a fishery, in recent times, the inclusion of a statement of principles and policy relating to sustainable utilisation and responsible fisheries is *en vogue*. The Marine Resources Act of Namibia, for example, has as its purpose to 'provide for the conservation of the marine ecosystem and the responsible utilisation, conservation, protection and promotion of marine resources on a sustainable basis; for that purpose to provide for the exercise of control over marine resources; and to provide for matters connected therewith'. The South

[27] Molenaar E.J. (2007).
[28] UN (2005), UNGA Resolution 60/31.
[29] FAO (2007a) at page 11.

Africa Marine Living Resources Act of 1998 has a similar provision as does Nauru, New Zealand and Papua New Guinea.

The part of this chapter on the legislated management principles and guidelines and the way the states named in the paragraph above have legislated the paradigm shift from optimum utilisation to responsible fishing demonstrate the manner by which states are attempting to translate, in a more transparent way, the concept of sustainable development into law. Although it is important to see how these principles are elaborated in the operational aspects of the fisheries legal framework in order to benefit from enforceability, the significance of the general 'guiding principles' cannot be underestimated for they indicate the intent of the legislature to ensure that the management process must, where possible, achieve sustainable development goals.

5.5.2 EAF and the precautionary approach

The EAF (see also Section 1.2), according to FAO 2003, 'is, in effect, a way to implement sustainable development in a fisheries context' by building on current fisheries management practices and explicitly recognising the interdependence between human well-being and ecosystem well-being.[30] Seen from this angle, the efforts to implement sustainable development in fisheries law as discussed before will also address EAF.

International binding and voluntary fisheries instruments are more progressive in the area of facilitating EAF in specific terms. The LOS Convention reflects foresight in espousing certain aspects of EAF through its provisions on the conservation of living resources in the EEZ (Articles 61.3 and 61.4); stocks occurring within the EEZ of two or more coastal states or both within the EEZ and in an area beyond and adjacent to it (Article 63); conservation of the living resources of the high seas (Article 119); and the relevant provisions of Part XII on Protection and Preservation of the Marine Environment (Articles 192 and 193).

The UN Fish Stocks Agreement expanded the EAF-related provisions of the LOS Convention further in relation to straddling and highly migratory fish stocks (Article 5 – General principles and Annex 1, Article 6 – Application of the precautionary approach and Annex II, Article 7 – Compatibility of conservation and management measures) and, in as far as its provisions are adopted and applied by states at their own volition, in relation to these stocks in areas under national jurisdiction (Article 3 – Application).

The major non-fisheries binding instrument that helped institutionalise EAF is the CBD. The CBD facilitates EAF through its core principles of multiple-use management of biodiversity emphasising the conservation of biodiversity, the sustainable use of its components and the fair and equitable sharing of benefits.

It is the voluntary fisheries and non-binding instruments, however, that deal with EAF in elaborate terms to bring it to the fore in fisheries. Chief among them is the FAO Code of Conduct which is widely recognised as the most complete operational reference for fisheries management with many of its provisions which, when considered together, raise issues of concern, principles and guidelines for developing and applying EAF.

However, states have not been too far behind in elaborating aspects of EAF in national legislation and may have paved the path for EAF development in the international sphere. National legislation now calls for the effects of fishing on non-target or associated species or

[30] FAO (2003) at page 11.

the aquatic environment to be considered in determining the types and extent of management measures that should apply in a fishery. Legislation that demonstrates this trend can be found in New Zealand and South Africa. Laws of other jurisdictions may not necessarily refer to environmental protection, as in New Zealand, or allow for environmental impact assessments, as in South Africa. Nevertheless, other management actions required under fisheries laws may have the effect of protecting the environment. Sustainable use of the fish stocks and the protection of the environment are now key elements in the relatively recent legislation and institutions of Albania, Hungary, Lithuania and Romania.

In addition to the above references of 'best practice' in national legislation, the following excerpt from the Ecosystem Approach to Fisheries Technical Guidelines concerning management measures and approach is highly relevant in guiding the possible way in which fisheries legislation should facilitate EAF at the operational level:

> The measures available to managers to adopt an EAF will, at least in the short term, be an extension of those conventionally used in [target resource-orientated management]. Thus the range of input and output controls and technical measures (including spatial measures) used to regulate fishing mortality remain highly relevant; but these controls will need to be considered in a broader context. This means recognising that the range of measures chosen should not only address a series of target species concerns, but should also enhance ecosystem health and integrity. Managers should consider as far as possible a coherent mix of approaches that takes account of the interdependencies and functioning of the ecosystem.[31]

Thus, fisheries legislation which ordinarily states the range of management approaches and measures should, at the very least, empower, or not create obstacles for, the manager to make choices as well as facilitating a possible mix of coherent approaches. The section on fisheries management approaches and tools already notes that a majority of fishing nations' fisheries laws avail the manager with a broad range of fisheries management approaches and measures but leaves it to the manager to determine which management approach or measure or combinations thereof will best achieve the management objectives of a fishery. The section then describes how fisheries law facilitates specific management approaches, measures and processes including those identified by the Ecosystem Technical Guidelines which, if also used to address ecosystem concerns, will institutionalise and support EAF.

A related feature of EAF is the precautionary approach or principle. The precautionary approach is advised when 'ecosystem resilience and human impact (including reversibility) are difficult to forecast and hard to distinguish from natural changes'.[32]

The manner of implementation of sustainable development and EAF in legislation is evidently similar to the implementation of the precautionary approach. It will be noted that legislation of many countries stipulates the precautionary approach together with other EAF components, although the precautionary approach is stated as a distinguishable concept operating in tandem with other conservation and management concepts. An early incorporation of the precautionary approach and related principles that demonstrate this style is found in section 3 of the Australian Fisheries Management Act of 1991.[33]

---

[31] *ibid* at page 29.

[32] *ibid* at page 85.

[33] See Edeson W., Freestone D. and Gudmunsdottir E. (2003).

The increasing reference in national legislation to the precautionary approach is viewed as an effort by states to give effect to international instruments, particularly Principle 15 of the Rio Declaration, the UN Fish Stocks Agreement and the FAO Code of Conduct. Even if the precautionary approach is only mentioned in a preamble provision or a broad policy statement and may at best be used only as an aid to interpretation, its significance should not be underestimated, for it 'represents a major change in the traditional approach of fisheries management, which until recently has tended to react to management problems only after they reached crisis levels'.[34]

5.5.3 Deep-sea fisheries

UNGA Resolution 59/25 expressed the global concern for deep-sea fisheries in areas beyond national jurisdiction. The resolution called on states to take urgent action and consider interim prohibition of destructive fishing practices that adversely impact on vulnerable marine ecosystems (VMEs), including seamounts, hydrothermal vents and cold water corals located beyond national jurisdiction, until conservation and management measures are adopted in accordance with international law. The resolution supported RFMOs or arrangements with the competence in regulating bottom fisheries by adopting appropriate conservation and management measures and ensuring compliance. The resolution called for RFMOs or arrangements without the appropriate competence to expand their competence in this regard and for states to urgently cooperate in the establishment of new RFMOs or arrangements with competence to regulate bottom fisheries and the impacts of fishing on VMEs in areas where no such relevant organisation or arrangement exists.

UNGA Resolution 61/105 following up on UNGA Resolution 59/25 recalled the need for closing the governance gap in order to regulate fishing practices that adversely impact on VMEs, including seamounts, hydrothermal vents and cold water corals located beyond national jurisdiction, and commended FAO's efforts in developing guidelines for the conservation and management of deep-sea fisheries and VMEs. Such guidelines would contribute to better conservation and management in deep-sea fisheries.

States are expected to translate these global resolutions into policies and legislation, including through RFMOs and other regional arrangements, in much the same way the driftnet fishing and other past fisheries-related resolutions have been implemented. The implementation by enactment of national enabling legislation for the Compliance Agreement and the UN Fish Stocks Agreement which require Flag States to exercise effective control over their vessels including through authorisation of high seas fishing could also serve to address activities by their vessels involved in deep-sea fisheries.

5.6 Law review and the manager

The optimal state for the primary fisheries legislation is that it provides for a full range of management powers, functions and responsibilities, is clear, not inconsistent or in conflict with other laws and is not subject to frequent changes.[35] It is also an important part of the FMA task to ensure that the regulatory framework is developed or revised to reflect the current fisheries

[34] Freestone and Hey (1996) pp. 249–268.
[35] FAO (1997a) at page 62.

management policy. In this regard, the FMA is required to continually monitor and evaluate the national fisheries policies and strategies, regulations and management measures including the performance of the FMA in implementing these to determine their suit-ability and cost effectiveness. Such monitoring and review may result in shifting emphasis in management action and re-prioritising, and obviously, the management authority can only do so much within the limits of its resources. When the shifting of emphasis and re-prioritising are clearly inadequate options because the fisheries law which should provide the necessary legal support fails to do so due to obsolete or unenforceable provisions, then the fisheries law should be revised and strengthened so as not to undermine the overall legal regime and the level of compliance.

Law review is an involved process. It involves analysing the substance of the law, assessing its operation, evaluating the importance of legal change and finding an appropriate solution. That law reform is a matter for lawyers and law institutions is an erroneous view. Ensuring that law reform and development result in effective law is not a matter of finding technical solutions but requires the full involvement of stakeholders – government and non-government institutions, communities, resource-dependent people and the private sector.[36] Broad participation in law reform not only improves the quality of the law, but also creates legitimacy, stimulates organised support and removes indifference or passive resistance thereby improving implementation.[37] Participation publicises legislation among those directly affected by it and those expected to enforce it.

Managers are instrumental in the review effort as they report on the areas where the fisheries legal framework has been inadequate in supporting management action. The manager and the management authority staff also provide technical advice to the review process. In an effective legislative review, the manager and other technical persons are part of the review team providing advice to the lawyer and draftsman as and when needed so that the latter is well instructed to undertake the complex work of legislative drafting. As widespread consultation with interested parties is important during the process, the manager plays a vital role in coordinating effective stakeholder consultation.

The ongoing concerns regarding IUU fishing and the search for better options to enhance compliance and enforcement, the dynamism in the fisheries sector to improve fisheries management through approaches to management, such as participatory and rights-based management, and the need to address emerging issues, from sustainable development to the precautionary and ecosystem approaches to fisheries, will continue to provide inspiration for future review of fisheries legal frameworks.

5.7 Synthesis and outlook

The body of law governing fisheries, ranging from international fisheries instruments to national laws, is an intrinsic part of modern fisheries management. Fisheries policy and the management regime that implements it can only matter in a legal sense if they are expressed in legislation so that the rights, duties, relationships, the general terms and conditions under which fisheries is managed and the means to regulate and resolve conflict can be enforced. Managers are therefore compelled to develop a degree of awareness of the law, particularly those areas that relate to their powers, duties and functions.

[36] Kuemlangan (2006) at page 55.
[37] FAO (2002) at page 13.

The manager should note that where actions have the potential of impacting on persons in a substantive way, such as in enforcement action, the law will be precise on the extent of the management authority's powers. Limits laid down in the law should be respected.

The majority of national fisheries legislation provides a basic legal framework to support fisheries management process and measures, but the emergence of new concepts, approaches and techniques is slowly stretching the relevance of current fisheries legislation to its limits, particularly legislation enacted prior to the advent of the LOS Convention. On the one hand, issues such as rights-based management, co-management and other forms of participatory management and the use of VMS as an MCS tool have acquired a level of maturity (in terms of discussion of their implications) for facilitation by the legal framework. On the other hand, issues such as EAF and the precautionary approach continue to warrant exploration of ways to give them practical effect and for law to step in to facilitate them. It is evident, however, that many jurisdictions are attempting to give them some legal form or to utilise existing processes and measures to give the concepts practical application. These trials should be observed closely and the lessons that arise from them put to good use.

The sovereign right of states to use PSM to ensure compliance with international standards has been underutilised. The global focus on PSM in complementing conventional approaches to alleviate the inadequacies of Flag State Control and assuring compliance with applicable conservation and management measures in areas beyond national jurisdiction warrants global support. The manager should ensure that policy makers are informed of developments and practice in this area.

The management of deep-sea fisheries and VMEs and the protection of the marine environment beyond areas of national jurisdiction in general in addition to PSM will be the subject of global attention for the coming years. It is safe to hazard a guess that from all this will come more international instruments both binding and non-binding to add to the international legal and normative framework governing fisheries. States will then be expected to give effect to these instruments in areas and to persons under their jurisdiction.

The aforementioned management issues and their legal aspects in the context of IUU fishing will continue to define and guide the roles and responsibilities of the fisheries manager. With this in mind, the potency of the fisheries manager lies in effectively combining options under fisheries laws to achieve management objectives while providing practical guidance in developing relevant and forward-looking legal frameworks.

Sources and recommended reading

Cacaud, P. 1999. *Legal Issues Relating to Vessel Monitoring Systems*. Report of a Regional Workshop on Fisheries Monitoring, Control and Surveillance, Kuala Lumpur and Kuala Terenganu, Malaysia, 29 June–3 July 1998. Suppl. 2, GCP/INT/648/NOR, FAO.

Cacaud, P., Kuruc, M. and Spreij, M. 2003. *Administrative Sanctions in Fisheries Law*, FAO Legislative Study 82.

Edeson, W., Freestone, D. and Gudmunsdottir, E. 2001. *Legislating for Sustainable Fisheries: A Guide to Implementing the 1993 FAO Compliance Agreement and the 1995 UN Fish Stocks Agreement*, The World Bank Law Justice and Development Series, Washington, D.C.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome, FAO. 41p.

FAO. 1997a. *FAO Technical Guidelines for Responsible Fisheries Management No. 4*. Rome, 82 p.

FAO. 1997b. Organization of Eastern Caribbean States, Discussion Document, Draft High Seas Fishing Bill. GCP/INT/606/NOR, Fisheries Management and Law Advisory Programme (FIMLAP).

FAO. 2001. Related Legal and Institutional Issues National, Subregional or Regional Perspectives, Legislative Study No. 71.

FAO. 2002. Law and Sustainable Development Since Rio – Legal Trends in Agriculture and Natural Resources Management, Legislative Study No. 73.

FAO. 2003. *FAO Technical Guidelines for Responsible Fisheries, Fisheries Management, No. 4, Suppl. 2, The Ecosystem Approach to Fisheries*. Rome, 112p.

FAO. 2004. Legislating for property rights in fisheries, FAO Legislative Study No. 83.

FAO. 2007a. Report of the twenty-seventh session of the Committee on Fisheries. Rome, 5–9 March 2007. FAO Fisheries Report No. 830. Rome, FAO. 74p.

FAO. 2007b. Report of the FAO/FFA Regional Workshop to Promote the Full and Effective Implementation of Port State Measures to Combat Illegal, Unreported and Unregulated Fishing. Nadi, Fiji, 28 August–1 September 2006. FAO Fisheries Report No. 810. Rome, FAO. 198p.

FAO. 2008. Report of the Technical Consultation on International Guidelines for the Management of Deep-Sea Fisheries in the High Seas, Rome 4–8 February and 25–29 August 2008. FAO Fisheries and Aquaculture Report No. 881, Rome, FAO. 42p.

Flewwelling, P. Cullinan, C. Balton, D. Sautter, R.P. and Reynolds, J.E. 2002. Recent trends in monitoring, control and surveillance systems for capture fisheries. FAO Fisheries Technical Paper No. 415. Rome, FAO. 200p.

Freestone, D. and Hey, E. 1996. Implementing the precautionary principle: challenges and opportunities. In: *The Precautionary Principle and International Law: The Challenge of Implementation*. Freestone, D. and Hey, E. (eds). Kluwer Law International, The Hague.

High Seas Task Force. 2006. *Closing the Net: Stopping Illegal Fishing on the High Seas*. Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN and the Earth Institute at Columbia University.

Kuemlangan, B. 2000. National legislative options to combat IUU fishing. In: *Report and Papers Presented at the Expert Consultation on Illegal Unreported and Unregulated Fishing*. Sydney, 15–19 May. FAO Fisheries Report No. 666.

Kuemlangan, B. 2006. Law reform and development for nation-building in the Pacific. In: *Pacific Futures*. Powles, M. (ed.). pp. 53–60. Pan McMillan, London.

Macfadyen, G., Cacaud, P. and Kuemlangan, B. 2005. Policy and legislative frameworks for co-management. *Paper prepared for the APFIC Regional Workshop on Mainstreaming Fisheries Co-management in Asia Pacific*. Siam Reap, Cambodia, 9–12 August. FAO/FishCode Review No. 17. Rome, FAO. 51p.

Molenaar, E.J. 2007. Port state jurisdiction: Toward comprehensive, mandatory and global coverage, *Ocean Development and International Law*, 38: 1, 225–257.

Pomeroy, R.S. and Berkes, F. 1997. Two to tango: The role of government in fisheries co-management. *Marine Policy*, 5(21): 465–480.

Swan, J. 2000. Regional fishery bodies and governance: issues, actions and future directions. FAO Fisheries Circular No. 959. Rome, FAO. 46p.

Swan, J. 2004a. *Decision-making in regional fishery bodies or arrangements: The evolving role of RFBs and international agreement on decision-making processes*. FAO Fisheries Circular No. 995. Rome, FAO. 82p.

Swan, J. 2004b. *International action and responses by regional fishery bodies or arrangements to prevent, deter and eliminate illegal, unreported and unregulated fishing*. FAO Fisheries Circular No. 996. Rome, FAO. 64p.

Web resources

FAOLEX – (Computerised Legislative database of national legislation and international agreements concerning food and agriculture including fisheries, forestry and water). http://faolex.fao.org/faolex/index.htm

FAO. 2007. Essential References on Port State Measures. ftp://ftp.fao.org/FI/DOCUMENT/tc-psm/port_state_biblio.pdf

Illegal Fishing Information. http://www.illegal-fishing.info/

Port-Lex – FAO Computerised Database on Port State Measures. http://www.fao.org/fishery/psm

Chapter 6

The Fishery Management Institutions

François Feral

6.1 Introduction

The objective of this chapter is to provide fishery managers with some understanding of the institutions involved in fishery policy making and management with particular emphasis on the linkages with the supporting legal framework within which the respective roles and responsibilities of the different actors are established. The chapter will often distinguish the management of the whole sector from that of individual fisheries which, while necessarily nested, may require different considerations.

Fishery management is institutionally complex. It is concerned with the selection, on the basis of scientific advice, of the fishing strategy most appropriate to meet policy objectives. Its main difficulties, however, come from the regulation of human behaviour, negotiation between diverging interests. As stated in Chapter 5, the rules applicable to fishing are usually established by the administrative authorities of the State or delegated by it. However, other rules set up by other administrative sectors for regulation of the civil society in general and not necessarily inspired by the principles of responsible fishing may also play an important role and, together with the rules specific to fisheries, form the body of law referred to as fisheries law. The set of rules and organizational structures governing the fishing sector primarily aim to facilitate the core functions of the sector, for example control, production, servicing, decisions, checks and balances; and ensure representation of interests groups, for example fishers, shipowners, communities, wholesale traders, territorial collectivities, conservationists, and control and police administrations. They constitute the complex fishery institutional system within which fishery managers and the sector must operate. Their complexity has emerged from *ad hoc* solutions to successive crises and affects management decisions and their outcomes.

Fisheries management cannot be separated from public policies and administrations which are its organic and functional framework. The FAO Code of Conduct (FAO, 1995) calls on States to adopt measures for conservation and sustainable use of fishery resources *through an appropriate policy, legal and institutional framework* (Article 7). Public policies are the responses needed for improved public action. They are also a way of approaching a problem according to a political rationality and society options which lead to social, political and economic transformation (Ricker and Ordeshook, 1973; Mény and Thoënig, 1989).

Nor can responsible fisheries management be separated from sustainable fishery development. The trend noted in Chapters 5 and 17 from industrial fisheries development to the sustainable and responsible use of fishery resources was inspired by the corresponding shift in general

public policies. The effects are felt not only in fisheries but also in other economic sectors with which fisheries are in competition and bring their share of overriding and contradictory objectives and constraints.[1] In addition, the use of fishery resources falls under the national legal systems regarding public property, labour laws and environmental protection, the ideological concepts of which might be quite far apart from the bio-economic principles of fisheries.

The FAO Code of Conduct underlines the need for States to provide an effective legal and administrative framework. In most countries the sector is administered through (1) a system of public organization that formally structures the sector and the relations with the actors of civil society; and (2) a system of public action that intends to control the sector, its dynamism and performance. This system can be seen through fishery laws, that is the set of legal regimes applicable to assets, persons and activities involved in fishery policies (Chevallier and Loschak, 1978). The fisheries administration is generally complex, heterogeneous, bureaucratic and (still often) centralized and sometimes overdeveloped (Féral, 2002). Nonetheless, it has continuously evolved, changing methods of control, means of intervention, processes and structures.

This chapter should be read in conjunction with Chapter 5. Section 6.2 will present the institutional environment within which the manager operates, with its diverse legal regimes and systems of rights, reviewing the actors' duties and responsibilities and the implications for management. Section 6.3 focuses on the complexity of the institutional system underpinning the fishery management function and reviews key aspects of the decision process.

6.2 The manager in the institutional environment

The organization and implementation of fishery policies is a State responsibility to be fulfilled within the international policy, institutional and legal framework. The State remains the true entity responsible for fisheries in the areas under its jurisdiction. However, this formal responsibility is not sufficient to define concretely who is in charge of public fisheries policies and management. The prime difficulty in implementing this responsibility comes from (1) the large range of modalities to fulfil this responsibility and (2) the complexity of the administrative organization in a mutating sector, facing repeated crises. Numerous and sophisticated legal formulas exist for delegation of the management action to public or private institutions or to the fishing operators. This delegation may even be implicit and so does not always help clarify responsibilities. Nevertheless, an institutional framework is usually in place that the manager needs to decipher in order to operate efficiently. The fishery manager, however, is himself or herself a part of the institutional fishery system and as such must find his or her own place within the institutional environment.

6.2.1 The diversity of fishery managers' legal regimes

Depending on the country, the fishery manager, whether as the natural person or other legal entity invested by the State with the responsibility for fisheries management, will find

[1] Poverty alleviation, coastal development, tourism, protection of nature, commercial and port infrastructures, health-care policies, application of labour law, etc. may sometimes be higher priority folders within highly constrained budgetary policies.

different legal and institutional situations dependent on the State's principles and practices and on the legal system shaped by jurisprudence, history and traditions. Chapter 5 describes the web of laws in form and substance that comprise the fisheries legal regime which in turn influences the fisheries management institutional structure. Some of the sources of fisheries law or aspects of the legal environment that influence the institutional framework are (1) the fishery-specific laws adopted by the designated State authorities complemented by non-fishery-specific laws of relevance to the sector, that are enacted to implement general public policy objectives, for example in public property, labour law, environmental protection, town planning, tourism; (2) the general rules of interest groups (e.g. fishing partners) that govern internal and inter-group relations.

The different models for monitoring and regulating fisheries are the outcome of many years of negotiations and institutional adaptation to changes in resource exploitation. The traditional economic organization of the enterprises involved, the nature of the resources and the environment, the acquired rights, the history of the fisheries, the evolution of the markets, etc., have all influenced the content of the legal framework and can explain the observed differences in management systems. Three regimes can be distinguished: (1) free access and economic liberty; (2) State control through public administration; and (3) delegation of control to given actors or institutions. Most often, the system used to manage the sector or its fisheries is a combination of the three.

The regime of free access and economic liberty

The principle of freedom of access to marine areas and fishery resources has played a decisive role in the formation of pressure groups, the management of use rights and the acquisition of knowledge about the ocean. It was grounded on Western liberalism, that is upon the tradition according to which nature belongs to no one and everyone may enjoy its resources.[2] In practice, since the UN Law of the Sea (LOS) Convention, we have witnessed the decline in the freedom of fishing, including outside of the jurisdiction of individual States. States can still defend their citizens' right to fish on high seas but only on the condition that they exert the control foreseen in the framework of relevant international conventions. In any case, what is now provided by fishing laws and institutions is a conditional freedom.

The freedom of access to the sea has been recognized since the 17th century in international legal tradition. Within this concept, ocean spaces and all structures dependent on it were considered common resources (*res communis*).[3] This means that when there were no other rules or regulations on use and access, these spaces were, as a rule, under the legal regime of freedom. The freedom to navigate, catch fish, use, and occupy ocean space, was then recognized for anyone. However, this use of ocean resources did not constitute any real right, that is a right opposable to a third party. Today, this situation of freedom is exceptional because numerous management and policing rules have been adopted by the States. But on high seas, freedom still constitutes the basic principle upon which the manager must build the rules for the management of the right to fish (Russ and Zeller, 2003).

[2] The 1958 UN Convention on Fishing and Conservation of the Living Resources of the High Seas recognized the freedom to fish just after the liberty to navigate. The Montego Bay convention maintained this principle in its Article 87 but made it considerably more subtle (United Nation, 1983; Levy, 1980).

[3] *res communis* is a Latin Roman legal notion meaning global common property of the resources.

Another principle of law that must also be taken into consideration in most countries is the economic freedom granted to persons. The freedom to trade and carry on business implies that individuals and legal persons have 'the right to practice the economic activity of their choice, in any way they choose and to set up business wherever they see fit' (Dreyfus, 1976). Naturally, this right is regulated but it is still considered fundamental and has been reinforced by the international conventions on trade (e.g. the World Trade Organization or the European Union's economic principles) as well as the constitutional rights in the United States. In order to limit the exercise of such fundamental individual economic right, the manager will have to provide proof that the restrictive measures are necessary, proportional and enacted in order to fulfil legitimate objectives (Ruiz Garcia, 2000).

The regime of public administration

The principles of economic liberty and freedom of access create difficulties for sustainable development and responsible fisheries management. The establishment of Exclusive Economic Zones has transferred the responsibility of implementing these principles to the coastal States by recognizing the national character of their resources in a process sometimes seen as a privatization by the State (Beurier, 2006/07: Chapter 114; Charles, 2000). The State can therefore legitimately exclude or limit access of the fishing vessels from other countries. It has also the power to supervise the exercise of freedom by its own users and to intervene in the development of the resources. The most usual approach to fishery management today is for a State to entrust public administrations with the mandate to manage the spaces and the resources through unilateral measures of administrative policing or measures authorizing or prohibiting access. This is why fishing is referred to as an administered activity and a regulated profession. Within this system, the management of the individual fisheries and the general fishery policies are inextricably interlinked, giving rise to significant difficulties in decision-making.

In order to define, implement and enforce fishing policies, governments designate a political authority to deal with the fishing sector, for example, most often a minister or Secretary of State (e.g. of Agriculture, Commerce, or Transport) who becomes the political and administrative authority with executive power to define and implement the fishing policies. In the State's name, this authority fulfils the necessary functions of: (1) representation of the government within the fishing sector and with other States; (2) development of the legal norms applicable to the sector (e.g. laws, rules, regulations and directives); and (3) management of the administrative services in charge of the supervision of the social and economic activities of the fishing sector.

However, very often, different political organs are put in charge of certain aspects related to fishing, within other missions. The fishery policy may therefore depend on several ministerial departments which share a number of functions related to the administrative supervision of: (1) certain activities which can affect fishing as an economic activity, for example market control, shipyards, transport, the legal and fiscal regimes of the country, the social maritime regime, quality control of fishery products, navigation control, and port control; and (2) certain assets of relevance to the fishing sector such as: statutes of the ship or of marine territories; regulation of the equipment needed for production and trade, etc.

Under these conditions, a coordinating organ may often be set up for decision-making (inter-ministerial committee or council). The authority in charge of fisheries, therefore,

finds itself dependent on a coordinating institution which *de facto* exercises the function of governmental decision-making in the fishery domain. Within most developed countries, administrative traditions result in the fishing sector falling under the competence of several types of administrations such as: a military maritime administration constituted in order to organize and control navigation for which the 'fishing police' aspects are therefore often dominant; the central administration of agriculture which, by analogy with its central responsibility, will be better at tackling economic aspects of fisheries; a specialized administration such as the Fishery Ministry or the Ministry of the Sea in which case the resource and industry issues may be adequately dealt with; and a fragmented system with different types of administration sharing the various competences.

The scientific administration of fisheries was established during the fishing industrialization period, when States created public scientific structures in charge of gathering scientific information on fishery resources. The purpose was to promote the use of these resources through diffusion of industrial production techniques, in conformity with the 'productivist' model of agriculture. Nowadays, these scientific structures are required to conceive and monitor the application of fisheries management and conservation in conformity with the guidelines of the International Community such as the FAO Technical Guidelines for responsible fisheries. In many cases, scientific administrations enjoy a legal status with a certain degree of autonomy. Their creation was encouraged at an international level in order to constitute a network of expertise and establish an objective knowledge base for fishery management, and they are the main scientific instruments assisting the State in decision-making.

The regime of delegated administration

Under this third management model, the State may decentralize its administration or delegate the administrative functions to the private sector.

Territorial de-concentration of the administration is the instrument for spatial redeployment of the central State. Delegated civil servants represent the central administrations on several levels of decentralized territorial circumscriptions. Most often, these levels correspond to the country's general administration levels, for example regions, municipalities or districts, and rarely coincide with the territories that would be most relevant for fisheries management. *A contrario* port circumscription can be pertinent to the identification of the group that might be responsible for a particular fishery. The administrative actors responsible for these circumscriptions are put in charge of certain hierarchical tasks which are defined within the State or government-controlled bureaucracy, for example authorizations to practice the profession, control of the investments and equipment, administrative policing of fishing operations, maintenance of a record of fishermen and sailors, security and safety control, registration of ships and their movements, control of landings; and resource assessments. The fragmentation of fishery functions between several ministries at the central level mentioned earlier can repeat itself at local level in such a manner that the users must work with several administrative interlocutors. As a result, the functions related to the policing of the production process, the status of ships or persons, the economic intervention, or the product quality control may fail to be integrated.

The creation of specialized structures depending directly on the State is the instrument for technical redeployment of the central State. These structures may fulfil administrative functions on its behalf. In this case, the representation of the State is either sectoral or subsectoral. The intermediate organs created by the State, and therefore institutionalized in the

same manner as the delegated administrations, may include: a local fishery research centre; an *ad hoc* establishment for a port management; a fishery school; a centre for maritime safety; and an administrative centre for extension work, for example on fishing techniques.

The delegation of power to private or public persons put in charge by the State of certain technical missions leads to public service delegations or public market holders, for example: a chamber of commerce can be in charge of building and managing a fish auction house; a bank may be subsidized to grant loans and promote maritime investments; a university can be in charge of setting up a fishery resources observatory; an NGO can be put in charge of training fishermen's wives in business management techniques; and an international organization (e.g. FAO) can be in charge of providing technical assistance within a specific program.

6.2.2 The allocation of rights

The right to exploit the common property fishery resources is allotted to the State which is expected to administer them on behalf and in the interest of the communities they represent (custodial powers), preserving the collective property in a satisfactory condition for future generations. This legal reality and the societal expectations influence the types of rights that a fishery manager can grant on spaces and resources and the design of the mechanisms available for such allocation (see Chapter 10).

The limits of rights

Ocean waters and fishery resources are considered public (*res communis*) and their use is part of public rights. As a matter of principle, the fishery resources belong to whoever catches them. The prime holder of harvesting rights is the generic user of the sea and of the related public properties, and the State exercises its rights on his/her behalf in order to ensure public order. The harvesting act, even repeated for a long time, is not acquisitive (does not create a real right) because, most of the time, the ocean space is imprescriptible. The individual right to use the sea can therefore be described as the right to draw from it all the utility it can provide as long as this does not interfere with public use.

The right to use and manage these resources was extended in an exclusive economic zone, managed by coastal States under the 1982 Law of the Sea Convention (LOSC). However, when exerting their sovereign rights, for example when elaborating their fishery policies, States cannot totally ignore these general user's rights. The fishery manager's main difficulty will, therefore, be to enact a number of occupational rules, in accordance with the principle of *res communis*, while preserving the resource. The notion of sustainability equally authorizes making the most profitable use of the resources, as long as their renewal capacity is maintained for future generations. Managers have at their disposal a number of instruments and measures allowing for resources management and control of the exploitation (see for instance Chapters 5, 7 to 11, 14, and 16). Their managerial powers are indeed stronger than in any other economic sector as the State retains the monopoly of fishery resources allocation and numerous opportunities to limit control and audit the fishing enterprises.

In many developing countries, access to the fishing profession is free and even not yet legally defined. By contrast, in many countries, there is a statute of seafarers and more specifically a statute for fishermen. The fisherman is first and foremost a sailor and this

differentiates him from the ship-owner who owns the ship and its equipment. This statute can be described as the legal and administrative regime applicable to the physical natural person actually exercising the profession of fisherman. In all, the status of fisherman confers a privileged right of access to the resource defined by the right to use certain equipment for the harvest, including ships, and specific gear. For the fishery manager, the status and the classification of fishing activities constitutes a means of regulation, used to influence the conditions of access and harvesting, for the implementation of fishery policies.

As mentioned in the first paragraph of this section, the freedom of access to aquatic resources has created *de facto* an occupation of many fishery areas and a monopolization of the resources but no 'real right'. However, privileged rights to use a fishery space or resource may be accorded by the State to a group or an individual, in contradiction with the *res communis* rule, for the following purposes: (1) to validate a precedent traditional and collective occupation; (2) to promote sustainable use (cf. Hardin, 1968; Troadec, 1981); or (3) to reduce the precariousness of fishing investments by improving the legal security to the enterprise providing operators with a guarantee acceptable by banks.

The State cannot, however, concede more rights than it actually has and it is difficult for it to transmit real ocean-property rights to private operators. Nevertheless, allowing fishing under certain conditions can be a factor of sustainability. The right to fish granted by a State is closer to a personal than to a patrimonial or real right[4] in the sense that the beneficiaries are included in an administrative system which confers a personal status on them under certain conditions. These rights disappear when the measure is abrogated or when the people no longer fulfil the initial requirements. Therefore, fishing rights can only be recognized within a process of administrative legality by becoming an integral part of a management model. Such rights may easily be challenged by a third party (e.g. the general user of the sea) and may be contested.[5] Finally, it should be stressed that the transferability of these rights is a modality of their administrative status which does not confer on them the nature of real rights.

The foundations of rights

The rights recognized to private individuals to access fishery resources and spaces are based on different recognition mechanisms guaranteeing their exercise to a limited degree:

- Implicit recognition. This is the case of village communities and the families of fishermen without formal statute. As long as these groups do not enter into competition with the other users of the spaces and the resources, public authorities implement the rule of the first occupants upon a *res communis*. This is a *de facto* recognition.[6]

[4] The real rights are exercised by the holder through a thing (in the case of fisheries, the fish before capture), and the real right is given with the thing when the property of the thing is transferred. A personal right is a debt of a person among another things. The problem in fisheries is that the thing is undetermined and in common property: the fisherman has an authorization to fish, a debt among the public power, but does not really have the property of the resource before the capture.

[5] For example, 'the conflict in Iceland' by the villages' fishermen among the exclusive concession given to industrial fisheries companies.

[6] But certainly not a protection: village communities are regularly dispossessed of their spaces and resources, to the benefit of other operators (for industrial fishing, aquaculture, tourism or urban development).

- Legal recognition of personal rights, to the benefit of an individual, a company, an establishment or a group of individuals, can find its origins either within the law or the rules and regulations. The source of the right to special occupation of the fishery spaces and the right to special access is a unilateral decision of the State. This procedure creates a legal statute for privileged access to the resource.
- Contractual recognition of the rights allows the increase of the user's responsibility. Public authorities may use the convention procedure, privileging the contractual mode. Licenses, concessions, or authorizations, often subject to conditions, therefore, provide the future holders with rights founded on the acceptance of conditions formulated within the legal specifications.

The types of rights

The rights conceded to civil society institutions can be distinguished by their content, precisely determining the nature and the extent of the operator's rights and, in particular, their limits and opposability to a third party (see also Chapter 10). For example:

– Authorizations for a privileged use of the fishery spaces. Most often, the systems of license are the authorizations to use, under certain conditions, certain equipment for fishing within determined marine areas. These authorizations may equally have as their purpose the privatized occupation of a space in order to practice certain kinds of exploitation, for example for the establishment of fish farming pens or the building of fixed fishing gear such as fish pounds, set nets, traps, barriers and fish pots;
– The allotting of resources where the purpose of the concession is the capture of a certain quantity of resource*s* (quota) fixed beforehand by the administrative authorities. These administrative authorizations may often be transferred (e.g. through auctions) on the private market[7];
– The concessions of fishery management and police, whose purpose is to transfer, by convention or unilateral rule, all or part of the State's management and regulation responsibilities, into the hands of a delegated institution. The concessionaire is therefore subrogated in State rights: the concession can be accorded to a professional corporation, a community, a company, a consortium, a cooperative, or a private individual.[8]

A concession is a contract by which the State authorizes an individual to exploit, for himself or on behalf of the State, the common resources or to occupy public spaces or to undertake building work or public services on behalf of the community. The concession may be granted to, *inter alia*, a person, a group of people, a commercial or industrial company, a public or a private collectivity, a union, a cooperative, a municipality, a corporation, or a village. These

[7] This does not change the nature of the rights, the number and associated constraints of which are determined by the State which can revise them. The auctioning serves only to determine the identity of the holder (most often in exchange for a fee).

[8] The convention provides the legal foundations of the delegated authority. The delegated concessionaire exercises a dual power (of internal discipline and external police) opposable to a third party and guaranteed by the conceding State. When the delegated institution is a small-scale fishery community, this option seems to be most suited to guarantee the community's rights and ensure the internal discipline of the group (FAO, 2004).

regulatory authorizations are, today, the most widespread method used to regulate access to fishery resources and territories. These maritime activities are rarely established on private properties: a regime of administrative authorization is very often used for the installation and exploitation of fishery or fish-farming infrastructures. The license to fish is a type of concession, authorizing a limited number of people to use certain fishing gear or to harvest certain quantities of fishery resources on the basis of a unilateral administrative decision. The concession can also refer to all or part of the State's servicing or policing activities through concession for public work or delegation of public service.

Because of their characteristics, concessions offer none of the guarantees of land property. They most often rest on unilateral authorizations which are both precarious and revocable. This underscores the precarious nature of the fishery or fish farming concessions, the related investments, and the amortization and remuneration of these investments. Numerous legal developments exist in most countries to mitigate this precariousness, for example; (1) transferability of the right of access to spaces and resources that allows companies to remunerate their non-tangible right on an authorized activity; (2) compensation of the company in the case of revocation of the concession or difficulty in the exercise of their access rights; (3) the taking charge of investments, provision of subsidies, or guaranteeing of loans; (4) the reduction or suppression of taxes, in particular regarding national traditional fishing activities; and (5) the limitation of the right of access, therefore creating *de facto* a group of privileged actors.

6.2.3 Duties and responsibilities

When the FAO Code of Conduct refers to 'responsible fisheries', it evokes explicitly the concept of responsibility. However, since its adoption, there has been little progress with regard to imposing an efficient responsibility regime in fisheries. In law, the notion of responsibility establishes the obligation made to a subject of law, for example, a natural person, to repair the prejudice caused by his or her fault or as a result of his or her activity. In the context of this chapter on institutional frameworks, the focus would be on what institutional mechanisms, if any, are established to enforce an allocated responsibility or duty. Several questions arise:

Who is legally responsible for unsustainable fishing?

The FAO Code of Conduct is wide in application and calls on states, Regional Fisheries Management Organization (RFMOs) and other fishery bodies, governments and administrations and agencies, NGOs, the private sector and individuals to ensure responsible fisheries. Thus responsibility may be allocated to States, State authorities, the economic operators and the consumers, but the assignment of responsibility, and the mechanisms to enforce this, should be founded in law.

– The States are the most general recipients of the recommendations of the FAO Code of Conduct (e.g. Article 8). The Code encourages States to organize and set up appropriate policies according to explicit principles. In the international sphere, however, it would be difficult for one or several sovereign States to enforce implementation against another State unless the States concerned are parties to a binding agreement which sets out an

agreed dispute settlement mechanism. Enforcement of 'responsibility' under a voluntary instrument such as the FAO Code of Conduct, however, is not possible. The State, within its own jurisdiction, could be subjected to the duty to implement the requirements of the FAO Code of Conduct only if such requirements, and the right to challenge the State, are expressed as commitments in national legislation.

- The authorities or institutions to which fishery management authority has been delegated act on behalf of the State. They are therefore responsible due to the delegation of competence and powers they have received. In the domestic sphere, the authorities could be subject to challenge for not fulfilling the State's duty if this is stipulated in legislation.
- The economic operators identified as perpetrators of irresponsible exploitation of the fishery resources bear the responsibility. It is before the States in charge of implementing the measures for sustainability that the operators shall have to answer for such irresponsible behaviour or for their part in such behaviour. The State or authorities could also enforce responsibilities in the forum or through the process designated in law.
- Consumers may also have a responsibility as, through the act of purchase, they provide the incentive for excessive fishing. They benefit from a scarce resource and the undervaluation of such resource by the market is to their advantage.

Who are the victims?

Only persons or entities that suffer direct and real injury arising from 'unsustainable and irresponsible fishing' can lodge claims against the perpetrator of the act (or omission) that caused the injury. However, there could be problems in establishing real injury in connection with the notion of sustainability which suggests that acts that promote or are designed to achieve sustainability are for the benefit of collective groups including the world's populations and the future generations. This fuzziness is very prejudicial to any legal action, since only truly identified victims or their formal representatives may ask for reparation for present and actual damage. In the future, systems for representation of the victims could, perhaps, be institutionally recognized and would therefore be able to start legal actions. For example, environmental NGOs might be recognized to act in the interest of the public and the users or of the communities who are victims of irresponsible fishing. The process of representation would also allow the emergence of the notion of collective damage, which exists in certain countries and within different special laws.

What damage and what prejudice?

As stated in the earlier paragraph, damages only for present and actual injury can be claimed. It is difficult to evaluate the present and actual injury that the law generally considers as warranting reparation. Hypothetical and future damages are not recognized by law. Oil slicks have supplied us with examples where only the assessable prejudices of the legal persons and natural persons were recognized by international judicial fora. These were limited to restoration expenses, including some loss of sales, only with much reservation. The demonstration of a collective prejudice is therefore necessary in order to be able to take irresponsible fishing to court. By analogy, consumer and labour laws supply interesting models of collective prejudice and institutional representation (Bourgoignie, 2004).

What fact generates damage?

The general law on responsibility provides that, in order to be imputed to a person, the damage must be caused by a fault due to the risks inherent in his or her activity. For example:

- The State. assumptions can be made regarding the culpability of the State for not taking the measures necessary to ensure sustainable fisheries in accordance with Article 8 of the FAO Code of Conduct. However, in practice, establishing a detrimental fault is not an easy matter. For example, failure of a State to exercise control over the ships flying its flag, does not, for the time being, give rise to the State's automatic legal responsibility.
- A delegated authority. The delegation of fishery management responsibility to an authority to act on behalf of the State (i.e. as subrogate in the State's actions) implies that the same principles of imputation applied to States can be applied to the authority, unless the delegating State did not supply the means necessary for the exercise of such delegation.
- Other actors. The fault is easier to attribute to other actors. The measures taken by States for protection and restriction within the fishery sector define the field of responsibility of the actors, while the fault is non-compliance. But these are most often a penal responsibility, which indicates that the fault is an administrative one.

The difficulty of assessing the connection between the likely causes (e.g. the incapacity of State authorities, actors' offences and delegates' deficiencies) and their likely consequences (the observed damage) remains and is complicated by the interference of natural environmental variability, the impact of which is always very difficult to separate from human effects.

What sanction is there for the obligation of responsible fishing?

There is no international court, tribunal or other fora specifically charged with sanctioning unsustainable fishery policies or fisheries management by the State.[9] The policies can be right, but the implementation or compliance can be wrong and we have seen above that it is difficult to set up an efficient institutional framework based on legal grounds to sanction this responsibility. However, a number of mechanisms could still progressively emerge. The difficulty regarding sanctions is the most obvious at State level. But, through international frameworks, some solutions may exist at other levels:

- Fishery bodies: within the framework of fishery management organizations, international community pressure should progressively improve the degree of responsibility in fisheries. Obligations have been formulated for the States' parties to apply the agreed conservation and management measures. However, this cannot directly sanction the adoption of an inappropriate policy and only aims at 'bending' these policies in the right direction.
- Aid programs and bilateral collaboration: through these bilateral or multilateral relationships, it may be possible to contribute to a correction of policies considered to be inopportune, but only in the countries asking for assistance or collaboration.

[9] Specially, the international fisheries institutions have no legal power among their members.

- Commercial and trading agreements: through these frameworks, it is agreed that measures restricting the commercial exchange can be founded upon considerations of sustainability while remaining compatible with the World Trade Organization treaty.[10] With regard to these sanctions, we may remember the boycotting by certain trade operators from the Northern hemisphere of fishery products considered as harvested under non-ecological conditions.
- At the State internal level: One can imagine that action could be engaged against the administration for its deficiencies and its incapacity to exercise its responsibility in control, police, or poor management of the user's resources. New Zealand was sued by Greenpeace for inadequate management of the orange roughly. These actions remain very marginal or even hypothetical, even though, by analogy, similar actions already exist in Europe within health, consumer, labour and public safety law (Sousse, 1997).
- At the actors' level: We have seen above that their responsibility could be engaged on the basis of breaching measures for control or protection through fishing or trade activities. However, we can note that this repressive aspect is never accompanied by a plan for damages/compensation for the degradation caused to the environment. Nonetheless, this type of sanction is likely to be among the most effective in developing true awareness about sustainable use.

6.3 Institutional environment and decision-making

The fishery manager is part of an institutional system of relations quite different from the usual socio-economic relations of the market and he or she faces organized actors whose socio-economic situation depends on his or her administrative decisions.

6.3.1 The fishery management institutional system

Because fishery management is also concerned with the regulation of human behaviour and the satisfaction of diverging interests, it has to deal with a set of rules and organizational structures which are not necessarily inspired by the principles of responsible fishing. The mix of fishery and non-fishery rules and structures is elaborated by the community and either voluntarily accepted by individuals (self-adhesion) or imposed on them by constraint. It constitutes the fishery institutional system within which fishery managers and actors must act and which influences decisions and management interventions and their outcomes. In the following sections we will briefly look at the systemic nature of the fishery sector and at the implications for the system of institutions governing it.

The fishery 'system of systems'

The notion of management is applied in a confused manner to two different subjects, both complex, but of a radically different nature: (1) the development and implementation of fishery sector policies and (2) the bio-economic management of individual fisheries.

[10] WTO has not clearly accepted the principle of banning imports of aquatic products fished with methods considered unsustainable, but the agreement to examine the request and assess the measure means that it could be compatible with the treaty (cf. Rosiak P., 2004).

The fishery sector is a sector of global economy, divided into as many national fishing sectors as there are sovereign States. This sector is subject to public fishery policies defined and conducted by the different State members of the international communities. This sector is also subject to international public fishery policies conducted within the United Nations framework and of which the FAO is the specialized agency for fisheries. The content of these policies can vary a great deal depending on the level of development of the countries, the nature of the resource, the professional history and tradition, the nature of the markets, etc. However, the principles adopted by States are now entrenched in the FAO Code of Conduct, even if this does not automatically ensure that they are implemented. The fishery sector includes a number of very heterogeneous activities and professions only unified by the harvesting of fishery products and for which objectives are in competition and contradiction. The organized actors pressurize the public authorities to reinforce or defend their own interests (Muller and Jobert, 1987; Wilson *et al.*, 1994). National, regional or international fishing sectors can therefore be seen as different and interconnected 'fishery systems'.

A single fishery is a delimited segment of activity within the fishery sector to which specific management measures may apply, in addition to those relevant to the whole sector. The criteria used to define a single fishery can be: (1) political, for example national, regional or straddling fisheries; (2) biological, for example the bluefin tuna fishery; (3) geographical, for example the Gulf of Lions fishery in the western Mediterranean; (4) anthropological, for example the N'Guendar fishery in Senegal; (5) Socio-economic, for example industrial, artisanal, recreational, or traditional fisheries; (6) Technical, for example purse seine or trawl fisheries, gleaning; or a combination of any of these criteria, for example the artisanal bluefin tuna driftnet fishery by Caro fishermen in the Gulf of Lions. Experience shows a great sense of pragmatism in the definition of the fisheries but the political opportunity criteria are probably the most important (Bonzon, 2000). Within a public policy framework, fisheries are often defined so as to resolve political, economic or social crises and in order to justify the management interventions (McGoodwin, 1990).

The fishery sector is therefore a nested system of systems with a high degree of complexity, numerous components, a large number of interrelations, functional complexity, feedback loops, a capacity of self-evolution and innovation, a degree of unpredictability, etc. (Garcia and Charles, 2007). A systemic approach to fishery institutions is therefore necessary (Easton, 1965) in which the institutional system can be seen as a social, economic and political organization of interacting and interdependent groups, and organs, connected by doctrines, ideas, and principles, serving a common purpose[11]: the regulation of the use of fishery resources. Being part of this system, the fishery manager is very rarely in the position of a company manager with real power for directing and commanding. He or she can be better described as the principal regulating actor in the fishery sector or a specific fishery.

Institutional complexity

The legal competencies of the manager in charge of a particular fishery are much less extensive than those of the person in charge of the entire fishery sector policy. But in the bureaucratic tradition, and in many countries, the manager of the fishery sector is also the manager of the various fisheries operating in his or her area of competence. The management

[11] *Merriam Webster online dictionary*, http://www.m-w.com/dictionary

of the various fisheries is, in theory, the sole responsibility of the department in charge of the sector. Conventionally this was done in a bureaucratic and centralized manner. Nowadays, one of the tasks of the manager is to determine and establish the best possible system of delegated management responsibilities.

The fishery institutions are heterogeneous. The States are the basic institutions from which ensues the legitimacy of all the other institutions intervening in fishery management. Public institutions are instruments of the State public policies and ought to serve the interests of the national collectivity. Other (non-public) institutions express the economic short-term interests of a small number of people or of a social or economic pressure group.

The institutional system depends on the particular history of the various fisheries and the administrative traditions of the different States. The evolution of these institutions and their effectiveness result from the synergy between the lives of the social groups of the sector and the modalities of the public authority interventions. The resulting fishery institutional environment is often unstable. The number of its institutions tends to increase with time while their performance decreases.

Institutions tend to proliferate. Because of the multiple crises and the mobility characterizing the sector, the institutions constantly reconfigure themselves by multiplying the specialized organs in charge of resolving difficulties and making decisions (Easton, 1965). States have created numerous specialized organs in charge of regulating, informing or controlling, for example scientific institutes, offices, fishing committees, maritime chambers, fishing villages, and management agencies. Industry has also created numerous structures for representation and management, for example consortia, professional unions, cooperatives and professional or specialized associations. Pressure groups of users of spaces and resources exploited by fisheries have also been constituted, for example associations for the preservation of the environment or certain species, the users of natural spaces, as well as recreational navigation and fishing groups. Most often, these institutions accumulate as obsolete institutions are rarely dismantled[12], resulting in an institutional system increasingly difficult to understand, control or predict.

Institutions tend to change. It can be demonstrated that specialized institutions, quite naturally, seek autonomy from the structures which have established them (Chevallier and Loschack, 1978). Sooner or later, these institutions tend also to exceed their initial functions. Paradoxically, large institutions seem to have problems in smoothly adapting to change. The people in charge and the staff may strive towards satisfaction of their personal or group interests[13]. As a result, they may totally lose their representativeness and utility without, however, abandoning the socio-political field, functioning only on the basis of their legal status and their capacity to influence decisions (Crozier and Friedberg, 1997; Muller and Surel, 1998).

6.3.2 Typologies of fishery institutions

Considering the complexity of institutional systems a typology would be useful. However, each country has its own institutional system as well as fishing and legal traditions.

[12] For example, in the Kingdom of Morocco, the Maritime Fishing Chambers created in 1999 did not substitute the fishing committees and associations of fishermen but rather 'added' themselves to the list of representative organizations.

[13] Therefore, for example, a scientific fishery administration whose function is to advise a minister of fisheries may accumulate means and develop activities that may have no connection with its initial mission.

Nonetheless, two typologies can be proposed, based respectively on the functions and nature of the institutions (Féral, 2002).

Functional typology

The organization of the fishery sector can be presented as a group of organs interacting to accomplish the socio-economic functions necessary to the sector. Most of these institutions tend to accumulate several functions that the manager must identify through their statutes and activities.

Resources harvesting

Harvesting is the central function and can be subdivided in two secondary ones: (1) the economic function of collecting the capital and (2) the technical function of harvesting fishery species (including fitting-out operations). Nowadays, the function is generally ensured by a private enterprise and rarely by a public (State-owned) one. The juridical status of an enterprise depends on the composition of its capital and its owners. The modern model of an enterprise is that of a commercial firm, formed through a contract binding several people to form a distinct legal entity. Its role is to collect capital to invest in a profit-making activity. For instance, the role of the fitting-out companies is to acquire and equip vessels for fishing. The harvesting operations *sensu stricto* stand apart from capital setting, forming a separate function and profession. However, due to their traditional origins, a great majority of fishing enterprises are composed of individual companies incorporated by the will and the capital of a single person in charge of all the functions: workforce, direction, capital setting and know-how. In many developing countries, these companies are very often informal and not legally identified. Examples of institutions involved in harvesting are: a fitting-out company, a fishing company, a fishermen's village or a household, etc.

Commercial or collective servicing

The fisheries need numerous servicing enterprises: for example ship equipping, shipbuilding, catering, ship chandler, on-land services, wholesale fish trading, packaging and valueadding. Investments are generally made by profit-making groups of interest in the form of private and (sometimes) public companies. In order to have access to specific services, artisans and individual enterprises often join together to establish a collective (cooperative) services institution. The difference is that the cooperative institution is founded on the 'one man, one voice' principle, whereas the sharing of power in a commercial company depends on the shares of the social capital. The collective sector often receives State incentives such as public loans and regulatory advantages. The archetype of these institutions is the cooperative for service, the aim of which is to propose advantageous services to their associates in order to accomplish a particular operation: fish auction halls, transport, distribution of fuel and materials, legal advice, bank loans, infrastructure management, etc. The Italian system of enterprise consortium can also have as an objective the provision of common services. Fitting-out cooperatives exist, the setting-up of which has often been encouraged by the State so as to build up the number of fishing vessels and gather crews in a phase of promotion of industrial fishery development (e.g. as in Morocco or Tunisia in the 1960s). Finally, professional chambers

bind groups of professionals within the framework of private administrations. These corporatist establishments can equally provide collective services: infrastructure management, training, legal advice, social assistance, etc. The artisan chambers, the chambers of commerce and industry, the maritime chambers, the Spanish *cofradías* (brotherhoods) and the French *prud'homies* (industrial tribunals) come under this category (Féral, 2002).

Representation of interest groups

Fishing involves competition between actors in civil society, organized in interest groups, to monopolize the resources and obtain privileged access from the State as well as grants, subsidies, rules and regulations which favour their projects and positions. The position of a group can be strengthened by the setting-up of a collective representation organ to speak in the name of the group, presenting claims, defining objectives, and elaborating a common line. To better influence the decision-making institutions, it must build its representativeness, uniting the maximum number of members and synthesizing their claims with minimum internal conflict despite the spirit of individual competition of the members.

One can distinguish representation institutions from the professional and that from the non-professional groups of interest. The professional union is the archetype of the organ for professional representation. Its particular status often supplies a legal and institutional recognition which allows it to automatically sit in on decision authorities. One cannot deny the existing difficulties regarding the representation of the individual companies within this particular context: the weight of the large commercial companies often imposes itself as model of representation and complicates negotiation with the fishery manager.[14] The non-profit-making association[15] generally considered of public utility, constitutes the legal status generally recognized by the public authorities for non-professional groups of interest subject, sometimes, to approval or authorization procedures. They may receive subsidies. In both cases, the State's role in the institutionalization of the association is often very important. Sometimes, the status of the professional union is not very well defined, complicating the public authority's authorization, and a better defined non-profit association may take over the role of representation.

Negotiation and co-management

Representation by professional and non-professional institutions in claims or protests is only one of the aspects of these institutions. Their objective is to penetrate the circle of political decision. This entails participating in the management of the fisheries in such a way as to ensure that it serves the interests of the group. Under pressure from the representation institutions, the public authorities are led to create institutions for dialogue, negotiation and co-management to harmonize the different pressure groups' points of view and facilitate decision-making. The selection of the representation institutions authorized to sit in on these

[14] The 'shipowners' may tend to dominate the representation of the 'fishermen', *de facto* depriving the artisanal fisheries people of adequate representation.

[15] Often called 'non-governmental organizations', they are also considered 'foundations of public utility' or non-profit-making institutions.

institutions is carried out by the State in accordance with its objectives and its representations. The efficiency of the groups in gaining recognition is therefore very important. These institutions have the tendency of progressively substituting themselves for State institutions so as to confiscate control of the sector to the benefit of the best organized groups (e.g. the boat owners). The perfect examples are professional associations or professional unions.

Piloting, control and professional discipline

Because of the conflicts and crises within the fishery sector, numerous institutions aim at exercising power of control, discipline, sanction, and organization upon some of the actors of the fish production chain or on their own members. Legally, or informally, they exercise a function of order and regulation and are often integrated into the fishery administrative system. One can distinguish several secondary functions within the function of discipline: (1) regulating fishing operations, fixing the general rules concerning the harvest: for example time and area closures, banning of certain gear and practices; (2) regulating access to resources: control of access of the profession or of certain practices; (3) control of operations, watching compliance with professional norms; (4) jurisdiction: judging and sanctioning those who do not comply with the profession regulations; and (5) arbitration: resolution of disputes between the members of the professional group.

The function of discipline is usually exercised by the State, which has a monopoly on the sanctions and coercion upon its territory and over its nationals. Its bureaucratic machinery often performs all of the regulatory missions, in particular those pertaining to fishing operations. However, these functions are often exercised in the State's name by corporations, companies, delegated authorities, and fishery managers. The Spanish *cofradías* and the groups of producers recognized by the European Union authority are two examples of institutions for regulation and control of the profession.

Socio-political typology

Institutions are also the organs attached to the systems of power and interests, with characteristics that cut across the functional aspects identified in the preceding section. State institutions conflict and collaborate with the institutions of the civil society (Chemillier-Gendreau, 1993; Benoit, 1995), and the public/private separation of powers and interests is important even though it is progressively blurred through the creation of hybrid institutions set up to modernize fishery governance.

Corporative institutions of civil society

The corporation is defined as a constituted group of interest. The institutions of the civil society play an important and even decisive role in fishery policy and management. Their influence is founded on their technical competence, representativeness, capacity of intervention in the sector functioning, material and financial means. Corporative institutions have external and internal political functions. Externally, interest groups organize structures to represent themselves and put pressure on the circle of decision, public opinion and the media. They develop a common discourse reflecting the general interest and public objectives. They

formulate their legitimacy in terms of economic interest of a profession, demographical influence, social impact and, nowadays, sustainability. Their representatives participate in the preparation of the decisions and negotiate with the public authorities about advantages and constraints (Wilson, 1990; Hecquart-Thérond *et al.,* 1996). Internally, the corporatist institutions mobilize the group towards obtaining material and legal advantages through the use of pressure of all kinds on the public authorities, including public demonstrations, strikes, obstruction of the infrastructure and other confrontations. The institutions also help inform and train the members so as to increase their capacity for action and standardize their collective behaviour. They contribute to the disciplining of the group regarding negotiation or confrontation strategies and create a professional culture with its values and representations. Lastly, these corporatist institutions allow the gathering of innumerable technical, scientific and socio-economic information regarding the fishing sector (Olson, 1965).

State institutions

The State institutions are organized on the hierarchical bureaucratic model[16] based on the powers and technical competence of the top offices (Timsit, 1985). During the fisheries industrialization phase, the public fishery authorities constituted the central and scientific administrations as systems for command and expertise to support them in their missions. These administrations constitute the institutional foundation of the fishery bureaucracy and technocracy (cf. Glossary, this volume). They reorganize government decisions in this economic sector and supervise it, inspiring the content of public action, finding solutions and elaborating rules. The political influence of the bureaucrats and technocrats relies primarily on their legitimacy (respectively legal and scientific) and their control of the recruitment of civil servants with the same background, language and political representations (Chevallier and Loschack, 1978).

These organs are under the authority of the State government. They are organized as a hierarchical pyramid of specialized directions and offices covering all the questions that the fishery administration may raise. Resulting from the administrative tradition and the various political changes, the logic behind their composition, relations (flow chart) and responsibilities is often difficult to see. In theory, the tasks of the centralized administrations are to: (1) gather and process the necessary information for State decision; (2) coordinate the actions of the different administrations involved in management decisions; (3) reorganize the political decisions in the form of formal legal acts (conventions or unilateral acts); (4) enforce instructions and directives formulated at political level; (5) command services; and (6) supervise and control the different segments of the fishery sector.

Delegated and hybrid institutions

The confrontation between interest groups and the public administration has created numerous hybrid institutions to which management and decision-making are delegated. Their growing numbers over the last decades shows the difficulty encountered by States in conducting the policies through unilateral and centralized bureaucratic procedures.

[16] The term is not a pejorative; it refers to the model of the State pyramidal centralized and hierarchical administration considered by Max Weber (1923) to be the 'science of administration'.

Inter-professional institutions aim to organize the fishery sector along the economic production chain, integrating the different professions of the sector for coordinated action in accordance with the public authorities' policies. Many of the State decisions are made within this framework, which allows also some disciplining of the profession. The State administration participates in the work of these institutions, synthesizing the different points of view to define the content of public action.

In very many fisheries, the functions of control and discipline are delegated to a professional institution such as a consortium or group. This helps to raise the actors' awareness of their responsibility and to organize management at the fishing area level. It is believed to reduce management costs and improve compliance. However, this delegation may undermine the State's authority and lead to confiscation of common resources by one of the professional categories (e.g. industrial fishers). The public administration's supervision of these delegated institutions should also be a guarantee for transparency (making decisions public) and equity (charging fees to counterbalance privileges).

Independent fishery management institutions have sometimes been established under the control of the political representation (i.e. the institution reports to the Parliament or the Ministry in charge of fisheries) but not under the hierarchical authority of the public administration. The legal statute of such agencies ensures their independence as well as the publication of the details pertaining to their activities, and the mechanisms ensuring transparency are a condition of their efficiency (Clarke and McCool, 1996). The agency has its own independent experts and is shielded from political pressure. Its public statute avoids the dispossession of the community and outright conceding of the resource exploitation to the professionals.

Lastly, it should be remembered that there are almost 50 international institutions in charge of different fisheries on straddling stocks, highly migratory species or regional fishing areas. These authorities rarely have enough legal powers to efficiently manage the fisheries and the decisions, requiring consensus, are implemented by the member States themselves. These bodies are, therefore, more diplomatic fora than management institutions *stricto sensu*, and their performance in terms of resources conservation is a source of controversy.

6.3.3 Institutional analysis of fishery management

Fishery development is an activity of direction and command whose legitimate nature depends on the States' authorities and responsibilities. A very great number of institutions claim to intervene in the sector and vest in the field of decision in order to defend their own sectional interest or to provide a specialized function. The manager must understand the characteristics of each potential partner institution in order to decide on its place in the decision process (Young, 1982; Authier, 1981; Balle, 1990).

Characteristics of institutions

When considering the involvement of institutions in fishery management, the manager ought to have the answers to the fundamental questions listed below, particularly the first three:

– Representation. Which sectional interests does it represent? What main institution or social group created the institution?

- Function. What is its main function? Is the social purpose of the institution to provide a service? To represent the interests of a group?
- Competencies. Which are its legal capacities and administrative competences? What are its institutional powers of internal and external discipline?[17]
- Genesis. What is the genesis of the institution? When did it come into existence? How was it created? By whom? Why? How has it evolved? What are its main activities?
- Nature. How real is it? What is the effective composition and dynamism of the institution and its leaders? Is it a formal legal representation or a real social representative? The activity, the composition of the organ and the demographical characteristics of the group must be documented.
- Autonomy. What are its ties to, and degree of autonomy from, other institutions? Is it indeed the representation of: a group, an individual, a public administration, a dominant company; a State?
- Spatial ascendancy. Is it a local, national or international institution?
- Legal regime. What are its statutes, internal rules of procedures, legitimacy, and legal and regulatory frameworks?
- Capacities. What is its capacity to discipline its founders and those giving it its mandate? Does it stand for collective action in public opinion? Does it penetrate the circle of political decision?

Hierarchy of management institutions

The manager must clarify the relative importance of institutions to organize their hierarchical place in the decision-making process. Different types of decisions, taken at different levels, may call for different institutions or for the same institutions but in different roles.

National management

The State administrations make decisions to organize the sector according to management strategies, using instruments such as licences, quotas, authorizations to fish, vessel regulations, fishing or protected areas, fishing or closed seasons, and gear specification. The Ministerial departments or the administrative heads generally have the legal competence to limit the actors' freedom. Hopefully, as provided by the LOSC and the FAO Code of Conduct, these decisions are based on scientific assessments provided by national or international scientific administrations, or institutions established or recognized by the State.

The content of management decisions is often a synthesis between, on the one hand, the scientists' recommendations and, on the other hand, the claims of professionals and pressure groups. Furthermore, the FAO Code of Conduct and good governance principles require involvement of the actors in the assessment, decision and implementation processes. The degree of representativeness of the partner institutions must be verified. The operation may be delicate but essential to reassure the manager of the legitimacy of the partners and their

[17] Numerous so-called fishermen's associations or unions are in reality associations of shipowners or wholesale fish traders with little or no control over fishing operations and who may not be in a position to truly discipline the behaviour of the fishermen.

ability to forward down the rules of conduct. The creation of numerous institutions has been encouraged by States to promote dialogue between the administration and the actors, for example professional unions, groups of producers or cooperatives.

Supranational management: the European Union

At the highest level of political integration, an international authority exercises all or part of the State's sovereign rights on fisheries and therefore makes the main decisions concerning the sector. The model for supranational management is the organization of fisheries within the European Union, where the waters under the State members' sovereignty are classified as 'community waters' subject to decisions adopted at the European Union level. Since October 1970, a common fisheries policy (CFP) has been established which imposes equal access and exploitation to all the ships under a State member flag, a common regime for control, a common fishing licence, a common organization of the markets and a common conservation and management policy. In this supranational set-up, the State members keep only a residual competence, even within the 12 mile limit. However, European Union members are principally responsible for implementing these policies in waters under their jurisdictions, integrating the community management measures into internal rights with controls and sanctions. The European Union, in the name of the States, also negotiates international fishing agreements with third-party countries in order to obtain new fishing zones for the shipowners of the community. The Union's competences therefore cover the whole sector – all community fishing areas as well as areas conceded by third-party countries according to a process of integration.

Intergovernmental management

International conventions encourage the States to cooperate, particularly in marine fisheries. This cooperation entails the creation and functioning of numerous (presently 49) international institutions often created on the initiative of FAO which has significantly contributed to their establishment.

At a lower level of integration, FAO has multiplied the creation of regional fishery bodies under Article VI of its constitution as institutions of dialogue, information and scientific advice. These authorities are subsidiary organs of the FAO and their legal authority is very limited compared to that of the States themselves. Their main characteristic is that of being open to all interested States and their broad agenda covering all aspects of fisheries (e.g. statistics, assessment, management, development, trade and MCS) within and outside national jurisdiction. Despite being only advisory mechanisms, they have played a fundamental role in the development of the international relations in fisheries. These organs have contributed to a global awareness by creating the 'virtuous circles' within which the States, without being constrained by treaties, must face the international community's disapproval in the event of a serious breach of their obligations.

At a higher level of integration, one may find RFMOs and other international arrangements created by bilateral or multilateral agreements (e.g. a constitutive treaty) to manage a fishery region (e.g. the Asia-Pacific Fisheries International Commission, APFIC[18]) or a

[18] It is established under Article XIV of the FAO Constitution related to treaties regarding food and agriculture resulting from a technical conference.

group of species (e.g. the International Whaling Commission, IWC) on behalf of the signatory States, without, however, having all the pertaining powers. The organs' general assemblies are composed of State members and have the exclusive power of recommendation and resolution. The management decisions are usually taken by consensus, and member States are committed to implement them unless they have formally objected to them. Legally speaking, these organs do not therefore effectively exercise the States' sovereign rights on behalf of their members. But they do participate in the regulation of activities and are a fundamental framework for negotiation which has strongly modified the parameters of the world exploitation of fishery resources. Nevertheless, the fact that, with very few exceptions, these bodies have not been effective is clearly indicated by the generally poor state of the resources. A general assessment of their performance has been recently recommended at the UN level.

Institutional participation

The involvement of the sectoral actors of fishery resource exploitation, in fishery management procedures, is now considered unavoidable and necessary even though the institutions of the civil society form a galaxy, difficult to identify and a fortiori to control. Various aspects of the question are examined in some detail in Chapters 3, 11, 12 and 15.

The FAO Code of Conduct recommends that, when defining and implementing public policies and management strategies, the States organize an effective dialogue with and among the main actors of the fishing sector for several reasons: (1) improving the information basis of the decisions, particularly regarding the resources and the socio-economic implications of management measures; (2) facilitating implementation, increasing the understanding and sense of responsibility of the actors; and (3) improving cost-efficiency through decentralization or devolution of responsibilities (FAO, 1999). Two aspects are of particular interest in this chapter and are elaborated below: (1) the increasing diversity of powerful and organized pressure groups that the manager must deal with and (2) the growing international dimension of some of them.

A growing diversity of actors

Fishery policies and management are integrated into hierarchically superior national policies, the constraints from which seem to grow every day and which the manager must help implement in the fishery sector. For example, growing pressure for urban and industrial development of coastal zones has increased the number of actors involved in decisions which affect the management of the fishery spaces and resources:

- Environmental NGOs. The intrusion of the organisms for the protection of nature is the most significant event of the last 30 years. Their activism, expertise, fund-raising capacity, pyramidal organization and effective communication strategies have earned many of them recognition and credibility in elaboration and implementation of public policies.
- Other coastal actors. In their fishery areas, fishers and fish farmers must now deal with other maritime or coastal functions. The damage or pollution from harvesting and the spatial occupation by fishery infrastructures compete with, for example, navigation, recreational fishing, tourism, housing development and other activities often supported by

local authorities. As a consequence, numerous associations participate in the management of the ocean space interfering in the management of the fishery spaces.

- Fishery corporations. The representation of the different fishery professions (including cooperatives, unions and associations) has been reinforced by the introduction of negotiated management decision processes. Public authorities have established mixed institutions within which the different lobbies sit and can express their opinions and influence decisions. These authorities may rapidly be controlled by the shipowners and wholesale traders who hold the capital and control the markets, dominating the professional discourse and claims.
- Scientific institutions. Lastly, expert institutions intervene more and more and are sometimes presented both as scientific authorities and as places for reference and reflection able to influence management decisions. Environmental sciences and social sciences are increasingly intervening to complement or contrast conventional fishery science. As expertise has become a very important commodity, it is important that these scientific institutions are shielded from undue commercial pressure and coercion from government, fishing or environmental corporations.

A growing international dimension

Civil society institutions now organize themselves as international, national or local organizations, depending on the levels of decision or management. The recognized legitimacy of NGOs has allowed for a proliferation of institutions which intervene with governments and international mechanisms. The means of communication and the nature of the messages do not always provide very clear information on the exact nature of the institutions, their representativeness and their true objectives, for example:

- Protection of Nature. At international level, the large federations for protection of nature such as the WWF, IUCN or Greenpeace are now unavoidable interlocutors of international fishery bodies (without voting rights), reminding States about the conservation dimension of fishery policies.
- Fishery lobbying. The globalization of pressure groups is equally visible in the professional world: international professional associations are constituted with and by industrial fishers, shipowners and collectively organized small-scale fishermen. The phenomenon is therefore institutionalized and even encouraged in order to ensure discussion and transparency in development and management.
- Science. The organizations for scientific expertise and research which intervene more and more in the fishing sector now take on an international dimension thanks to the technologies of communication, public relations and information. International media coverage has strengthened their scientific image without necessarily providing the guarantee of independence and credibility.

The decision process

Fishery policy making and management can be presented as a set of decisions which unceasingly adjust the institutional and legal framework within which the actors of the sector perform

(Sfez, 1981; Sabatier, 1999). The fishery manager is legally responsible for his or her decisions but acts within the framework of the fishing institutions and in accordance with the principles of responsible fisheries.

The legal and institutional environment of decisions

Fishery policies and management strategies are defined by political leaders or by the people invested with this responsibility by the State as an expression of its sovereignty. However, the policies and types of management measures that should be considered, as well as the way in which decisions should be made, are conditioned by the national and international legal environment. For example, the general principles of responsible fisheries provided for in Article 6 of the FAO Code of Conduct establish general policy objectives such as resources and biodiversity conservation and rebuilding, habitat protection, food security, value adding and waste reduction, and improvement of working conditions and the well-being of fishing communities. They indicate the necessary means such as science-based decisions, the precautionary approach, participation and international cooperation. They stress the authority and responsibility of port States and flag States, the need for social policies and for non-discriminatory trade relations. The articles of the Code contain a wealth of guidance on how to implement these principles. Aligning national and international policies with internationally agreed principles adds to the legitimacy of decisions taken regarding straddling or high sea stocks as well as EEZ resources (Schelling, 1978).

From a formal point of view, the authorities' decisions are written in the form of unilateral legal acts, enacted or decreed by government executives or by the authorities invested with management responsibilities (laws, decrees and circulars).

The nature of decisions

For the decisions made to be true to the international philosophy propounded, for example, in the FAO Code of Conduct, they should reflect the good governance principles discussed in some detail in Section 17.2.2. Briefly stated, decisions should: (1) aim at sustainability, raising the concept from the resources to the ecosystem level through the Ecosystem Approach to Fisheries (EAF); (2) be science-based, that is, produced by reliable scientific authorities, recognized for their competence, neutrality and independence, integrating traditional knowledge; (3) result from participative processes involving all relevant fishery actors including small-scale communities, NGOs and non-fishery actors as appropriate; (4) be transparent and impartial particularly when allocating rights and resolving conflicts, involving all parties concerned and making all results publicly available; (5) seek to empower the stakeholders, setting the legal and financial mechanisms needed to promote their responsibility during the management planning process; and (6) seek to protect the most vulnerable actors and communities often in danger of being excluded by the industrialization and modernization processes.

Obviously, ensuring all these characteristics (and reconciling them) is a challenge for the manager and few fisheries, worldwide, can claim to have achieved that objective. However, progress is being made as the FAO Code of Conduct gets better implemented and through the action of NGOs.

The phases of the process

The decision cycle has been described (cf. Section 1.2). Management decisions are most often made through a process of proposals and counter-proposals and the final decisions are shaped through debate in committees or commissions with the support of scientific experts. These decisions, and the rules constituting the policies of the fishing sector, modify the conditions under which fishing is permitted, formulating authorizations and prohibitions, targets and limits; formalizing management procedures (see Sections 9.4.3 and 12.4.1); etc. They constitute a group of juridical acts which emerge from a number of functional stages of design and formalization in search of coherence and efficiency: (1) scoping and information gathering; (2) identification of issues and setting of related objectives; (3) assessment and identification of possible solutions; and (4) formulation of decisions and rules. The quality of the decisions is analyzed *ex ante* (during the assessment phase) and *ex post* through the monitoring and evaluation phase.

Influences on the process

Such a process requires the highest degree of participation, consensus and negotiation authorized by the legal and institutional system within which the manager operates (Ostrom, 1990). Even the most bureaucratic, unilateral, command-and-control approach most often includes formal and informal consultations with institutions whose function is to formulate opinions and recommendations which may be convincing if not mandatory. The decisions are, therefore, always influenced by pressure groups: for example fishermen, boat owners, traders, environmentalists, scientists and the local collectivities. The different internal bureaucracies of the States also weigh on the decisions (e.g. the Ministry of Finance desirous of making the most from fishing licence fees and international trade). The following factors also influence the decision-making process:

- Market pressure grows with growing relative scarcity and rising fish price providing positive spin-offs for the actors and the sector economy and pressure to water down scientific recommendations to reduce fishing.
- Clientelism and corruption may keep the manager from acting deliberately, either because the hierarchy is guilty of favouritism and renders arbitration benefiting certain privileged actors or because the carrying out of the decisions is slowed down by the indulgence or complicity of the ground agents.
- Threats of social disorder. Public authorities dread confrontations, conflicts and social disorders triggered by management decisions. The fishing world has been accused of being particularly vindictive, tending to stick together and to have great capacity for blocking the functioning of infrastructures (Schelling, 1960).
- Acquired privileges such as free access to resources, monopolistic access to certain fishery territories, derogations to use ancestral fishing gear, exclusion of new entrants or foreign fleets, and control of the market, strongly motivate the groups of actors and are difficult to withdraw even if counterproductive for management.
- Existing over-investments, often co-financed by public authorities, make decisions to adjust capacity to resources potentially difficult and hard to implement. The modern manager faces a process of structural adjustment calling for substantial financial means for compensation and redeployment if social dramas are to be avoided.

The importance of resistance factors underlines the need to obtain adherence of the actors to management projects. The practice of conflict resolution through separate and secret

negotiations in which political authorities attempted to circumvent professional movements or NGOs may not have completely disappeared but are complicated by the modern requirement for transparency and the media coverage of public action.

The same trend for consensual decision-making is under way at international level where decisions to be made at conferences are prepared through: (1) preliminary or informal consultations and (2) drafting of consensual proposals by leading groups (e.g. by 'friends of the Chair'), elaboration and publication of position reports, expert consultations etc. that can progressively assemble and 'iron out' the elements of the decision. Here again, the role of scientific and technical authorities in the maturation process of the decisions is fundamental. Their advice contributes to the convergence evolution of States' positions and allows them to convince their constituency. The problem is that the 'speed' of these consultative processes may not match the urgency of conservation or rebuilding measures.

6.4 Synthesis

The management of fisheries requires the capacity to lead the social group to adopt a new position compatible with sustainable development principles. Knowledge of human group characteristics, the legal organization of society and the rules governing institutional life is essential to managing the transformations of the different actors' strategies. The areas in which fishery managers tend to encounter most difficulty are human behaviour, arbitration between diverging interests, negotiations between different groups of actors and, sometimes, the competition between sovereign States. The core of this chapter therefore exposes the practical ways in which the management of fisheries must be organized, that is, the institutions and legal framework within which the respective roles and responsibilities of the different actors involved can be lawfully established.

This chapter does not give all the keys of the fishery managers' decisions and of fishery policies, but it gives some social sciences and legal definitions used in public management and applied to the fisheries sector. The typologies built in the chapter are original and founded on many concrete examples coming from many fisheries in the world. The legal and institutional approaches of maritime fisheries show the complexity of the public management data and the difficulties to organize a sustainable and responsible policy in this socio-economic field. During the last 50 years, biological, ecological and geographical information demonstrated the natural resources management crisis to public opinion and to governments. Today, the difficulty is to promote a new policy of conservation and management. This requires public decision and social negotiations that mobilize law and institutions. This chapter gives some minimal legal and institutional information needed in this delicate endeavour.

The first part deals with the manager's responsibilities and competencies. It clarifies and stresses the prominent role and responsibility of the State in fishery management, including legal and economic interventions, in the territories under its direct jurisdiction as well as in international waters. Defining the scope of the rights of the State is important as these define the scope of the interventions by the manager. The chapter then elaborates on the competencies delegated by the State to the manager and the role of the latter in the complex institutional environment within which it operates. It stresses, in particular, the very complex legal regime; the diversity of management models available (free and open access, State management, delegated management); the respective rights and duties of the manager and the fishery actors; the thorny problem of defining a damage, and a victim when fishery resources are used irresponsibly; and the use of fishing rights as fishery management instruments.

The second part describes the fisheries administration as a complex institutional system, distinguishing the management of fishery sector (through sectoral policies) from the management of the single fisheries or areas (through management measures and regulations). It underlines the complexity stemming from the proliferation of institutions of the State, the private sector, the civil society and mixed (hybrid) institutions. It also presents two typologies of institutional systems based on their function, on the one hand, and on their socio-economic characteristics on the other. An institutional analysis looks at management at State and inter-State levels as well as the supranational management characteristic of the European community. Finally, it examines the process and criteria of decision-making, its institutional environment, juridical principles, scientific basis, deliberative character, transparency and equity, focusing briefly on the means to increase the responsibility of the actors and to cater for the most vulnerable strata of the sector.

Sources and recommended reading

Almond, G. 1974. *Comparative Politics Today*. Little Brown, Boston.

Authier, M. 1981. *L'analyse institutionnelle*. PUF. Paris.

Balle, C. 1990. *Sociologie des organisations*. PUF. Paris.

Bénoit, F.P. 1995. *Notions et concepts, instruments de la connaissance juridique: les leçons de la philosophie du droit de Hegel*. Mélanges Gustave Peiser: PUG, Grenoble. 23p.

Beurier, J.P. 2006/07. *Droits maritimes*. Dalloz, Paris.

Bonzon, A. 2000. Development of economic and social indicators for the management of Mediterranean fisheries. *Marine and Freshwater Research,* 51(5): 381–384. CSIRO Publishing.

Bourgoignie, T. 2004. *Droit et politique communautaires de la consommation*. Une évaluation des acquis Mélanges en l'honneur de Jean Calais-Auloy, pp. 95129. Dalloz, Paris.

Charles, A.T. 2000. *Sustainable Fishery Systems*. Fishing News Books, U.K.

Chemillier-Gendreau, M. 1993. *L'apport de la dialectique à la construction de l'objet juridique*, RDP, Paris. pp. 611–639.

Chevallier, J. and Loschak, D. 1978. *Science Administrative*, L.G.D.J., Paris.

Clarke, J.N. and McCool, D.C. 1996. *Staking Out the Terrain: Power and Performance Among Natural Resource Agencies*. State University of New York Press, Albany.

Crozier, M. and Friedberg, E. 1977. *L'acteur et le système*. Seuil, Paris.

Dreyfus, F. 1976. La liberté du commerce et de l'industrie Berger-Levrault, Paris.

Easton, D. 1965. *A System Analysis of Political Life*. John Wiley and sons, New York.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. FAO, Rome.

FAO. 1999. *Proceedings of Technical Consultation on Decentralization for Rural Development. 13–18 December 1997*. Rome, FAO.

FAO. 2004. *Maritime societies, fisheries law and institutions in the western Mediterranean*. FAO Fisheries Technical Paper. No. 420. Rome.

Féral, F. 2002. La contribution du droit et de l'analyse institutionnelle aux politiques publiques des pêches maritimes. Le cas des pêcheries de Méditerranée occidentale. *Océanis*, nº 28-1/2, Paris.

Garcia, S.M. and Charles, A.T. 2007. Fishery systems and linkages. From clockworks to soft watches. *ICES Journal of Marine Science*, 64 (4): 580–587.

Hardin, G. 1968. The tragedy of the commons. *Science*, 162 (3859).

Hecquart-Thérond, M. *et al*. 1996. *Le groupe et le droit: corporatisme et néo-corporatisme*. Presses Universitaires des sciences sociales de Toulouse. Toulouse.

Levy, J.P. 1980. *La conférence des nations unies sur le droit de la mer Pédone*.

McGoodwin, J.R. 1990. *Crisis in the World's Fisheries: People, Problems, and Policies*. Stanford University Press, Stanford.

Mény, Y. and Thoënig, J.C. 1989. *Politiques publiques*. PUF Thémis, Paris.

Muller, P. and Jobert, B. 1987. *L'Etat en action*. Politiques publiques et corporatismes. PUF. Paris.
Muller, P. and Surel, Y. 1998. *L'analyse des politiques publiques*. Montchrestien, Paris.
Olson, M. 1965. *The Logic of Collective Action*. Harvard University Press, Cambridge.
Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge.
Riker, W., Ordeshook, P. 1973. Introduction to Positive Political Theory. Prentice-Hall, Englewood Cliffs.
Rosiak, P. 2004. Le nouveau droit international économique. L'Harmattan, Paris.
Ruíz García, J.R. 2000. *Tributación de la empresa pesquera*. Cuadernos de Derecho Pesquero Fundación Pedro Barrié de la Maza : 281–290. A Coruña.
Russ, G., and Zeller, D. 2003. From mare liberum to mare reservarum. *Marine policy*, 27 (1).
Sabatier, P. 1999. *Theories of the Policy process*. Westview Press, Boulder, Colorado.
Schelling, T.C. 1960. *The Strategy of Conflict*. Harvard University Press, Cambridge.
Schelling, T.C. 1978. *Micromotives and Macrobehavior*, W.W. Norton, New York.
Sfez, L. 1981. *Critique de la décision*. Presse de la FNSP Paris.
Sousse, M. 1997. *La réparation du dommage en droit administratif français*. LGDJ.
Timsit, G. 1985. *Théorie de l'administration*. Economica, Paris.
Troadec, J.-P. 1981. Introduction to fisheries management: advantages, difficulties and mechanisms. FAO Doc. Tech. Pêches. No. 224. 57p.
United Nations. 1983. *The Law of the Sea: United Nations Convention on the Law of the Sea*. United Nations Publications, New York.
Weber, M. 1961. *Histoire économique générale. 1923*. New York, Collier Books.
Wilson, G.K. 1990. *Interest Groups*. Basil Blackwell, Oxford.
Wilson, J.A. Acheson, J.M., Metcalfe, M. and Kleban, P. 1994. Chaos, complexity and community management of fisheries. *Marine Policy*, 18: 291–305.
Young, O.R. 1982. *Resource Regimes: Natural Resources and Social Institutions*. University of California Press, Berkeley.

Additional reading

Appollis, G. 1981. *L'emprise de l'Etat côtiers sur les espaces maritimes*, Pédone.
Bentley, A.F. 1908. *The Process of Government. A Study of Social Pressures*. Chicago University Press, Chicago.
Boussaguet, L., Jacquot, S. and Ravinet, P. 2006. *Dictionnaire des politiques publiques*, 2ème édition. Références Presses de Sciences Politiques, Paris.
Burke, W.T. 1994. *The New International Law of Fisheries: UNCLOS 1982 and Beyond*. Clarendon Press, Oxford.
Chayes, A. and Chayes, A.H. 1995. *The New Sovereignty: Compliance with International Regulatory Agreements*. Harvard University Press, Cambridge.
Clark, C.W. 2006. *The Worldwide Crisis in Fisheries: Economic Models and Human Behaviour*. Cambridge University Press, New York.
Comte, A. 1851. *Système de politique positive*. Librairie scientifique-industrielle de L. Mathias, Paris.
Crozier, M. 1963. *Le phénomène bureaucratique*. Seuil, Paris.
Demolombe, C. 1850. *Cours de droit civil*. Editions Auguste Durand.
Di Maggio, P.J. and Powell, W.W. 1991. *The New Institutionalism in Organisational Analysis*. University of Chicago Press, Chicago/London.
Durkheim, E. 1973. *Les règles de la méthode sociologique*. 1895. Editions PUF.
FAO. 2002. *Comprender las culturas de las comunidades pesqueras*. Documento Technico de Pesca. No. 401. Roma.

Féral, F. 2000. Approche dialectique du droit de l'administration : l'appareil d'Etat face à la société civile. L'Harmattan/ CAP Paris.
Gehring, T. 1994. Dynamic International Regimes, Institutions for International Environmental Governance. Peter Lang, Frankfurt, Germany.
Grawitz, M. and Leca, H. 1985. Traité de Science Politique Tome IV Les politiques publiques PUF Paris.
Hardin, R. 1982. *Collective Action*. Johns Hopkins University Press, Baltimore.
Hauriou, M. 1925. La théorie de l'institution et de la fondation. Cahiers de la nouvelle journée, 4: 2–45.
Hassenteufel, P. 1995. Les groupes d'intérêts dans l'action publique. *Pouvoir*, Paris. 74 p.
Kaye, S.B. 2000. *International Fisheries Management*. Kluwer law intl. Amsterdam, Nederland.
Kelsen, H. 1962. *Théorie pure du droit*. Dalloz, Paris.
Lyster, S. 1985. *International Wildlife Law*. Grotius Publications, Cambridge.
Manteca Valdelande, V. 2000. *Organizaciones pesqueras internacionales*. Cuadernos de Derecho Pesquero Fundacíon Pedro Barrié de la Maza: 47–62. A Coruña.
March, J.G. and Olsen, J.P. 1989. *Rediscovering Institutions*. Free Press, New York.
Ostrom, E. 1992. Community and the endogenous solution of commons problems. *Journal of Theoretical Politics*, 4: 343–351.
Peters, B.G. 1999. *Institutional Theory in Political Science: The New Institutionalism*. Pinters, London. Singleton, S., and Taylor, M. 1992. Common property, collective action and community. *Journal of Theoretical Politics*, 4: 309–324.
Sobrino, J.M. 2000. La progresiva reducción del principio de libertad de pesca. Cuadernos de Derecho Pesquero Fundación Pedro Barrié de la Maza: 75–108. A Coruña.Victor, D.G. 1998. *The Implementation and Effectiveness of International Environmental Commitments*. MIT Press, Cambridge.
Young, O.R. 1983. Fishing by permit, restricted common property in practice. *Ocean Development And International Law*, 13: 121–170.
Young, O.R. 1994. *International Governance: Protecting the Environment in a Stateless Society*. Cornell University Press, Ithaca.
Young, O.R. 1996. Institutional linkages in international society. Polar perspectives. *Global Governance*, 2: 1–24.
Ziller, J. 1993. *Administration comparée*. Montchrestien, Paris.

Web resources

http://www.admiraltylaw.com/fisheries
http://www.afs. allenpress.com
http://www.en.wikipedia.org.public_policy
http://www.fao.org
http://www.foodandwaterwatch.org
http://www.intfishinet
http://www.mngt.waikato.ac.nz
http://www.myanmar.apcel.org
http://www.oceanlaw.net
http://www.onefish.org

Part III

Management Measures and Tools

Chapter 7

Regulation of Fishing Gears and Methods

Åsmund Bjordal

7.1 Introduction

The need for fisheries management arises as the surplus production from fish stocks is overtaken by the catching capacity of fishing fleets. Catching capacity is the product of the fishing effort and the combined efficiency of the fishing gear and the fishing vessel (e.g. loading capacity, engine power, range capacity, fish finding and navigational equipment), as well as the skills of the crew.

When using input controls (see Section 9.2.1) in fisheries management, it is important to adjust for the so-called effort creep – that is, gradually increased effort due to developments in technology – such as the introduction of double trawl systems, change to more powerful engines, more effective hook designs, better echo sounders and more accurate navigation instruments. Thus, it is not unusual that the very same vessel or fleet may double its fishing effort over a 10-year period and hence input controls in fisheries management should be adjusted accordingly to avoid overexploitation and depletion of stocks. As catch per unit effort (CPUE) is widely used in stock assessments, monitoring of and adjustment for effort creep is also very important to reduce assessment errors.

Fisheries management includes different management measures. Among these are technical regulations on fishing gears in order to obtain the overall goal of high-sustainable yield in the fisheries. These are regulations, for example on mesh size, to improve the selective properties of a fishing gear so that bycatches of juvenile fish are reduced, thereby safeguarding recruitment to the larger size groups of a fish stock, including the spawning stock.

In recent years there has been a growing focus on 'ecosystem effects of fisheries', addressing the impact of fishing operations not only on the target species but also on bycatch of, or other effects on, non-commercial species or habitats. Energy efficiency, reduced pollution and improved quality of the catch are also important aspects related to fishing gears and fishing operations (FAO Code of Conduct, Paragraph 7.2.2). From a situation where the development of fishing gears and methods only focused on the highest possible catching efficiency for the target species, now fisheries research, fisheries management and the fishing industry are challenged to develop gear, methods and regulations that meet the different considerations mentioned earlier. This is part of an emerging ecosystem approach to fisheries management.

7.2 Fishing gears

7.2.1 The ideal fishing gear

Some criteria for the ideal fishing gear could be:

- highly selective for the target species and sizes, with negligible direct or indirect impact on non-target species, sizes and habitats (FAO Code of Conduct, Paragraphs 7.2.2, 8.4.7, 8.5.1 and 8.5.4);
- effective, giving high catches of target species at lowest possible cost;
- quality orientated, producing catches of high quality (FAO Code of Conduct, Paragraph 8.4.4).

According to these and additional criteria that could be added to the list, it can easily be stated that the ideal fishing gear does not exist, as no fishing gear fulfils the complete list of the desired criteria and properties. However, in the process of moving towards sustainable fisheries management, different fishing gears with their specific properties and potential for improvement are an important part of the 'fishery manager's toolbox'. A basic understanding of the properties, function and operation of the major fishing gears and methods is therefore fundamental for decision-making in fisheries management, particularly when it comes to technical measures in fisheries regulations.

7.2.2 Classification of fishing gears

Fishing gears are commonly classified in two main categories: passive and active. This classification is based on the relative behaviour of the target species and the fishing gear. With passive gears, the capture of fish is generally based on the movement of the target species towards the gear (e.g. traps), while with active gears capture is generally based on an aimed chase of the target species (e.g. trawls, dredges). A parallel on land would be the difference between the trapping of and hunting for animals.

In the following sections a short description of the major gear types is given, including their catching principle, construction, operation and common target species. Gear selectivity and properties related to ecosystem effects of fishing will be treated in Section 7.5.

7.3 Passive fishing gears

Passive gear are in general the most ancient type of fishing gear. These gears are most suitable for small-scale fishing and are, therefore, often the gear types used in artisanal fisheries. Some passive fishing gears are often referred to as 'stationary' fishing gears. Stationary gears are those anchored to the seabed and they constitute a large group of the passive gears. However, some moving gears such as drift nets may also be classified as passive gears, as fish capture by these gears also depends on movement of the target species towards the gear.

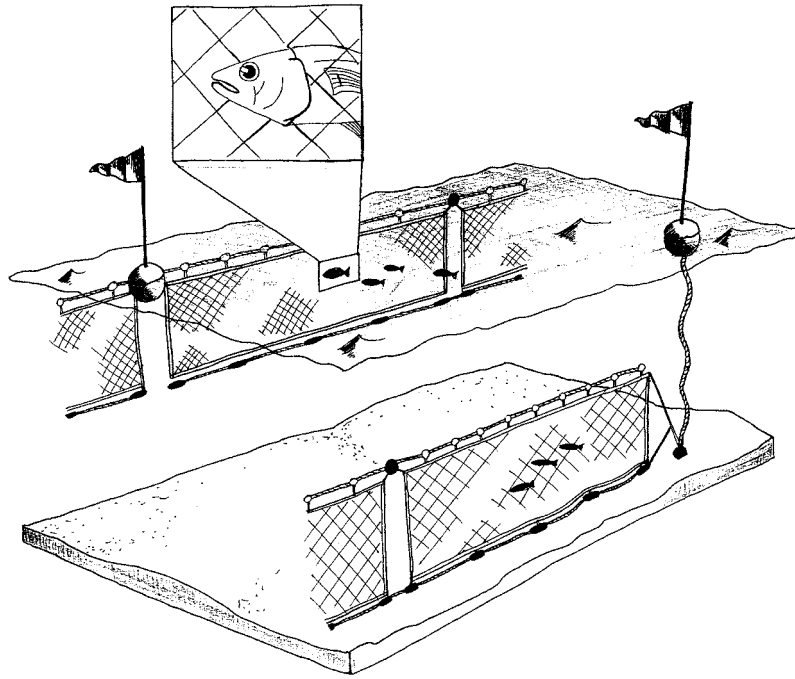


Figure 7.1 Catching principle (expanded view) and construction of gillnets, pelagic drift net (top) and bottom set (lower). Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

7.3.1 Nets

Gillnets

The catching principle and construction of gillnets are shown in Figure 7.1.

Catching principle

The gillnet is named after its catching principle, as fish are usually caught by 'gilling', that is the fish is caught in one of the meshes of the gillnet, normally by the gill region (between the head and the body). Thus, fish capture by gillnets is based on fish encountering the gear during feeding or migratory movements. As fish may avoid the gillnet if they notice the gear, catches are normally best at low light levels or in areas with turbid water.

Construction

A gillnet consists basically of a 'wall' or panel (e.g. 5 by 30 m) of meshes made of fine thread. The mesh panel is mounted to reinforcing ropes on all sides. To obtain a vertical position of the net in the sea, floats and weights are fastened at regular intervals to the top rope (float line, cork line) and bottom rope (sinker line, lead line), respectively. The size of

the meshes and hanging ratio (number of meshes per length of gillnet) are chosen to fit the desired target species and size.

Mesh size is commonly given as the length (in mm) either of a whole stretched mesh or the half-length (also called bar-length).

Today, gillnets are almost exclusively made from synthetic fibres, normally nylon (polyamide) – either as multifilament thread or monofilament (gut). Monofilament gillnets is increasingly being used because of its low visibility and correspondingly higher catch efficiency. Multi-monofilament is also becoming more common.

Operation

Gillnets are most commonly operated as a stationary gear anchored to the bottom at either end, but also as driftnets which float freely in the water. Stationary nets may be set on the seabed at different depths in the water column or with the float line at the surface. Similarly, drift nets may be operated with the float line at the surface or suspended from surface floats and corresponding float lines to the desired fishing depth in mid-water.

Gillnets may be operated from vessels ranging from the smallest non-mechanised fishing boats to big, well-equipped vessels capable of large-scale deep sea fishing. The gear used in small- and large-scale fishing is basically the same – the unit gillnet. However, with increased vessel size a larger number of net units can be carried and operated per day. Single gillnets are then linked into long fleets of up to several hundred nets.

Gillnets can also be operated from shallow to large depths and can be used for fishing on rough bottom and at wrecks. One specific problem with gillnets is the so-called ghost fishing. This refers to gillnets that are lost (most commonly after being stuck on a rough bottom) but continue to catch and kill fish over long periods of time. The FAO Code of Conduct (Paragraph 7.2.2) requires that the incidence of ghost fishing should be minimised.

Target species

Gillnets are used to catch a large variety of fish species. In general, bottom gillnets are used for catching demersal species such as cod, flatfish, croakers and snapper, while pelagic gillnets are used for species such as tuna, mackerel, salmon, squid and herring.

Trammel nets

The catching principle and construction of trammel nets are shown in Figure 7.2.

Catching principle

In trammel nets, fish are caught by entanglement which is facilitated by their special construction of three panels of nets attached on the same rope with a high degree of slackness.

Construction

At first glance, a trammel net may look like a gillnet. However, while the gillnet has a single panel of meshes, the trammel net has three – one middle panel of small meshes and two side

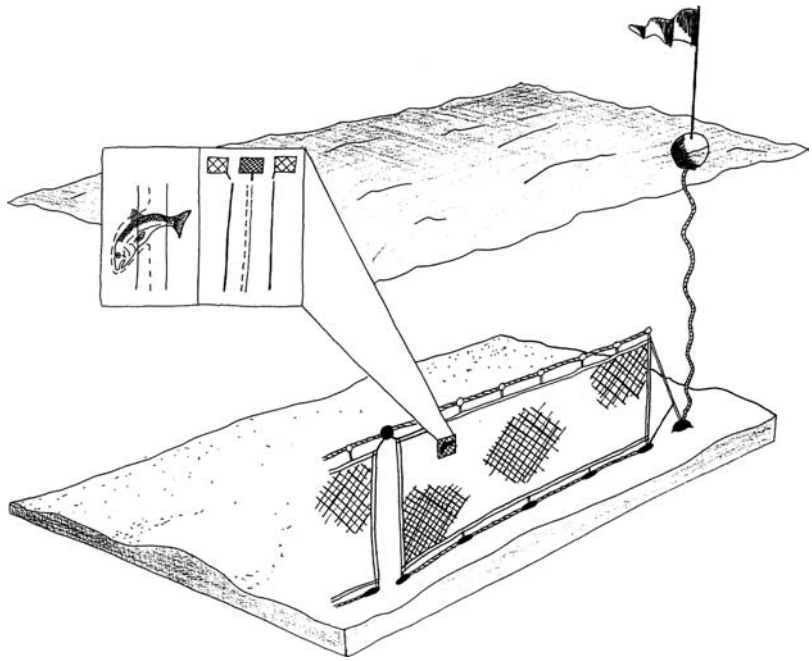


Figure 7.2 Catching principle (expanded view) and construction of trammel nets. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

panels of larger meshes. When a fish comes in contact with the net, it will press the small mesh net through an adjacent larger mesh so that it is caught by entangling or 'pouching'.

Operation

Trammel nets are usually set and operated like bottom set gillnets, mainly in small-scale, near-shore fisheries.

Target species

Trammel nets are used for catching a large variety of demersal fish.

7.3.2 Hook and line fishing

Different fishing methods are based on the use of fish hooks: longlining, trolling and various forms of handlining such as jigging (vertical line with lures, being moved rhythmically up and down to attract and hook fish). The general catching principle of hook fishing is to attract the fish to the hook and entice the fish to bite and/or swallow the hook so that the fish becomes hooked and retained.

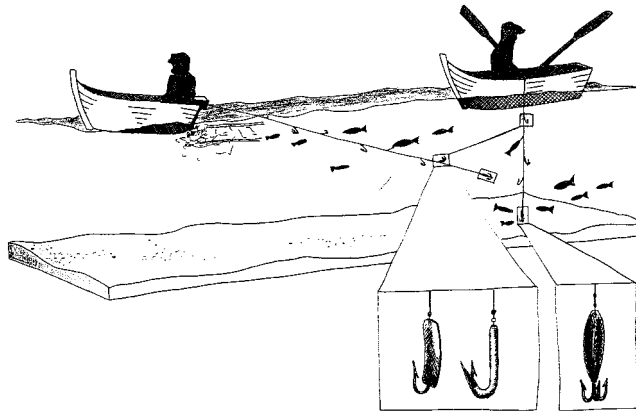


Figure 7.3 Catching principle and construction of trolling (left) and jigging (right). Expanded view: examples of lures and jig. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

Handlining and trolling

The catching principle and construction of handlining are shown in Figure 7.3.

Catching principle

The fish is attracted to the hook by visual stimuli, either natural bait or more commonly in the form of artificial imitations of prey organisms such as lures, jigs and rubber worms.

Construction

The gear is simple – a nylon monofilament is commonly used as line with one to several hooks at the end with bait or lures.

Operation

In handlining, the fishing line is vertical in the water column and is operated from a drifting or anchored vessel. Handlining is also conducted from the shore, with and without the use of a pole. From using only a single line, the operation can be scaled up by using several lines on larger vessels. In recent years, jigging has become mechanised and automated by the development of jigging machines.

Hook and line can also be used in trolling where the fishing line is towed behind the moving vessel. Semi-automation has also been developed in trolling, where power reels are often used for hauling the lines. Trolling is considered to be a separate type of fishing gear from handlining in the International Standard for Statistical Classification of Fishing Gear (Nédélec and Prado, 1990).

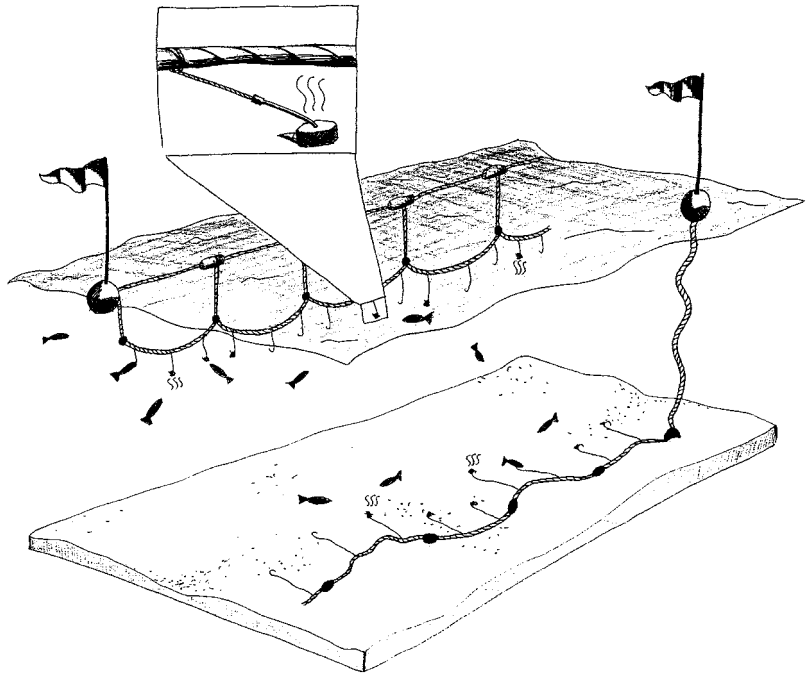


Figure 7.4 Catching principle and construction of longlines. Pelagic/drift (top) and bottom set (lower). Expanded view: baited hook connected with gangion (snood, branchline) to mainline. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

Target species

Typical target species with handlining are demersal-fishes such as cod and snapper as well as squid. Trolling is mainly directed towards pelagic species such as mackerel, tuna and salmon.

Longlining

The catching principle and construction of longlines are shown in Figure 7.4

Catching principle

Longlining is based on attracting fish by bait attached to the hook. While handlining and trolling generally exploit the visual sense of the fish to attract it to the hook by artificial lures, longlining exploits the chemical sense of the fish. Odour released from the bait triggers the fish to swim towards and ingest the baited hook with a high probability of being caught.

Construction

As the name of the gear indicates, this is a longline (mainline) with baited hooks attached at intervals – connected to the mainline with relatively shorter and thinner leader lines

(snoods, gangions). Depending on the type of fishery, there are great variations in the gear parameters, such as thickness and material of main and leader lines, the spacing between hooks, as well as hook and bait types.

Today, main and leader lines are almost exclusively made from synthetic materials such as polyamide (nylon) or polyester. Multifilament (rope) is generally used for main and leader lines with demersal longlines (set on the bottom), while monofilament (gut) is commonly used in pelagic longlining. Hook type (size and shape) varies greatly with target species. Naturally, larger hooks and correspondingly stronger main and leader lines are used for larger fish. There is also a great variation in baits used in different longline fisheries, but the major types of bait are either different pelagic fish (e.g. herring, mackerel, sardine, saury) or different species of squid.

Operation

The longline fishing cycle includes the following main operations: baiting (threading a piece of bait on each hook), setting, fishing ('soaking' the line for some hours), retrieval, removal of fish and old bait, gear maintenance, baiting, etc.

As with gillnets, the gear is basically the same in small- and large-scale operations with the length of the line and number of hooks increasing with vessel size. Small, open vessels normally fish a few hundred hooks, while the largest longline vessels (LOA 50–60 m) may operate 50–60 km of longline and as many as 40–50,000 hooks per day.

With increased vessel size there is normally an increased degree of mechanised gear handling. Most longline vessels are equipped with power haulers. In the so-called auto-lining, the laborious baiting process is also mechanised with machines that can bait up to four hooks per second as the line is set into the sea.

Target species

Pelagic (drifting) longlines are typically used for catching species such as tuna, swordfish and salmon, while bottom set longlines are used for demersal species such as snapper, grouper, cod, haddock, halibut, ling, tusk, hake and toothfish.

7.3.3 Pots and traps

Pots are considered within the International Standard Statistical Classification of Fishing Gear to be a type of trap (Nédélec and Prado, 1990) but are described separately here because of the differences in catching principle and construction between pots and other forms of trap. The general catching principle of pots (creels) and traps is to entice or lead the target species into a box or compartment from which it is difficult or impossible to escape.

The catching principle and construction of pots and traps are shown in Figure 7.5.

Pots

Catching principle

As with longlining, pot fishing is normally based on attracting target organisms by bait (chemical stimuli). When attracted to the pot, the target organism must enter the pot to gain access to the bait. This can be done through one or several entrances (funnels) of the pot.

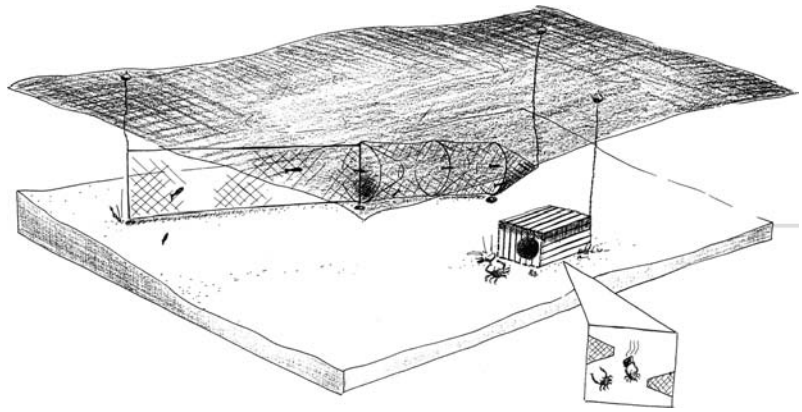


Figure 7.5 Catching principle and construction of pots (lower) and traps (fyke net – top). Expanded view: schematic illustration of entrances (funnels) and bait. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

Construction

Typical pot shapes are box, cone, cylinder, sphere or bottle. The size of pots may vary from small crayfish pots (conical: 0.3 m diameter and 0.2 m height) to large king crab pots (box shaped: 2 × 2 × 1 m). The pot entrances are usually funnel- or wedge-shaped so that the target organism is led into the pot fairly easily, but with low probability of escaping. Pots may be constructed from various materials such as wood, palm leaves, metal frames lined with webbing, wire mesh or plastic materials.

Operation

Pots are normally set on the bottom, either as single pots with a buoy line to the surface or in strings of several pots connected to a main line, at certain intervals. Pot gear is usually soaked overnight, but longer soak times may be used in certain fisheries. The operation cycle is similar to that of longlining, with baiting, setting, fishing and retrieval. The bait is either freely suspended in the middle of the pot or put in perforated bait containers to prevent it from being eaten by scavengers. As in longlining, different pelagic species like sardines, herring and mackerel are typically used for pot bait, but most kinds of fish and mussels may be used.

Target species

Pots are most widely used to catch different crustaceans, such as crabs, lobsters and shrimps. Pots are also used for catching different species of finfish such as sablefish, tusk and cod in temperate waters and reef fish such as groupers and snappers in tropical waters. Other species that are caught with pots are whelks and octopus.

Traps

Catching principle

Traps are normally not baited, but catch fish and other organisms by leading them into the trap, eventually to the fish compartment, that is designed for holding the fish entrapped with low possibility of escaping.

Construction

Compared with pots, traps are usually larger and often more permanent constructions. Tidal traps are based on walls or fences forming V-shaped constructions that entrap fish that have come in with the tide as the tide goes out. Typical salmon and cod traps are cage-like constructions made from webbing with long leader nets to guide the migrating fish into the trap. Tuna may also be caught with traps of this type. The fyke net (Figure 7.5) is a smaller form of trap, with a leader net connected to the trap or 'fyke' which usually consists of three compartments with funnels leading from the outer to the middle and finally to the inner compartment or 'fish bag'.

In tidal traps the fish are confined sideways by the leader walls, above by the sea surface and below by the sea bed. In larger fish traps like those used for cod and salmon, the fish are confined by side and bottom net panels while the sea surface serves as the top confinement. Fyke nets are set under the surface and thus the fyke (trap) has to be completely lined with webbing to confine the fish.

Operation

Tidal traps are usually permanent constructions where the fish compartment is emptied at low tide. Cod and salmon type traps are usually set out for the season and operated for one to a few months, emptying the fish compartment on a daily basis. Fyke nets are operated like pots, set one by one in the littoral zone, from one to ten metres depth and are usually moved to another spot after retrieval, usually on a daily basis.

Target species

A variety of target species are caught by tidal traps, both finfish and crustaceans, for example, shrimps, naturally dominated by species living in the tidal zone. As mentioned earlier, traps are traditionally used for catching cod and salmon (N. Atlantic), tuna (Mediterranean), small pelagic species in Far East Asia, some species of weakfish and others. Fyke nets are used for catching various species but are particularly used for eel and cod.

7.4 Active fishing gears

Fish capture by active gears is based on the aimed chase of the target species, combined with different ways of catching it.

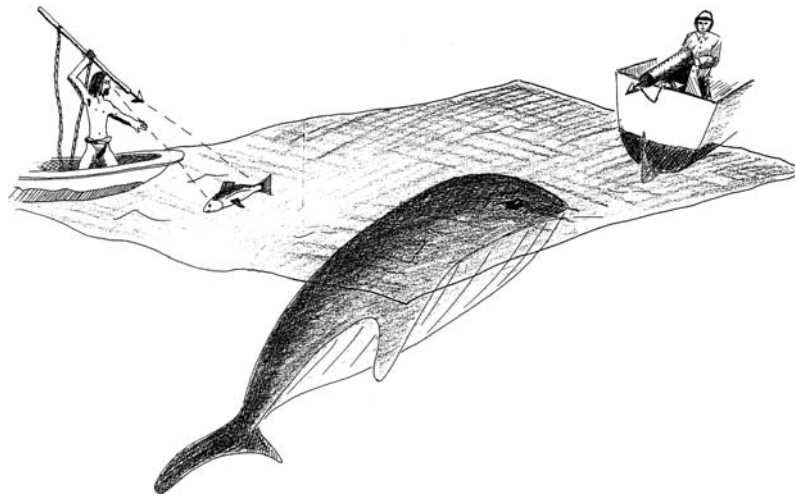


Figure 7.6 Catching principle and construction of spears/harpoons. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

7.4.1 Spears, harpoons

This is one of the most ancient ways of active fish capture.

The catching principle and construction of spears and harpoons are shown in Figure 7.6.

Catching principle

Capture with spears and harpoons depends on visual observation of the target species, which is then impaled by the spear or harpoon from a relatively short distance.

Construction

Basically, the spear or harpoon is designed for easy penetration of the target organism, but the spear head is equipped with barbs or flukes that hold the prey when it is hit. Usually, the spear or harpoon is connected to the fisher and boat by a line, so that it can be retrieved, with or without catch.

Operation

Spears and harpoons are most often operated from a vessel but can also be used from land.

Target species

Common target species with this fishing method are flatfish, swordfish, tunas and whales.

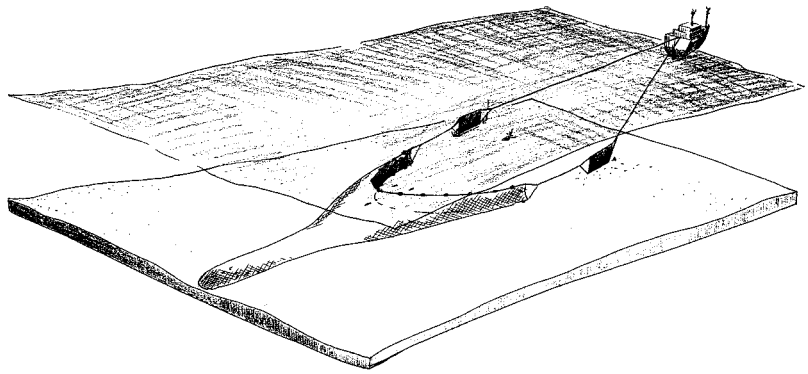


Figure 7.7 Catching principle and construction of an otter trawl, showing the trawl connected by the sweeps to the trawl doors (otter boards) and the warps between the trawl doors and the vessel. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

7.4.2 Trawls and dredges

Trawls and dredges are often called towed gear or dragged gear.

Catching principle

The catching principle and construction of trawls are shown in Figure 7.7.

Construction

In principle, trawls and dredges are netting bags that are towed through the water to catch different target species in their path. During fishing, the trawl entrance or trawl opening must be kept open. With beam trawls and dredges, this is done by mounting the trawl bag on a rigid frame or beam. With otter trawls the horizontal opening is maintained by the so-called otter boards (trawl doors) in front of the trawl which keep the trawl open sideways, while the vertical opening is maintained by weights on the lower part (ground-rope) and floats on the upper part (headline). With pair trawling, the vertical opening is also maintained by weights and floats, while the horizontal opening is maintained by the distance between the two vessels that are towing the trawl. In otter trawling, the trawl is connected to the trawl boards by a pair of sweeps (rope or steel wire) and the trawl doors are connected to the vessel by a pair of warps (normally steel wire). In otter trawling and partially in pair trawling, the sweeps and warps are also part of the catching system, as they will herd fish towards the centre of the trawl path and the approaching trawl, so that the trawl may catch fish over a larger area than that of the trawl opening. With beam trawl and dredges, there is little or no herding of target species in front of the trawl, so the effective catching area is that of the trawl or dredge opening.

Operation

Beam trawls and dredges are exclusively operated on the bottom, where they are towed for a certain length of time (towing time) and distance before being retrieved for the emptying of the catch and being set again for another tow.

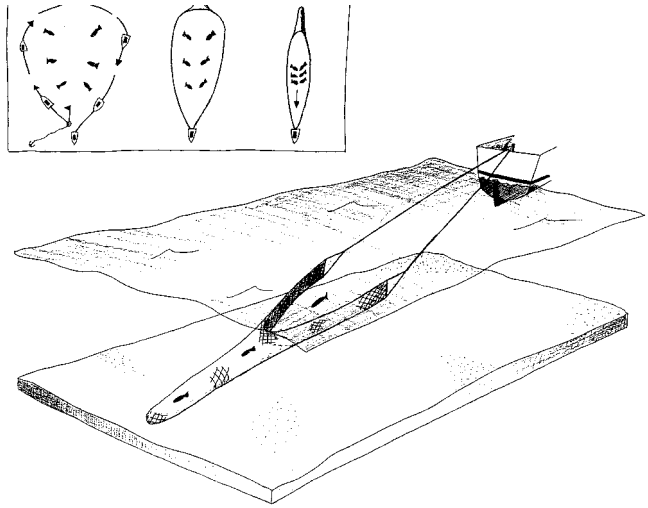


Figure 7.8 Catching principle and construction of seine nets. Expanded view: three stages of the catching process. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

Otter trawls and pair trawls are most often operated on the bottom to catch different demersal target species. However, these gears are also commonly used for pelagic (or midwater) trawling at different depths between the surface and the seabed. This is done by attaching more floats to the head rope of the trawl opening as well as regulating the trawl depth by varying the length of warp and towing speed. In most pelagic trawling, the trawl depth is monitored by depth sensors on the trawl so that the fishing depth can easily be adjusted to that of the fish targets.

Target species

Beam trawls are mainly used for catching flatfishes such as plaice and sole as well as for different species of shrimp. Dredges are commonly used for harvesting scallops, clams and mussels. Demersal otter and pair trawls are used to catch a great variety of target species such as cod, haddock, hake, sandeel, flatfish, weakfish, croakers and shrimps. Pelagic trawls are used in the fisheries for various pelagic target species, such as herring, mackerel, horse-mackerel, blue whiting and pollock.

7.4.3 Seine nets

Catching principle

The catching principle and construction of seine nets is shown in Figure 7.8.

Seine netting (including two variations known as Danish seining and Scottish seining) can be described as a combination of trawling and seining (see later). When setting the gear, the first warp (rope) is attached to an anchor with a surface buoy (Danish seining) or a buoy only (Scottish seining) and set in a semicircle. Then the seine bag is set before paying out

the second warp in another semicircle, back to the buoy (attached to the anchor in Danish seining). When the seine and warps have sunk to the bottom, the warps are hauled. As they are tightened, the warps move inwards towards the centre line between the vessel and the seine bag. Fish in the encircled area will then be herded towards the central part of the area. As the warps are further tightened, the seine bag moves forward and catches the fish.

Construction

As mentioned earlier, the main parts of a seine net are the seine bag and the warps. The seine bag is similar to a trawl bag, where the entrance is kept open by floats on the headline and a weighted ground line (foot rope). The warps are usually made of heavy rope, so that they maintain good contact with the bottom for as long as possible during tightening in order to herd the fish towards the central area for later capture by the seine bag.

Operation

The seine net was originally constructed for the capture of flatfish on soft and smooth bottoms and operated as described earlier. In later years, this gear has also been developed to be operated on rougher bottoms and in the pelagic zone. A more recent mode of operation is, for instance, used on mid-water shoals of cod. The fishing depth of the seine net is then determined by large surface floats connected to the head rope of the seine net by lines, the length of which corresponds to the desired fishing depth.

Target species

The seine net is still commonly used to catch different flatfishes such as plaice and sole, but has in recent years become an important gear also for cod and other demersal target species.

7.4.4 Beach seines

The catching principle and construction of beach seines are shown in Figure 7.9.

Catching principle

The operation of beach seines is based on encircling fish schools by a netting wall made of webbing, where the meshes are so small that the target species does not get entangled.

Construction

The beach seine is an ancient gear that is still widely used. The seine consists of a wall of webbing, for example, with a depth of 5 m by 100 m length, with an upper float line and a lower sinker line. In principle, a similar construction to the gillnet but with smaller meshes,

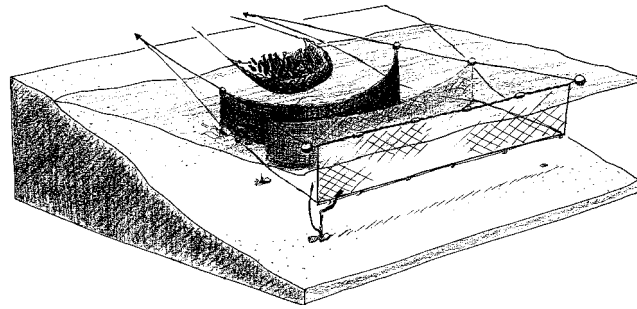


Figure 7.9 Catching principle and construction of (beach) seines, showing four stages of the catching process. Illustration drawn by Ms. Silje Soldal – based on sketches by the author.

so that the fish is entrapped instead of being gilled or entangled. At either end of the seine there are long warps (rope).

Operation

As the name indicates, the beach seine is operated from the beach – using the beach as an additional barrier in the catching process. The gear is normally operated from a small vessel. First, one of the end warps is paid out perpendicular to the beach. Then the seine is set parallel to the beach, and the second end warp is taken back to the beach. The warps are pulled in so that the seine approaches the beach in a semicircular form – most of the fish in the area between the seine and the beach are likely to be caught. In many seine fisheries, both beach seine and purse seine, light is used to attract and concentrate fish before the seine is set.

Target species

Beach seines catch a variety of inshore fish species, both demersal and pelagic.

7.4.5 Purse seines

Catching principle

The purse seine is used to encircle fish schools in mid-water, close to the surface, by a netting wall with small meshes. The lower part of the net is then closed to prevent escapement by diving.

Construction

The purse seine was developed in the 20th century, for offshore fishing. Basically, its construction is similar to that of the beach seine. However, below the sinker line, the purse seine is equipped with a series of metal purse rings spaced at regular intervals. By hauling in the

purse line that runs through the purse rings, it is possible to purse and close the bottom part of the seine so that the encircled fish cannot escape.

Operation

The purse seine is always operated from a vessel, varying in size from small coastal purse seiners of 15 m in length to large ocean going purse seiners as large as 100 m length. When a fish school has been located, the catching operation starts by dropping a surface buoy with a line connected to the end of the seine. As the vessel moves forward, the drag from the buoy line will pull the purse seine overboard and the seine is paid out in a circle around the fish school. When the setting is completed, the buoy is picked up, and the purse line is pulled in to purse and close the bottom of the seine. Then the seine is pulled in until the fish are concentrated in the last (and often reinforced) part of the seine from where they are taken on board with a brailer (large dip net) or by a fish pump.

In modern purse seine fisheries, hydro-acoustic equipment (sonar) is widely used for locating fish schools and also for monitoring the position of the school relative to the gear during the setting of the seine.

Target species

Purse seine fishing is used almost exclusively for pelagic fish such as herrings, sardines, sardinellas, anchovies, mackerels and tunas.

7.4.6 Other fishing gears and devices

The most common fishing gears and methods are briefly described earlier. There are, however, a great variety of different gears which are specialised varieties of the main gear types and methods. For more details, or description of gears that fall beyond the scope of this manual, it is recommended to use some of the more comprehensive works on fishing gears and methods cited in 'Sources and recommended reading'. Some devices and techniques are, however, used with different fishing gears to improve the catch efficiency.

Light is used to attract fish in many fisheries but is most often used with purse seining, beach seining or other varieties of seine fishing. In darkness the light will attract the target species either directly or indirectly by attracting and illuminating prey organisms. The light source is often lamps mounted on a vessel or small raft. After some time the net is set around the light source with the attracted fish.

Fish aggregating devices (FADs) are also commonly used in some areas to aggregate fish. These can consist of anchored rafts of logs or other material and act as artificial habitats that will attract fish and other organisms over time, and hence create good fishing spots that can be exploited by different gears. This is also the case with artificial reefs that are made either by shipwrecks or by deliberately dumping objects on otherwise flat and sandy seabeds to create fish habitats. The FAO Code of Conduct (Paragraphs 8.11.1–8.11.4) encourages the use of such structures, provided they are used in a responsible manner.

Different stupefying devices are also used to capture fish. Explosives (dynamite) will stupefy fish, some of which will float to the surface so that they can be picked up. The use of

explosives with fishing is, however, regarded as a very destructive practice as the explosion most often kills far more fish than those that are caught – and can, in addition, ruin valuable fish habitats such as coral reefs.

Different chemicals can also be used in the same way. Rotenone (a poison derived from plants) is one of the best known examples used to stupefy fish, mainly in freshwater systems. As with explosives, the use of chemicals gives a high risk of killing far more fish and other organisms than those that are harvested. The use of chemicals with fishing should therefore be considered as not responsible.

The FAO Code of Conduct (Paragraph 8.4.2) specifically calls for the prohibition of 'dynamiting, poisoning and other comparable destructive fishing practices'.

7.5 Gear selectivity and ecosystem effects of fishing

Before commenting on the selectivity properties and ecosystem effects of different fishing gears, it may be useful to give a brief description of relevant factors and definitions.

The catching process

The catching process starts as the fishing gear is deployed in the water and ends as it is retrieved from the water – be it ashore or on the deck of a fishing vessel. Throughout the catching process, there may be encounters between the gear and various fish and other marine organisms, including sea birds, and bottom habitats.

Ecosystem effects of fishing

The effect of fishing on the ecosystem is primarily the removal of the organisms caught in the fishery, but also includes the direct and indirect effects caused by the gear during the catching process – such as destruction of bottom habitats (e.g. corals), 'ghost fishing' by lost fishing gears, pollution, etc.

Selectivity

The selectivity of a certain fishing method depends on its ability to select the desired ('target') species and sizes of fish from the variety of organisms present in the area where the fishery is conducted.

The total selectivity of a fishing method is the combined result of the inherent selective properties of the fishing gear and the way it is operated. With most fishing gears, it is possible to impair or improve the selectivity by changing the gear configuration or the operation. For example, in trawl fishing the catch of small fish can be reduced by increasing the mesh size and/or by the use of sorting devices such as sorting grids or large mesh panels that allow for escapement of the smaller fish. The fisher can also select for target species and sizes by avoiding areas and periods where there is a high probability of catching small fish or otherwise undesired bycatch. The FAO Code of Conduct (Paragraphs 7.2.2 and 8.5) requires the minimisation of the catch of non-target species and of discards.

Bycatch

Bycatch is anything that is caught in the fishing process beyond the species and sizes of the targeted marine organisms. There is a great variety of bycatch species, ranging from jellyfish, sponges and corals to unwanted or unmarketable fish species or sizes, as well as turtles, marine mammals and sea birds. Bycatch can be classified into three main groups: (1) marketable and legal (2) non-marketable and/or (3) non-legal. Non-economic bycatches consist of organisms that are non-marketable for the fisher, while non-legal bycatches are sizes or species of marine organisms that are protected by regulations.

Thus, in most cases, marketable and legal bycatch is welcomed by the fisher, while all other bycatch should be avoided. However, the capture of some bycatch is normally unavoidable. Most fisheries regulations do, therefore, allow for a certain amount of bycatch, for example a certain percentage of undersized catch of a target species or a certain amount of an otherwise protected species. For example, in the New Zealand trawl fishery for squid, a certain number of sea lions are tolerated as bycatch, but the fishery is closed as soon as this number is reached for the specific fishing season. In the Barents Sea cod fishery, a bycatch of 15% (in numbers) of undersized fish (less than 42 cm) is tolerated within the legal frames of the fishing regulations.

Discards

Discarding, which means throwing parts of the catch back into the water, is a common practice in most fisheries, although the amount of discard varies significantly between different fisheries. Discards are most often organisms that are not marketable or give a low price compared with the more valued target species. The survival of discarded organisms depends on the ability to survive in air, the time they are kept out of the water and how they are handled before being discarded. However, it should be expected that most discarded organisms suffer high mortality, which adds a 'hidden mortality' to the fishing mortality that is calculated from the landed catch.

Unintentionally, modern fisheries management has encouraged increased discarding in many fisheries. With the introduction of quotas and licences for different species, it is often illegal to catch and land certain species of fish. Thus it is not uncommon, particularly in mixed-species fisheries, to find large-scale discarding of valuable, marketable fish (e.g. cod and saithe) because the trip quota or monthly quota has been exceeded. In addition, in some fisheries, small fish under the legal size limit for landings may also be discarded.

'High grading' is another form of discarding where only the most profitable part of the catch is retained, while less valuable fish are discarded. This phenomenon is also often linked to a quota system where the fisher tries to get the maximum value from a limited quota by keeping only the most valuable part of the catch and discarding the rest.

Unaccounted mortality

Unaccounted mortality is the mortality of marine organisms from injuries caused by encounters with the fishing gear during the fishing process. One example is fish that die from infections or osmotic imbalance caused by scale loss after escapement through trawl or gillnet meshes. The introduction of mesh size regulations, for example in trawls, should therefore be taken into account, and be accompanied by, studies of the survival of fish that are released

through trawl meshes or sorting devices. If the released fish suffer high mortality, there is little to be gained by sorting them out of the fishing gear, which is the case with vulnerable species like herring. However, studies have shown that cod and several other demersal species have high survival rates after escapement from or encounter with fishing gear.

Ghost fishing

The term 'ghost fishing' is used to describe the capture of marine organisms by lost or abandoned fishing gear. This is particularly a problem with gillnets, trammel nets and pots. The gear is usually lost because it becomes stuck on rough bottoms containing corals and stones, causing the buoy line to break during retrieval. Nets or pots may then continue to fish for years. Captured fish and crustaceans will die and serve as attracting bait for more fish and other organisms. Ghost fishing may therefore represent a serious problem in many areas, causing 'hidden fishing mortality' over a long period of time. The FAO Code of Conduct (Paragraphs 7.2.2 and 8.4.6) draws attention to the need to minimise ghost fishing.

Habitat effects

Destruction of bottom habitats is particularly a problem with the use of dragged demersal gear such as beam trawls, otter trawls and dredges. Corals and other epifauna have been and may be destroyed over large areas. It is still debated as to whether these gears have any real negative effect on soft, sandy bottoms. However, it has been documented that trawling has ruined large areas of coral, which has a very low recovery rate, and other epifaunal organisms (see also section Demersal trawls). Here, the FAO Code of Conduct (Paragraph 7.2.2) calls for the development and use of environmentally safe fishing gear.

Catch quality

Properties of fishing gears, and the way in which they are operated, also affect the quality of the catch, thus having an indirect ecosystem effect by the misuse of natural resources. In gillnet fishing, poor quality results from too long a soak time. This results in fish dying in the nets and either rotting or becoming damaged by scavengers; therefore, that part of the catch is not marketable and has to be discarded. This may also be a problem in longline and pot fishing. In trawling, particularly with large catches, it is not uncommon that part of the catch is ruined by squeezing in the trawl bag or becomes of inferior quality because of too long storage on deck before it is processed. This too is contrary to the requirements of the FAO Code of Conduct (Paragraph 8.4.4).

Energy efficiency

Use of energy, particularly fossil fuel, is also an ecosystem-related aspect of fisheries. The energy efficiency (i.e. fuel consumption per unit of landed catch) varies considerably with different fishing gears and methods, from negligible use of fuel to more than 1 litre of fuel per kilogram of landed catch. This is covered in the FAO Code of Conduct (Paragraph 8.6), calling for energy optimisation.

Pollution

Fisheries can contribute to air pollution through emission of combustion gases. The relative pollution effect from different fisheries is closely related to their energy efficiency.

Pollution of water from fisheries is mainly by loss of fishing gear or by deliberately discarding old gear and equipment as well as oil products and chemicals at sea. These two aspects are covered by the FAO Code of Conduct (Paragraphs 8.8 and 8.7, respectively) in response to the provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL73/78).

7.5.1 Selectivity properties and ecosystem effects of different fishing methods

The following is a description of the general selectivity properties and ecosystem effects of the different fishing gears and methods mentioned under Sections 7.3 and 7.4. For a proper evaluation of the ecosystem effects of fishing, each specific fishery has to be analysed separately, as the selectivity properties and ecosystem effects of a certain fishing method may vary considerably with geographical area, time of year and how the gear is operated.

The following are a few examples.

- Gillnets that are operated in shallow water and are hauled on a daily basis will yield catches of higher quality and with less risk of gear loss and ghost fishing compared with gillnets operated in deep water with a soak time of several days.
- Pelagic gillnets that are fished in the vicinity of sea bird breeding sites may have high bycatches of sea birds in the breeding season but not in other periods.
- Bycatch of juvenile fish in demersal trawling may vary considerably with the availability of juveniles, the species composition, towing speed and general catch rates.

So, even if the intrinsic selective properties and other ecosystem impacts of a certain fishing gear may be regarded as fairly constant, the effects caused by the gear on fish stocks and the rest of the ecosystem may vary with diurnal, seasonal and long-term changes in species and size composition of organisms available to the fishing gear and with differences in fishing practice.

Gillnets

In general, gillnets are considered to be very size-selective with catches of fish sizes that correspond well to the chosen mesh size. However, due to entangling a small proportion of larger and smaller fish may be taken. The species-selectivity of gillnets is not particularly good and as different fish species grow to different sizes, there is always a possibility of catching juveniles of a large species when using small-mesh gillnets for a smaller target species. Another negative impact of gillnets is the bycatch of sea birds, marine mammals and turtles. Although limited information exists on the real effect of such bycatches on the populations of these organisms, it has generated concerns, particularly for pelagic gillnet fishing.

Information on unaccounted mortality of fish after escapement from gillnets is scarce. However, observations of fish with wounds from gillnet meshes are commonly made in catches by other gears, but the actual mortality rates from such injuries are not known.

Ghost fishing is one of the most criticised aspects of gillnet fishing and may have severe negative effects, particularly in deep water gillnet fisheries. The energy efficiency of gillnet fishing is generally high with a correspondingly low air pollution effect.

As mentioned earlier, the catch quality of gillnet caught fish can be high. However, gillnets that are operated with soak times of several days tend to produce catches of inferior quality, as fish caught early in the fishing period may die and start to deteriorate long before the nets are retrieved.

Trammel nets

Compared with gillnets, trammel nets have very poor size-selective properties and they will also catch a greater variety of species. The problem of ghost fishing is, however, lower as trammel nets generally are operated in shallow water with less risk of gear loss. Nevertheless, ghost fishing problems should be anticipated due to loss of trammel nets that get stuck on rough bottoms like coral reefs.

Handlining and trolling

Handlining and trolling are not particularly size-selective and in principle not very species-selective either. However, these gears are commonly used in specific seasons or at specific grounds where the fishers, by experience, are able to catch only one or a few species, so that the catches are usually dominated by a few targeted species. Otherwise, handlining and trolling are generally regarded as ecosystem-friendly and energy-efficient ways of fishing which produce catches of high quality.

Longlining

Despite the fact that longlines may attract and catch a large variety of fish species and sizes, this gear is considered to have medium to good species and size-selective properties. The species-selectivity of longlines can clearly be affected by the type of bait used, as different species have been shown to have different bait preferences. The size-selective properties can partly be regulated by the hook and bait size as many studies have shown a correlation between the size of hook and bait and the size of the fish caught. The longline attracts fish from several hundred meters away, and as large fish have a greater swimming and feeding range than smaller fish, this adds to the size-selective properties of longlines.

Bycatch of marine mammals is no particular problem with longlining, but there might be significant bycatches of different seabirds which mainly are caught as they try to catch the baited hooks during the setting of the lines. This problem has been recognised by FAO member states, leading to the development of the FAO International Plan of Action (IPOA) for Reducing Incidental Catch of Seabirds in Longline Fisheries[1]. The IPOA specifies some optional, technical and operational measures for reducing the incidental catch of seabirds, including, for example, increasing the sinking rate of baits and the use of bird scaring lines

[1] See http://www.fao.org/fishery/ipoa-seabirds for the full text of the Plan of Action.

which are towed behind the vessel, above the longline being set. The use of circle hooks (as compared with J-hooks) has also proven to increase catch rates of fish target species while bycatches of, for example, turtles and sea birds are reduced.

Little is known about the unaccounted mortality of longlines, but fish that are lost during retrieval of longlines do often suffer mortality. Ghost fishing may be regarded as a minor problem with longlining and this gear is not considered to cause significant adverse habitat effects. The energy efficiency of longlining is generally high, with typical energy coefficients from 0.1 to 0.3 (kilogram fuel per kilogram of landed catch), which is in the same range as that of gillnetting.

Longline caught fish are in general of high quality, but as is the case for gillnetting, long soak times may lead to reduced catch quality mainly due to bottom scavengers (sea lice, hagfish) that may attack and eat parts of the hooked fish.

Pots

As with longlines, the species-selectivity of pots may be regulated by the bait used. Lobster fishermen, for instance, often use 'sour' or rotten fish as bait to avoid catching crabs in their lobster pots. As with longlines, the attraction of fish and crustaceans to baited pots tend to attract the larger animals in the fished area. The size-selectivity of pots may be further improved by the use of the so-called escape gaps, the size of which allows for escapement of smaller animals. Unaccounted mortality is not regarded as a problem with pot fishing, and this gear has negligible effect on bottom habitats. There is, however, a certain risk of ghost fishing, as lost pots may continue to fish long after they are lost. This can be reduced by having certain parts of the pot made from a bio-degradable material. Furthermore, pot fishing is regarded to have a high energy efficiency and good to superior catch quality, as the catch normally remains alive and in good condition.

Traps

Traps are usually constructed of relatively fine meshed webbing to avoid the tangling of fish and other organisms, so their size- and species-selectivity is generally low. As the caught animals usually stay alive, and as traps are most often operated in shallow water, they allow for easy release and high survival of unwanted catch organisms. With responsible fishing practices, the actual selectivity properties of traps may therefore be good and the unaccounted mortality is low. Traps in general have little adverse impact on bottom habitats, they are not considered to create severe ghost fishing problems and the energy efficiency and catch quality of trap fishing are high.

Spears and harpoons

The capture of fish and other animals by spears and harpoons is probably one of the most environmentally friendly fishing methods. As the target is identified before capture, the fisher can be very selective regarding both species and size of prey. Fishing with spear or harpoon may give some unaccounted mortality of wounded animals that escape and, when used in reef areas, the use of spears can lead to damage to coral, but apart from these, there are no

substantive adverse effects related to ghost fishing or habitat destruction and the energy efficiency and catch quality is generally high.

Pelagic trawls

Pelagic trawls generally have high species-selectivity as they are commonly used for catching schooling pelagic fish that tend to occur in single-species aggregations. The size- selectivity is poorer, as the fish bag of the trawl is usually made from small mesh webbing to avoid meshing by smaller individuals. Successful trials have been done with sorting grids that effectively release the smallest fish (e.g. with trawling for mackerel). However, these have not been applied in practical fishing, as many pelagic fish seem to suffer high mortality after being released from the fishing gear – mainly caused by the loss of scales which easily leads to secondary infections and osmotic imbalance. At present, sorting systems for the release and protection of juvenile pelagic fish are therefore not recommended. Unaccounted mortality is hence a minor problem with pelagic trawling and this gear, naturally, does not have any ghost fishing or habitat destructive effects.

The fuel consumption of pelagic trawling can be high, but still the energy efficiency might be relatively good as large catches are often made during short time periods. The catch quality of pelagic trawls is also relatively high, although large catches may give some squeeze- and pressure damage to the fish in the trawl.

Demersal trawls

Demersal trawls are used for the capture of a great variety of bottom fish and crustaceans (mainly shrimps and prawns) while dredges are used to harvest molluscs (clams and scallops).

Fish trawls

Otter trawls are widely used for the capture of different demersal fish species – most often in the so-called mixed-species fisheries. The size-selectivity may, to a certain degree, be regulated by the cod-end mesh size. Ideally, a certain mesh size should allow for the release of all fish below a certain size. However, the mesh size selection of trawls may be hampered in many ways. With increasing catch load in the cod end, the meshes tend to stretch and close, so that the effective mesh size is significantly reduced. Clogging (closing) of meshes by fish getting stuck in them is another common problem that leads to poorer selectivity. The choice of mesh size for a certain target species may not give ideal selection of other species with different growth characteristics, a problem that is related to all mixed-species fisheries.

Considerable research and development effort has been spent in recent years to improve the size- and species-selectivity of trawl gear. Different solutions have been developed and implemented, like the sorting grid that is now used in many demersal trawl fisheries. Figure 7.10 illustrates the sorting grid which is now mandatory in the Barents Sea bottom trawl fishery for cod and other demersal species. Most of the juvenile fish will escape through the openings between the metal bars of the grid, while larger fish will be retained.

Where introduced, sorting grids and other selective devices such as larger square mesh panels and escape gaps have led to improved selectivity of bottom trawls, first of all the

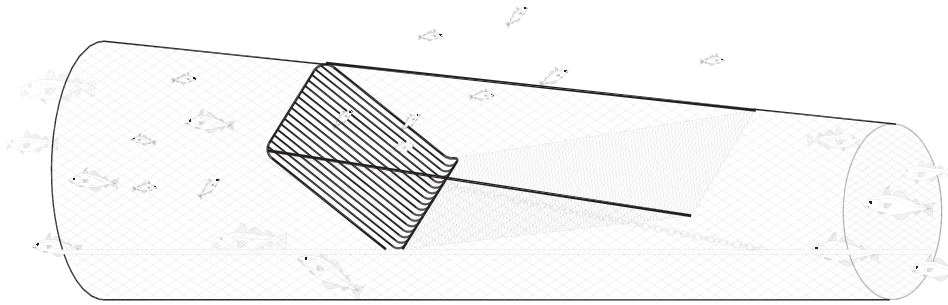


Figure 7.10 Section of fish trawl with sorting grid. Smaller fish are released through the grid slots, while larger fish swim or are swept down under the grid and go to the cod end (Figure adapted from Olsen 2008).

size-selectivity, but also the species-selectivity, although there is still a need for further improvement.

Releasing juvenile fish has little benefit if they do not survive. Extensive studies carried out on demersal target species like cod and haddock have shown very low unaccounted mortality of fish that have escaped through meshes or sorting grids. Although studies of survival after escapement so far have only been done for a restricted number of species, there seems to be a general indication of high survival of demersal fish after encounters with and escapement from fishing gears, when the fish are sorted out and released at fishing depth.

Demersal trawls do inevitably have an effect on bottom habitats. Several studies have been carried out within this field. On soft and sandy bottoms, there might be an adverse effect on the species composition in an area with a shift towards species that are less dependent on the epifauna removed by trawling. Most studies do, however, indicate that soft bottom habitats will be restored after some years without trawling. On hard bottom, trawling is likely to cause more long lasting or irreversible habitat effects, for example by destroying corals that have restoration periods from decades to more than a hundred years. Large areas of coral bed have already been destroyed by bottom trawling, particularly with the development of heavier and stronger trawl gear.

Trawls are occasionally lost, but this gear loss is not associated with any risk of ghost fishing.

The energy efficiency of demersal trawling is low, and air pollution from the emission of exhaust gases is correspondingly high due to the high energy needed for pulling the net, doors, sweeps and warps through the water.

The catch quality of trawl caught fish varies with the amount of catch and the towing time. Large catches do often lead to lower catch quality because of the squeezing of the fish in the trawl bag and a longer time before the last part of the catch is processed on board.

Shrimp trawling

Shrimp trawls are in principle comparable to demersal otter trawls for finfish capture and also have comparable ecosystem effects, except that the selective properties of shrimp trawling are very poor. This is due to the small meshes that have to be used in shrimp trawls in order to retain these relatively small target species. Shrimp trawling does therefore produce relatively

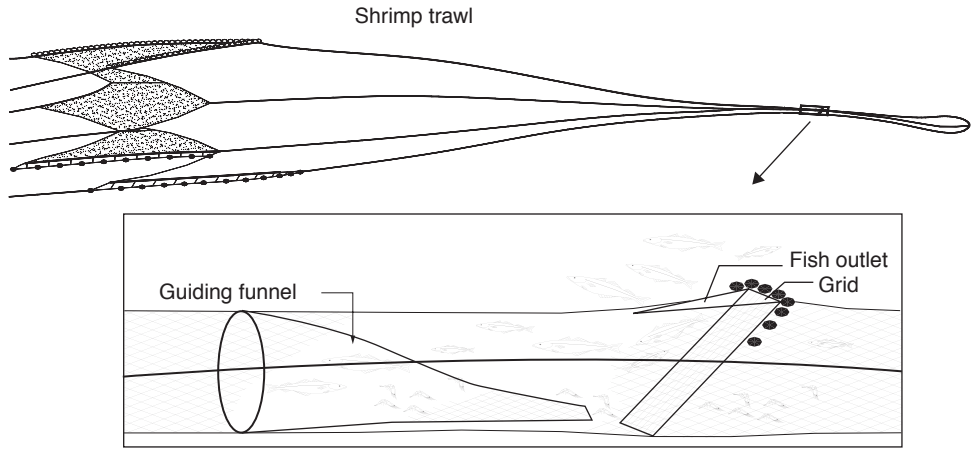


Figure 7.11 Shrimp trawl with sorting grid (expanded view). Shrimp and fish that pass backwards in the trawl are guided by a funnel to the bottom of the backwards slanting metal grid. Shrimp and fish of comparable size will pass through the slots of the grid and go to the cod end, while larger fish and other organisms (e.g. jellyfish) will slide upwards over the grid and are released through the outlet (Figure adapted from Isaksen and Valdemarsen 1994: Bycatch Reduction in Trawls by Utilizing Behaviour Differences. In Fernø and Olsen (Eds.) 1994).

large amounts of bycatch, a high proportion of which is discarded. The development of sorting grids has, however, improved the species- and size-selectivity in many shrimp trawl fisheries, as most fish over a certain size are released from the trawl through the sorting grid or bycatch reduction device (Figure 7.11). Bycatch of the youngest fish groups (1–2 year olds) is still a problem, as they have overlapping sizes with those of the shrimps.

Bycatch of turtles during shrimp trawling operations is a problem in some areas but is being widely addressed through the use of Turtle Excluder Devices (TEDs) which operate on similar principles to other bycatch reduction devices.

Beam trawling

The ecosystem effects of beam trawling are, to a larger extent, comparable to those of demersal otter trawls. Compared with otter trawls, however, beam trawls will generally have poorer energy efficiency and a stronger impact on bottom habitats.

Seine nets

Seine netting is also fairly similar to demersal trawling with respect to most ecosystem effects. However, the seine net is considered to cause less habitat destruction, is more energy-efficient and does produce a better catch quality overall.

Purse seine

Purse seining is a non-selective gear regarding fish size, as the mesh size is chosen to be so small that there should be no risk of mass meshing of fish, even by the smallest size groups of

the target species. However, in cases where the fish size in the catch is too small, as estimated from samples taken from the seine, there is usually an opportunity to release the fish. The species-selectivity is fairly high and both from the fishers' experience and by use of modern sonar equipment it is not too difficult to identify the species before the seine is set.

There is a certain risk of unaccounted mortality in purse seining. Pelagic fishes are in general sensitive to contact with fishing gears which easily leads to loss of scales and resulting mortality. This can be related to the above-mentioned release of unwanted species or sizes of fish, but the main cause of unaccounted mortality in purse seining is the escapement of fish after net rupture due to large catches and/or bad weather.

There is extremely low risk of ghost fishing with lost purse seines. The energy efficiency is high because of the relatively large catches that give a high CPUE in this fishery. Catch quality is normally also high, particularly in modern purse seining where the catch is pumped directly into refrigerated tanks on the fishing vessel.

Purse seining has generated some adverse publicity as a result of bycatches of dolphin in some tuna fisheries, but effective fishing methods to avoid such capture have been developed.

Beach seines

Beach seines have poor selectivity properties, catching a variety of species and sizes of fish and other organisms. There may be some unaccounted mortality associated with beach seining, while the energy efficiency and the catch quality of this gear are generally high.

7.6 Management considerations: selectivity and other ecosystem effects of fishing

Table 7.1 gives an example of how the properties of different fishing gears could be evaluated in terms of their selectivity and ecosystem effects. Here the various ecosystem effects are given a rank from 1 (non-favourable) to 10 (favourable), giving an overall index of average ecosystem effect. This table must of course only be regarded as a guideline and an example of how to approach an evaluation of different fishing gears and fisheries from a management point of view. Thereafter, the specific fishery in an area should be analysed in more detail and the proposed ecosystem factors should also be weighted according to their importance in a local or regional case. Although a fishing method might be characterised in general as being more or less responsible, attention should be paid to where, when and how it is being used. The evaluation and elaboration of technical regulations should be done in co-operation with the fishers to establish better understanding by them of the aim of the regulations and to hear and consider their advice on the regulations and their implementation (Chapter 11).

Other specific factors, for example the socio-economic implications of different gears, could be added to a specific evaluation, as a guideline to future management strategies with respect to choice and priorities between different fishing methods. These factors should be included with the information used to assist in the design of management strategies and plans (Chapters 1 and 16).

This form of evaluation can also be used to identify present or future ecosystem-related weaknesses with existing fishing methods and practises, as a baseline for research and development aiming at improvements of selective properties and undesired ecosystem effects.

Table 7.1 Generalised estimates of ecosystem effects of fishing for different fishing methods – ranked on a scale from 1 (non-favourable) to 10 (highly favourable) with respect to different ecosystem-related factors.

Ecosystem effects and gear type	Size selection	Species selection	Unaccounted mortality	Ghost fishing	Habitat effects	Energy efficiency	Catch quality	Ecosystem effect index
Gillnets	8	4	5	1	7	8	5	5.4
Trammel nets	2	3	5	3	7	8	5	4.7
Handlining	4	4	6	10	9	9	9	7.3
Longlining	6	5	6	9	8	8	8	7.1
Pots	7	7	9	3	8	8	9	7.3
Traps	5	5	8	8	9	9	9	7.6
Spear, harpoon	8	9	5	10	10	8	9	8.4
Pelagic trawl	4	7	3	9	9	4	8	6.3
Demersal trawl	4	4	6	9	2	2	6	4.7
Beam trawl	4	4	6	9	2	1	6	4.6
Shrimp trawl	1	1	7	9	4	2	6	4.3
Seine net	5	5	6	9	4	5	8	6.0
Purse seine	–	7	5	9	9	8	8	7.7
Beach seine	2	2	5	10	6	9	9	7.6

7.7 Synthesis and outlook

Since man started to exploit fish and other aquatic organisms, the creativity of fishermen has lead to the development of a variety of different fishing gears and methods. This chapter gives a brief description of various principles of fish capture and the major types of fishing gears used, as well as their properties regarding catch efficiency, selectivity, fuel efficiency and environmental effects beyond removing the target species and sizes from the aquatic ecosystems.

From a management perspective, it is important to have a basic knowledge of the function and effect of different fishing gears as a foundation for the introduction of technical measures and gear regulations in fisheries, even though final implementation of such regulations should be based on scientific experiments to clarify the magnitude of underlying problems in the specific fishery and corresponding expected effects of the regulations.

In the recent past, fisheries management was mainly concerned with development and increased efficiency in fisheries. Since the mid-1980s, however, fisheries management has gradually become more conservation oriented, mainly as a result of over-fishing and depletion of stocks. Together with other regulations, a series of gear regulations has been developed. In addition to regulations aimed at sustainable yields from target species, there has also been a recent trend towards regulations to reduce negative ecosystem effects of fishing, such as bycatch of mammals and sea birds and destruction of corals and other bottom habitats.

This conservation oriented trend within fisheries management has been reinforced by increased public awareness about fisheries. Consumers in many markets are increasingly questioning the sustainability of different fish products – including the methods of capture – producing slogans like 'long-line caught tuna', 'turtle free shrimp' – and many of the large supermarket chains are now competing to have some sort of eco-labelling on their fish products. This trend does obviously influence a development towards more ecosystem-friendly fishing gears and methods, which is now also taken seriously by many actors in the fishing industry. This is, in general, a positive trend towards more sustainable fisheries and an ecosystem approach to fisheries management. However, there is a tendency of global generalisation so that all fisheries within a certain category might be forced into global regulations – for instance introduction of turtle excluder devices (TEDs) in shrimp fishing – even if bycatch of turtles might not be a problem in a specific shrimp fishery. It is therefore important that the introduction of gear regulations is based on solid scientific evidence before their implementation. In the foreseeable future, however, this trend towards more ecosystem-friendly fishing methods is likely to be strengthened.

Cost efficiency and particularly fuel efficiency is likely to be another important factor for future trends in the use of different fishing gears. There is reason to believe that the price of fossil fuels will continue to increase in the future. In addition, many countries are now introducing extra taxes on fuel – related to combustion gases (like CO_2 and NO_x), to reduce the emission of suspected climate-affecting gases related to global warming. This trend will clearly favour the use of fishing gears with favourable fuel efficiency as compared with gears having high fuel consumption per unit of catch.

Sources and recommended reading

Alverson, D.L., Freeberg, M.H., Murawski, S.A. and Pope, J. 1994. *A global assessment of fisheries bycatch and discards*. FAO Fisheries Technical Paper No 339. Rome, FAO. 233p.

Ben-Yami, M. 1976. *Fishing with Light (An FAO Fishing Manual)*. Blackwell Science Ltd., Oxford. 132p.

Bjordal, Å. and Løkkeborg, S. 1996. *Longlining*. Fishing News Books, Blackwell Science Ltd., Oxford. 156p.

Brandt, A. von. 1984. *Fish Catching Methods of the World*. Fishing News Books, Farnham. [See Gabriel for revised edition of this work.]

Cowx, I.G. and Lamarque, P. (eds). 1990. *Fishing with Electricity (Applications in Freshwater Fisheries Management)*. Blackwell Science Ltd., Oxford. 272p.

Eayrs, S. 2007. *Guide to Bycatch Reduction in Tropical Shrimp Fisheries*. FAO, Rome, 120p.

FAO Technical Guidelines for Responsible Fisheries 350/2. Paper Technology and Fisheries Legislation, Annex 1.

Fernø, A. and Olsen, S. (eds). 1994. *Marine Fish Behaviour in Capture and Abundance Estimation*. Fishing News Books, Blackwell Science Ltd., Oxford. 221p.

Gabriel, O. (ed.). 2005. *Fish Catching Methods of the World*, 4th edition. Blackwell Science Ltd., Oxford. 53p.

Hall, S. 1999. *The Effects of Fishing on Marine Ecosystems and Communities*. Fishing News Books, Blackwell Science Ltd., Oxford. 296p.

Kaiser, M.J. and de Groot, S.J. (eds). 2000. *The Effects of Fishing on Non-target Species and Habitats*. Blackwell Science Ltd., Oxford. 399p.

Le Rey, J.-M., Prado, J. and Teietze, U. 1999. Economic viability of marine fisheries findings of a global study and an inter-regional workshop. Rome, FAO. 135p.

Moore, G. and Jennings, S. 2000. *Commercial Fishing (The Wider Ecological Impacts)*. Blackwell Science Ltd., Oxford. 72p.

Nédélec, C. and Prado, J. (eds). 1989. *FAO Catalogue of Small Scale Fishing Gear.* Blackwell Science Ltd., Oxford. 224p.

Nédélec, C. and Prado, J. 1990. *Definition and classification of fishing gear categories*. FAO Fisheries Technical Paper No. 222. Rev. 1. Rome, FAO. 92p.

Nolan, C.P. (ed.). 1999. *Proceedings of the International Conference on Integrated Fisheries Monitoring*. *Sydney, Australia, 1–5 February* Rome, FAO. 378p.

Olsen, S. 1994 Fish behaviour, selectivity and fish-capture technology. In Nakken O. (Ed.): Norwegian spring-spawning herring and Northeast arctic cod – 100 years of Research and Management. Tapir Academic Press, Trondheim. 177p.

Robertson, J. 2006. *Minimising Discards to Improve Global Fish Stocks*. Blackwell Science Ltd., Oxford. 256p.

Sainsbury, J.C. 1996. *Commercial Fishing Methods (An Introduction to Vessel and Gear)*. Blackwell Science Ltd., Oxford. 368p.

Scharfe, J. (ed.). 1989. *FAO Catalogue of Fishing Gear Designs*. Blackwell Science Ltd., Oxford. 160p.

Tietze, U., Prado, J., Le Rey, J-M. and Lasch, R. 2001. *Techno-economic performance of marine capture fisheries*. FAO Fisheries Technical Paper No. 421. Rome, FAO. 79p.

Tietze, U., Thiele, W., Thomsen, B. and Rihan, D. 2005. *Economic performance and fishing efficiency of marine capture fisheries*. FAO Fisheries Technical Paper No. 482. Rome, FAO. 68p.

Chapter 8
Area and Time Restrictions

Stephen Hall

8.1 What are area and time restrictions?

This chapter describes approaches to fisheries management that restrict access by fishers to a geographic area, either throughout the year or at particular times, usually in certain seasons. Although using the approach to help conserve fish stocks is a form of input control – the subject of Chapter 9 – we treat it separately because area and time restrictions also allow managers to meet wider conservation and equity objectives.

Article 2 g of the FAO Code of Conduct describes the fisheries manager's responsibility for wider conservation objectives by stating that fisheries should 'promote protection of living aquatic resources and their environments and coastal areas'. More recent policy developments place further demands on fisheries managers to embrace these wider goals. Most notable among them is the commitment by the 2002 World Summit on Sustainable Development to establish a representative network of Marine Protected Areas (MPAs) by 2012. Many countries are responding to this and other calls by integrating area closures into their fisheries management systems.

Practitioners refer to area closures (whether temporary, seasonal or permanent) by various names, each of which may have a particular formal definition, depending on the legislative or cultural context. Of these various terms, however, 'Marine Protected Area' is, perhaps, the most widely used. The International Union for Conservation of Nature (IUCN) defines an MPA as *Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment* (Kelleher and Kenchington, 1992).

Similarly, the Canadian Oceans Act defines an MPA as

> *an area of the sea . . . (that) has been designated . . . for special protection for one or more of the following reasons:*
>
> *(a) the conservation and protection of commercial and non commercial fishery resources, including marine mammals, and their habitats;*
> *(b) the conservation and protection of endangered or threatened marine species, and their habitats;*
> *(c) the conservation and protection of unique habitats;*
> *(d) the conservation and protection of marine areas of high biodiversity or biological productivity; and*
> *(e) the conservation and protection of any other marine resource or habitat as is necessary to fulfill the mandate of the Minister (of Fisheries and Oceans).*
>
> Section 35(1) Oceans Act, Canada.

Both these definitions leave great latitude on the limits for fishing. To give greater focus several groups have proposed classification schemes for the various levels of area restriction that fall under the MPA banner. As with most such schemes, however, there are still shades of grey at the boundaries between classes. It may be better, therefore, to think about a continuum between complete prohibition of access at one end (often termed a 'no-take' reserve) and fairly minor restrictions at the other.

One important distinction, however, is between area closures set up solely to limit fishing and multiple-use management areas that also place controls on other forms of use. On coral reefs, for example, rules might limit tourist operators to certain mooring locations to minimise anchor damage and fishers might have limits placed on the types of gear they can use.

Multiple-use zones usually arise when there is a coastal management framework that seeks to reconcile the interests and values of all stakeholders. Thus, the consultative and legislative context for creating and managing a multiple-use area is likely to differ markedly from that for an area set up solely for fisheries management purposes. While much of this chapter will deal with the fishery-specific issues surrounding closed areas, the reader should bear in mind the wider set of issues they must consider for multiple-use management areas.

8.2 Why would you establish area or time restrictions?

It is hard to overemphasise how important it is to identify clearly the objective for any proposed area or time restriction. Without clarity about what you want to achieve, it will be difficult to decide how best to implement the measure or to communicate and negotiate effectively with the relevant stakeholders. It is also impossible to know whether the measure has worked. As expressed in the definitions of an MPA noted earlier, one might choose to adopt an area or time closure for one or several of the reasons set out in the following list. One can place these possible objectives into three broad categories:

1. Fisheries management issues
2. Broader conservation considerations
3. Equity issues.

In reality, the boundary between these is rarely clear-cut, but it is convenient to make the distinction nevertheless.

8.2.1 As a fishery-management measure

Article 6.3 of the FAO Code of Conduct voices the general principle that 'states should prevent overfishing and excess fleet capacity and should implement management measures to ensure that fishing effort is commensurate with the productive capacity of the fishery resources and their sustainable utilization'. Area and time restrictions can help fishery managers in achieving these objectives in the following ways.

Limiting harvest of specific life stages

Often it is desirable to prevent fishing on particular stages of a species life cycle that are especially vulnerable to capture or are critical to overall production. One example is of species that aggregate in particular areas to spawn (see e.g. section Vulnerability to fishing in Section 2.3.2). If one allows fishing on these spawning grounds, it might not only disrupt reproduction in that year but also prevent most fish from having a long reproductive life. If there are important characteristics of the spawning habitat that fishing might affect, one may need a permanent area closure. Alternatively, closing the area during the spawning season may be enough.

There might also be a need to protect areas where juveniles live. Fishing for the adults in an area with a high proportion of juveniles may lead to high juvenile bycatch that fishers cannot land for legal or practical reasons. Closing the area would allow those fish to grow and contribute to the landed catch in later years.

While protecting particular life stages may require continuous closure of an area, it is often possible to only restrict fishing access during a particular season. The most suitable measure will depend on the biology of the species concerned. Closed seasons, for example, are most often used for fast-growing species with a short recruitment period, such as prawns and shrimps. In fisheries for such species, closing the fishery early in the season allows individuals to grow to larger and more valuable sizes.

Protecting depleted stocks and their habitats during the rebuilding phase of a fishery

If a fishery has collapsed, or is close to collapse, the action one must take to allow the stock to rebuild is likely to be severe. One alternative of course is a total ban on fishing. In some circumstances, however, it may be possible to protect stocks effectively with less severe measures that allow fishing in some areas but prevent it in those that are critical to the rebuilding.

Protecting genetic reservoirs

The value of a population being genetically diverse is important to understand, even though the benefits are often difficult to quantify. Understanding a few basic ideas helps one to appreciate why genetic diversity matters. The first is that the mortality fishing imposes often leads to differences in survival for fish with different characteristics. For example, most fishing is size selective and removes large fish while leaving smaller ones. Fish in the population that start breeding at small size are, therefore, likely to contribute more offspring to the next generation because fish that breed at larger size may not have a chance to spawn before fishers catch them. Thus, if size at first reproduction is a characteristic that passes on from parent to offspring (i.e. it is inherited), size-selective fishing will eventually reduce the average size at which fish breed. This is the process of natural selection. What does this mean for the fishery? In essence it means that adult fish will on average be smaller, which will usually be undesirable for the fishery. Setting up a reserve in which larger-bodied adults can persist may act as a genetic reservoir to offset this trend.

Another important idea is that genetic variation provides insurance against changing environmental conditions. For example, some individuals in the population may grow better in warmer years and others when it is cold. If fishing reduces the population to very low levels, one may lose individuals with a genetic trait that is important for the population in the future. This might reduce the capacity of the species to adapt to new circumstances. Protected areas to help preserve genetically diverse sub-populations may in some settings provide insurance against such possibilities.

Protecting habitat that is critical for the sustainability of fished populations

Some types of fishing gear can have large negative effects on benthic (sea, lake or riverbed) habitat that may be important for the sustainability of fished populations (see Section 7.5). Often such habitats will be inshore, where juvenile fish aggregate in areas with high physical structure such as seagrass beds or mangroves. Article 6.8 of the FAO Code of Conduct makes specific reference to protecting such critical fisheries habitat as a guiding principle for responsible fisheries.

Although such habitats are more easily identified in shallow water, there may also be environments in deeper water that are important for similar reasons. Structured benthic habitats are especially at risk from mobile fishing gears, such as trawls and dredges, which can destroy them with only a few passes of the gear. Thus, it may be desirable to prevent access to trawlers and dredgers in such areas, while allowing pot or trap fishing.

To restrain excess fleet capacity and optimise the value of the catch

Article 7.2.2a of the FAO Code of Conduct states that management measures should, among other objectives, ensure that 'excess fishing capacity is avoided and exploitation of stocks remains economically viable'. When there is excess fishing capacity, a short, properly chosen fishing season can prevent overexploitation of the stocks. However, although effective, such measures are by no means ideal from an economic perspective because they can lead to seasons of only a few days, when so called fishing derbys or the race for fish takes place.

With this approach, choosing the right time to open the fishery can have a big effect. In the Bering Sea pollock fishery, for example, managers delay the season until late January when the pollock roe commands the highest price at market.

8.2.2 As a wider conservation measure

Coastal waters in particular are often rich in habitats that we value for aesthetic or other nature conservation reasons. Some types of fishing will alter these habitats in ways that harm those values, and permanent area closures in particular provide a way to protect them. It is no surprise, therefore, that increasing their number is a key goal for many environmental groups and agencies. As noted earlier, the 2002 World Summit on Sustainable Development responded to these calls by committing to establish a representative network of MPAs by 2012. Many national governments are responding.

Importantly, MPAs for wider conservation purposes will normally seek to limit other activities besides fishing. Often, however, fishing is a primary target for control, partly because it is something that it is possible to limit, but also because, by definition, it directly exploits a biological resource. Other less direct impacts, such as pollution from diffuse sources on land, are more difficult to deal with, especially given the open nature of marine systems and high rates of exchange.

MPAs may also serve an insurance function. There is also the possibility that area and time restrictions can help fishery managers to achieve these wider conservation objectives in the following ways.

Protecting benthic habitats of high conservation value

As noted earlier, some benthic communities can be especially vulnerable to towed fishing gears. When such areas have high conservation value, a permanent closed area that prevents fishing by such methods is probably the only measure that will protect them. The FAO Code of Conduct supports such protection under Article 7.2.2d, which states that management measures should provide that 'biodiversity of aquatic habitats and ecosystems is conserved and endangered species are protected'.

Limiting bycatch

In some groundfish fisheries, for example off Alaska, the authorities set closed seasons to minimise bycatch rates or potential effects on marine mammals.

Protecting attributes of the ecosystem that are critical for preserving ecosystem services

The idea that ecosystems provide services to people is one that has only recently emerged (Costanza *et al*., 1997). In essence, the term 'ecosystem service' connotes the idea that ecosystems perform functions that we should value and that keeping the basic structure of the system will ensure that these functions continue. Many argue that we can help preserve ecosystem services by preventing fishing in particular areas.

One can divide these services into two classes – extractive services, which provide products for use, and existence services, which provide benefits simply by being present. Examples of the latter include biophysical regulatory functions such as control of water or nutrient flows or climate, and cultural (e.g. recreational and spiritual) benefits. Of course, extractive ecosystem services include providing fish, oil and minerals. Restricting access to particular areas is one approach for managing these. Of more relevance to this discussion, however, are the regulatory existence services, examples of which include water purification and nutrient regeneration.

Unfortunately, while stakeholders may often identify the need to protect ecosystem services, there is rarely a satisfactory basis for defining such services, the threat fishing

poses to them or the protective measures they need. However, studies can sometimes show that certain areas (e.g. reed beds, wetlands, mangroves or lagoonal areas) are important for protecting coastal environments because they remove high nutrient loads from land run-off before entering the sea. In such cases, one might justifiably argue for protecting these habitats from fishing methods such as trawling because it would preserve an important ecosystem function.

Despite the comments aforementioned, however, managers should be aware that justifications for permanent area closures, based on arguments about ecosystem function, may often be much more difficult to substantiate. Groups often claim, for example, that high levels of biodiversity are important for ecosystem function. While there are many valid justifications for protecting biodiversity, the evidence for a positive relation between diversity and ecosystem function remains a subject of great scientific debate. There may well be other factors that are far more important for preserving function than preserving the number of species and much sounder arguments for an MPA that do not depend on such contentious scientific hypotheses. Managers should be wary, therefore, of giving undue weight to justifications for an MPA on biodiversity-function grounds. Preservation of biodiversity for its own sake, however, may be perfectly appropriate.

8.2.3 To resolve equity issues

Many groups value our seas, lakes and rivers and derive benefit from them. The demands of these groups differ and often conflict. Area and time restrictions can offer a means for reconciling these demands fairly.

Providing a mechanism to resolve conflict over multiple use of areas or resources

The coastal zone in particular is an area where a multiplicity of users want access. Often, however, uses are incompatible with one another. Trawling in an area where pot fishers work, for example, can lead to major conflicts when the trawlers destroy pots. Similarly, combining a submarine practice area with trawling is a bad idea! There are many other possible conflicts of use (e.g. tourism, shipping and recreational fishing), where the only tractable solution is to restrict activities to certain areas by some form of zoning arrangement, either permanently or seasonally.

Reserving valued marine and coastal resources for the preferred use of residents or traditional users

Often indigenous cultures have traditional (and sometimes exclusive) claims on certain lands or resources. Providing exclusive use in an area or season is a way to honour such claims. Similarly, local fishers' cooperatives or communities might benefit from area-based rights protection. Non-governmental (community-based) management and customary tenure arrangements are often also important in these circumstances (see Chapters 10 and 11).

8.3 What are the advantages and disadvantages of area and time restrictions?

8.3.1 Advantages

Conceptual simplicity

It is relatively easy to explain and justify to many parts of the community the reasons and approach for setting up area or time closures. To use a terrestrial analogy, placing a fence around a piece of land clearly fixes a property right and identifies the basis for its use. Dividing the fishing season, or fishing grounds, among different fishers is an obvious parallel for resolving access issues. In principle at least, it is also a fairly straightforward matter to specify an area or time closure in legislative terms once there is agreement that the measure is fitting. For enforcement there are also clear advantages to a reserve system or fishing season when the local fishing community supports the initiative and polices it. For example, control of fishing effort by closed areas or seasons appears one of the few choices open to managers of marine municipal fisheries in the Philippines (see Section 8.4.2).

A good choice for protecting bycatch species that one cannot protect by other means

When bycatch species are at serious risk, closed areas or seasons offer a means for protecting them. It is important to recognise, however, that the appropriateness of such approaches critically depends on a clear understanding of the biology of the species concerned. For example, for highly mobile species that range over an entire region, a closed area may be ineffective or needs to be impracticably large.

A tractable approach for stock protection in complex fisheries or when data are poor or absent

The potential for permanent area closures to be a cost-effective means for managing coral reef fisheries has been recognised for some time, but now it is also advocated for some temperate fisheries. The major fisheries objective for such reserves is to build up spawning stock to ensure recruitment supply to fished areas via larval dispersal, and to preserve or increase yields in adjacent areas through spillover of large fish. If they work, they have the added advantage of often being easier to set up and run than more conventional fisheries management programmes. This feature makes them especially attractive for coral reef fisheries which are almost always multispecies and support many artisanal or subsistence fishers who use a wide variety of gears and land their catch at many sites over a wide area. These features make it difficult to collect even the most basic information such as catch and effort that conventional management approaches need.

A sound approach for protecting sensitive benthic habitats

Sensitive benthic communities are vulnerable to mobile fishing gears. If one wishes to protect these communities, which often have recovery times of 10–15 years following significant impact, some form of area closure will often be the only alternative.

Insurance against uncertainty

The information scientists can gather and the predictions they are able to make are uncertain (see Section 13.3). Indeed, much of the present focus of fisheries research is on finding ways to quantify and communicate that uncertainty to managers so that they can make informed decisions. With uncertainty comes the need for insurance policies that provide some degree of safeguard against unseen events.

Closed areas can sometimes provide such insurance and their use is consistent with the manager's need to adopt a precautionary approach as outlined by the FAO in its Technical Paper on the Precautionary Approach to Fisheries (FAO, 1996). For example, a reasonable management goal for a demersal fishery might be that the stock should remain at above 60% of the unexploited biomass over a given time horizon, say 20 years. Preserving such levels would put the stock at a sustainable yield that many fisheries aspire to. Using this goal, theoretical analyses for a large-scale demersal fishery on the temperate continental shelf suggest that setting up an MPA could be an important bet-hedging strategy. It could act as an effective insurance policy that would both protect the long-term future of stocks and yield higher average catches (Lauck *et al*., 1998). One should stress, however, that in this theoretical exercise, the MPA has to be very large to be effective. This latter conclusion is supported by independent work undertaken by the International Council for the Exploration of the Sea to examine the utility of a closed area in the North Sea to protect cod stocks. Given current understanding of fish movements and the behaviour of fishing fleets, even closing one quarter of the North Sea to fishing would do little or nothing to protect the widely dispersed and mobile cod. Although MPAs can theoretically serve to protect stocks, they will not do so in all cases (see Section 8.4).

A tool for continual improvement

An important benefit of an area or season closure is that it can be somewhere for researchers to learn more about how an ecological system works. Treating an MPA as a form of management experiment can give information to improve future decision-making. This may be the intended primary goal from an area or time closure but more often it will be ancillary. The most deliberate efforts to learn come from an adaptive management approach, where one tries new measures specifically to test ideas so that one can adapt management using what one learns. Section 8.4 gives a good example of this approach.

8.3.2 Disadvantages

Inter-agency negotiation

When the objectives for setting up an area or time closure affect the interests of those who are not fishers, it will be necessary to negotiate with other agencies and stakeholders. This can often be a long and drawn-out process that needs negotiating skill and political judgement. Critical to overcoming the difficulties inherent in the process is a clear and agreed set of shared objectives for the measure. If the parties can agree on these objectives, however, the added effort of including other agencies and stakeholders can strengthen commitment to and improve compliance with the measure.

Sometimes high economic cost

Although an area or time closure may be effective for conserving a stock, other measures for stock conservation may be more desirable on economic grounds. For example, if a closure forces fishers to work at greater distances from home ports or at times when catches are less likely, the economic efficiency of the fleet can fall.

Enforcement

Although setting up an area or time closure might look good on paper, the measure is pointless without a convincing way to enforce it. As noted earlier, when fishers support a closure there can be a strong incentive for self-policing, which can make enforcement relatively straightforward. In other circumstances, however, especially when the closure covers a large or remote area, the practicalities and costs of enforcement can be prohibitive. Always, one must weigh the cost of enforcement against the expected benefits from the measure. One technology that is becoming increasingly prevalent is satellite surveillance (see Section 14.3.2). This will become increasingly practical and cost-effective in future.

Enthusiasm versus appropriateness

There is great enthusiasm for setting up permanently protected areas. Unfortunately, however, this enthusiasm may lead to unsound judgement about the likely effectiveness of such a measure for achieving specific objectives. This possibility is especially likely for fishery management, where great doubts often remain about the effectiveness of permanent 'no-take' zones. While fish abundance and biomass inside protected areas usually increases when an MPA is set up, empirical evidence for increased fish catches remains controversial. Careful quantitative evaluation of the benefits that will flow from an MPA is especially important when the objective is stock protection. It may well be, for example, that other input or output controls are more suitable for managing the fishery. Indeed, under many circumstances it will be a combination of MPAs, effort reduction and other controls that will ensure a sustainable stock.

For wider conservation purposes, however, a permanent area closure may be enough. Indeed, if one wishes to protect sensitive habitats from mobile fishing gears it is difficult to see an alternative. This example serves, once again, to stress that clarity of objectives is essential.

8.4 Case studies

8.4.1 Gulf of Mexico: a mixture of area and time closures

One can find good examples of seasonal closures in many fisheries, but shrimp fisheries seem especially suited to the approach. This is because juveniles often develop in coastal estuarine environments and move offshore as they mature and reproduce, which is often within about a year. Thus, to prevent growth overfishing, which occurs when fishers catch individuals at sub-optimal size, closing the fishery during the early period in the growing season can be effective. Authorities in Texas, for example, close state and federal waters from mid-May

to mid-July. This measure protects juvenile shrimp migrating from the bays to the Gulf of Mexico, thus allowing them to grow to a larger, more valuable size.

The Gulf of Mexico also provides a good example of how a combination of area and time closures can minimise conflict between fishing sectors. In this example, the State of Florida has a closure zone which restricts the trawl fishery for shrimp and trap fishery for stone crab (Figure 8.1).

Coral reefs

There are many examples of the closed area approach for coral reefs, with authorities temporarily or permanently banning fishing on portions of or, sometimes, whole reefs. The

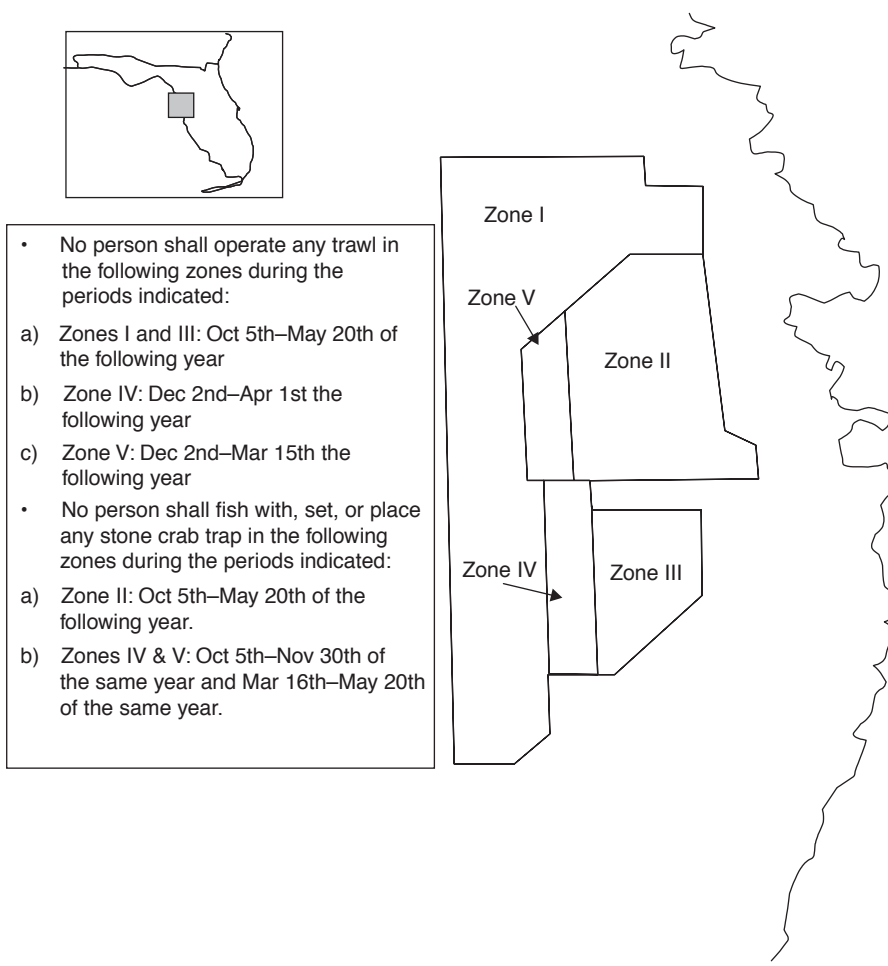


Figure 8.1 The State of Florida Citrus-Hernando shrimp/stone crab closure zone, a 144,000-acre closure area, which restricts access by each fishery to designated areas of seabed for defined periods each year.

objective is often to allow fish stocks to build in the protected regions and preserve or even increase yields in adjacent areas. Tourism may also benefit since unspoilt coral and a rich fish life should attract more visitors. Of course, given the destructive nature of some forms of tourism, or of destructive fishing (especially poisoning and dynamite fishing, which although illegal, still occurs), closed areas on coral reefs also serve a conservation purpose. Positive benefits to the fishery do not have to be a goal – getting these other benefits may be justification enough. Care may be needed, however, to address any equity issues that might arise when a closed area is established. Experience in several places has shown that local fishers can be disadvantaged while benefits accrue to people from outside the region who can take advantage of the new arrangement through non-fishing activities.

Affording protection to even relatively small areas of coral reef often increases the densities and biomasses of target species within the reserve area (Gell and Roberts, 2003). Perhaps the best demonstration of this effect is from the Philippines, where researchers compared fish populations in two small areas (Sumilon and Apo) where protection from fishing was variously imposed and then relaxed over a 10-year period. Figure 8.2 (Figure 9.1 from Hall, 1999) summarises the results of this study. For Sumilon, densities of large predatory fish decreased significantly when it was opened to fishing in 1985 and 1993, and increased significantly threefold following periods of protection. In contrast, at Apo there was a steady increase in densities over an 11-year period of protection while comparable non-protected areas showed little change.

These results and other similar results from other areas show that fish populations in both temperate and tropical regions respond to full protection, even in relatively small areas. In Kenya, for example, commercially important species became 10 times more abundant on a fully protected reef than in a reserve that allowed only artisanal fishing. Managers should note, however, that one can quickly lose these gains. In the Philippines study described earlier, for example, it took only 1.5 and 2 years of unregulated access to remove density and biomass gains from 5 and 9 years of marine reserve protection.

Another response that one often sees is an increase in the number of species found in protected areas. For example, researchers in Kenya could only find 58 of the 110 species found

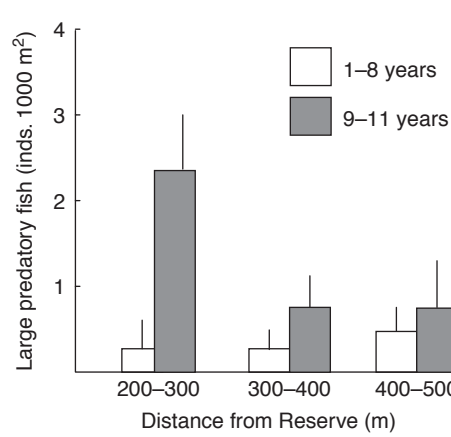


Figure 8.2 The densities of large predatory fish at different distances from the Apo reserve boundary during the first 8 years of reserve protection and from years 9 to 11. Data are means ±1 standard error of the mean. (Redrawn from figure 3 of Russ and Alcala [1996] and reproduced from figure 9.1 in Hall [1999].)

on protected Kenyan coral reefs when they looked on unprotected reefs. Other studies show similar responses; if the objective is conservation, marine reserves can be effective.

Although increases in abundance (and perhaps of species richness) within reserves is a general rule, managers proposing to set up an MPA for fisheries purposes must often justify the step on other grounds. Usually it is that a higher spawning stock biomass inside the reserve will contribute recruits to the adjacent fishery. While some studies do suggest this, it has proved difficult to show convincingly and as a general proposition it is controversial (see section Criteria for stock management for further discussion of this issue).

8.4.2 Surf Zone Fisheries

A tropical fishery, where there is good evidence that a marine reserve increases yields in adjacent fished areas, comes from the De Hoop Marine Reserve on the southern African coast (Attwood and Bennett, 1994). Here, tagging studies over a 5-year period showed that Galjoen (*Coracinus capensis*), a species exploited by anglers, showed two distinct behaviours. Part of the population was relatively sedentary with home ranges within the reserve, while the other part was nomadic. Estimates of the numbers dispersing strongly suggest that the reserve, which spans a 50-km stretch of coastline, was contributing to the fishery by providing a supply of mature fish to both nearby and distant exploited areas.

8.4.3 Georges Bank

On Georges Bank, off the northeast coast of the United States controls on mesh sizes, minimum fish sizes and seasonal area closures failed to conserve demersal stocks. As with many other temperate demersal fisheries, these measures failed because there was no direct control on fishing effort. In response, the authorities set up long-term area closures in 1994 (Fogarty and Murawski, 1998). These areas encompass areas of traditionally high catch per unit effort (i.e. good fishing grounds). They include part of the scallop grounds and important spawning grounds for cod, haddock and yellowtail flounder. The measure also protects sand and gravel areas that may be important for juvenile survivorship.

Murawski *et al*. (2000) describe the effect of this closed area showing that whitefish stocks increased. How much the closed areas contributed to this increase is difficult to know because other management measures also changed over the period. For scallops, however, large increases in the size of stock were almost certainly in response to the closure.

8.4.4 The Plaice Box

The Plaice Box is an area of about 38,000 km^2 along the Danish, German and Dutch coasts. The authorities established it in 1989 to protect juvenile flatfish (plaice and sole) by preventing large vessels from fishing in the second and third quarter of the year. In 1994, researchers analysed the impact of the measure by exploring the benefits of various management options. Their analysis suggested that, if the box were removed, long-term landings and spawning stock biomass would decline by 8–9%. However, it also showed that if managers were to extend the prohibition to cover the entire year, landings and stock biomass would increase by 24–29% (Table 8.1). This large increase was because discarding rates inside the box averaged

Table 8.1 Percentage increase in long-term landings and spawning stock biomass (SSB) for the North Sea fleet relative to the 1994 status quo quarter 2 and quarter 3 closure of the Plaice Box.[a]

Management option	Landings (%)	SSB (%)
Remove box	−8	−9
Extend to quarter 4	+11	+14
Extend to entire year	+14	+17
All year + no discarding fleets	+24	+29

Source: Adapted from Horwood (2000)

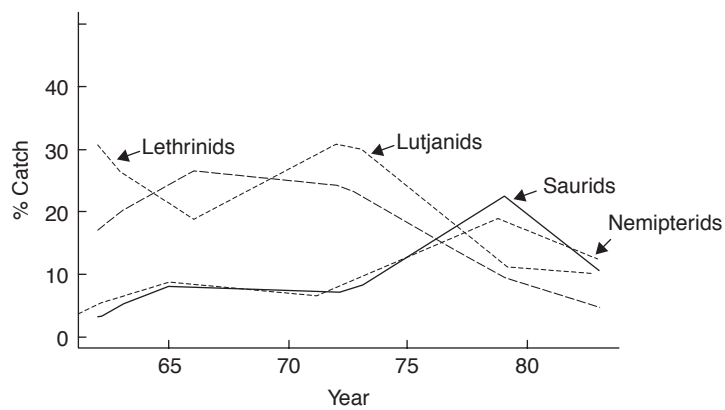


Figure 8.3 Trends in abundance of the four major exploited fish taxa on the Australian Northwest shelf. (Adapted from figure 14.2 in Sainsbury [1988] and reproduced from figure 3.7 in Hall [1999].)

83%. Because of these analyses, the authorities introduced new rules to ban fishing within the box year-round, except for selected vessels, especially those targeting shrimp.

8.4.5 Adaptive management using the closed area approach: an example from northwest shelf of Australia

As noted in Section 8.3.1 under the heading A tool for continual approval, one of the advantages of setting up closed areas is that they provide an opportunity to learn more about the marine environment and progressively improve management decisions. Perhaps the best example of such an approach comes from the northwest shelf of Australia, which also shows how important it is to include in decision-making the possible effects of fishing on fish habitat.

Research survey data from 1960 onwards show that, while the total biomass of fish has not changed as the fisheries of the region have developed, the fish community has altered. *Lethrinids* and *Lutjanids* declined and *Saurids* and *Nemipterids* increased (Figure 8.3; figure 3.7 from Hall, 1999).

The available data also show that the benthic environment has altered over the same period. In particular, the quantity of epibenthic fauna caught in trawls (mainly sponges alcyonarians and gorgonians) was lower than before the trawl fishery developed (Sainsbury, 1987). Underwater video data showed four habitat types in the region based on dominant benthic fauna, and fish catch data showed that *Lethrinids* and *Lutjanids* were almost always associated with habitats supporting large epibenthos. In contrast, the lower value *Saurids* and *Nemipterids* mainly occurred on open sand.

This information led researchers to ask several important management questions for the region:

- Could one reverse the change in the fish and benthic community?
- If changes were reversible, was it worth trying to do so given the uncertainties of the outcome and how long it would take?
- If one were to try, what would be the best way to do it?

The key to answering these questions lies in understanding why the changes occurred. To answer this, researchers identified four alternative hypotheses:

1. Intra-specific dynamics: the changes resulted from independent responses of each species.
2. Competitive release due to fishing: there was a negative influence of *Lethrinus* and *Lutjanus* on the population growth rate of *Saurida* and *Nemipterus*. Thus, when fishing removed the *Lethrinids* and *Lutjanids* it released the *Saurids* and *Nemipterus* from competition and their populations increased.
3. Competitive depression: *Saurida* and *Nemipterus* have a negative influence on the population growth rate of *Lethrinids* and *Lutjanids*, and the populations of these latter two species declined because the former increased for reasons independent of the fishery.
4. Habitat modification: habitat characteristics decide the carrying capacity of each genus separately, so trawl-induced changes in the area covered by each habitat type altered the carrying capacity of the different genera.

All four hypotheses are ecologically reasonable and consistent with the available data. It is important to recognise, however, that each has markedly different management implications. Hypotheses 1 and 2 imply a relatively low productivity of *Lethrinids* and *Lutjanids* with declines in the biomass of these taxa as a result of fishing. Thus, even if one could rebuild stocks, the sustainable yield from the fishery would need to be low to prevent the same decline happening again. In contrast, hypotheses 3 and 4 imply a relatively high productivity for *Lethrinids* and *Lutjanids* under some circumstances. Selective harvesting of these taxa under hypothesis 3 and harvesting without damage to benthic habitat under hypothesis 4 would result in high sustainable catches. These differing implications make deciding why the changes occurred much more than an academic exercise.

To tackle this problem, researchers used a formal evaluation procedure by stating the four hypotheses as explicit mathematical models. Building such models is worthwhile because they allow one to evaluate formally which explanation is most likely to be true given the available data. The statistical analysis suggested that there was a relatively low expected present value from continuing the existing licensed trawl fishery. Instead, the mathematical analysis suggested clear benefits from an immediate switch to a domestic trap fishery.

Partly based on this work, the management agencies for the northwest shelf agreed to conduct an experiment by subdividing the area into three zones. They left one part of the area open to trawlers, closed the second part to them in 1985, closed the third part in 1987 and allowed trap fishing throughout the region. The hope was that closing part of the area to trawls would allow the trap fishery to develop to exploit species which occur in less disturbed habitats.

Despite some difficulties, monitoring of an adapted experiment continued until the mid-1990s. Fortunately, this monitoring provided enough data to evaluate the four hypotheses (Sainsbury, 1997). Figure 8.4 shows how the area closed to trawling experienced an increase in the density of *Lethrinus*, *Lutjanus* and small benthos. The abundance of larger epibenthos stayed the same or perhaps increased slightly. In the area open to trawling, fish numbers declined along with the small and large epibenthos. Around 1997 the authorities further subdivided the spatial management zones, resulting in a more complex spatial arrangement of smaller zones, reflecting the depth zonation of the fish and benthic communities. At this time they also decided to monitor the fishery by measuring catch rate, rather than with fishery-independent surveys. As a result no further information on the state of the benthic communities has been collected.

These results provide a valuable perspective on fishery effects, but it is in the formal evaluation of the four mechanistic hypotheses mentioned earlier that the real strength of this study lies. This is because the data from the experimental period allowed researchers to update the

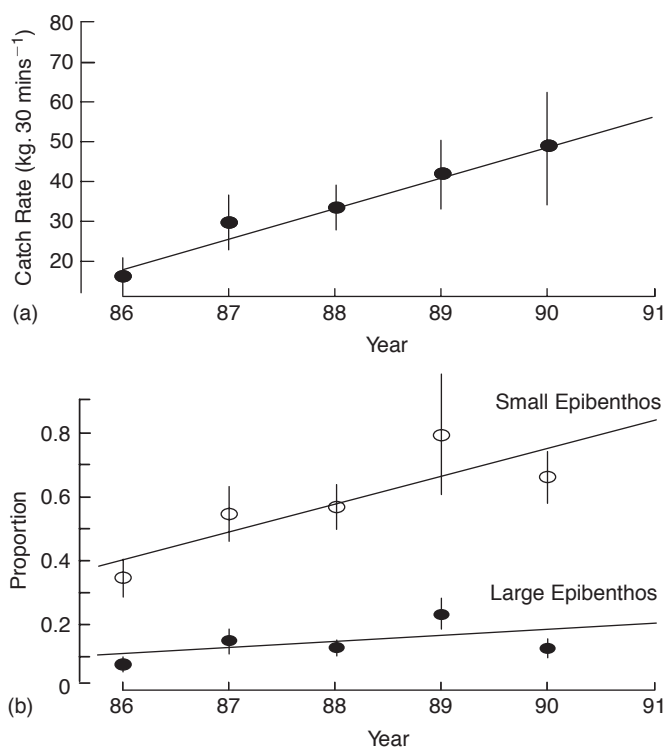


Figure 8.4 (a) Changes in the abundance of fish (*Lethrinus* and *Lutjanus*) (b) Changes in the proportion of large and small epibenthos in areas closed to fishing. (Adapted from figure 2 of Sainsbury *et al.* [1997] and reproduced from figure 3.8 in Hall [1999].)

probabilities assigned to each of the four hypotheses. These updated results showed that one could develop a high value *Lethrinus* and *Lutjanus* fishery on the northwest shelf by protecting the habitat. They also showed that habitat modification by trawling was the most likely explanation for most of the changes in the fish community. Managers who are able to draw on such quantitative and systematic scientific evaluations will be in a much better position to make informed decisions.

The northwest shelf is a good example of how careful study can lead to an improved fishery and a less disturbed benthic community. The ecological mechanisms at work in this area may not apply everywhere but they alert one to how improved understanding of fish ecology can help management if studies are properly focussed.

Another important finding for the northwest shelf, however, is that the timescales for recovery for epifaunal benthos are slower than previously thought. Rather than taking 6–10 years for sponges to grow to 25 cm, it now appears that they need at least 15 years. Video analysis of the effects of the trawl ground rope also showed that about 89% of encounters dislodge the sponge, which probably leads to its death. This slow growth rate and the high chance of removal by a trawl means that measures to protect the habitat need to be effective to preserve the sponge communities needed to support this high-value fishery.

8.5 What are the practical steps towards establishing time and area restrictions?

There is no single recipe for putting in place area or time restrictions, because the steps one must take and the people one must involve will differ depending on the legislative and cultural context. Nevertheless, some general principles can be described that will help managers along the right path.

Perhaps the first and the most important of these concerns the choice of people to involve in solving the problem.

8.5.1 Decide on the management constituency

Deciding who takes part in discussion and decisions (the management constituency) – and the nature of their relationships – is a critical step to developing durable management. As a general principle, a broad group of participants is likely to be more effective than a narrow one. Top-down approaches to design and implementation of management measures within the narrow confines of government departments are often fragile, especially when fishers do not accept them.

Article 10.1.2 of the FAO Code of Conduct refers to this need for wider engagement. It states: 'In view of the multiple uses of the coastal area, States should ensure that representatives of the fisheries sector and fishing communities are consulted in the decision-making processes and involved in other activities related to coastal area management planning and development'. Article 10.1.3 further states: 'States should develop, as appropriate, institutional and legal frameworks in order to determine the possible uses of coastal resources and to govern access to them, taking into account the rights of coastal fishing communities and their customary practices to the extent compatible with sustainable development.' Indeed,

there is great merit in taking this further and widening the circle beyond those involved in fishing, a principle that is discussed extensively in Chapter 11. Involving people and institutions that lie outside the immediate fishery domain, but which have an influence on or are affected by it, is likely to further increase management effectiveness.

Managers should take these articles seriously. Many national governments, development agencies, NGOs and researchers now promote co-management and community-based management approaches and they have a vital role to play. Increasing accountability of national and provincial governments to fishing communities, devolution of power to fishing communities and efforts to enhance the capacity of communities are growing trends that fisheries managers should welcome and embrace. This is perhaps especially true for developing countries where fisheries often take place in more remote areas and where most fishers are small-scale. Here, especially, it will be active involvement of local communities at all stages of planning and implementation of conservation and management initiatives that will lead to responsible and effective fisheries and conservation management (see Chapters 3 and 11).

The skills, tools and approaches needed to ensure productive participation are beyond the scope of this chapter, but managers should not underestimate their importance. Investment, for example, in building the capacity in fishing communities and local and district institutions to take effective part in discussions and decisions may be a vital first step that takes several years.

8.5.2 Set your goal and decide how you will measure progress towards it

This chapter has stressed how important it is to be clear about goals. There may, of course, be multiple objectives for the fishery, in which case it is important to try to specify them in order of priority. While there can be no firm rules about how detailed to specify objectives, being as specific as possible about what you seek to achieve at the earliest opportunity will help a lot. Being explicit about what you will measure to tell you whether you are achieving those objectives will add another level of rigour to your thinking.

If goals for the fishery include those presented in Section 8.2, an area or time restriction may well be the right choice to meet the stated objective. If it is, however, one must recognise that there are no simple standard procedures to draw on to implement the measure. Differing legal and social contexts mean that one will almost always have to adapt the approach taken in one country for use in another.

8.5.3 Specify criteria for site and time selection

Criteria for stock management

Once the objectives for an area or time restriction have been decided, the criteria for selecting candidate sites or time periods should follow logically. Often, the life history of the species involved and the characteristics of the various fisheries the measure is designed to serve will drive the choice. Adequate biological data to support the decision will often be available – nursery grounds and spawning seasons or areas are often relatively well known. Similarly, fishers are acutely aware of where and when conflicts occur. To justify permanent no-take zones in the adult habitat, however, data will often be less comprehensive and the potential

benefits more open to debate. Lauck *et al*. (1998) note the following as 'desirable' features for a no-take reserve, set up to fulfil fisheries management objectives:

1. It should be large enough to protect the fish population if overfishing occurs in the unprotected area.
2. The reserve should serve as a source that can replenish the exploited stock if it becomes depleted. In particular, reserves should protect spawning grounds and any other areas critical to the viability of the population.
3. Enforcement measures must fully protect the reserve, since the almost certain build-up of biomass inside the reserve will be attractive to poachers.

In my view these features are not just desirable, but essential if an MPA is going to work to protect stocks.

For point 3, there should be little difficulty working out what one needs, but it will often be hard to get political commitment to meet the costs. In contrast, points 1 and 2 are a major challenge for ecologists. To decide on the best size and location for closed areas, researchers need to know the relative proportions of the populations and communities of interest within the protected region. They also need to know their potential to serve as source populations for unprotected areas, and where one can find the sensitive habitats one should protect.

8.5.4 Criteria for conservation management

Most conservationists favour larger multiple-use protected areas that provide for several levels of access and of fishing and for collecting in different zones. This arrangement normally allows continued sustainable harvest of food materials in most of a country's marine area. Table 8.2 summarises the IUCN criteria for an MPA.

Assemble information and conduct a preliminary evaluation

Clearly, to address the criteria described in the previous section one needs good economic, social, biological and ecological information. As noted earlier, for many of the objectives one might set for area and time restrictions, biological and fishery data will be enough. For some forms, particularly of permanent area closures in adult fish habitat, the information for basing a decision about a closed area will often be poor or unavailable. Whatever, the available data, a manager must seek to learn from experience elsewhere and, if possible, from scientifically defensible quantitative models that predict the likely outcomes of different management scenarios. The following questions may be important to ask.

Will my measure protect fish stocks?

In the limit of course, where one closes most of an area to fishing, the answer has to be 'yes' (unless the small piece that is left open happens to be the only spawning ground). A better question, however, is under what range of circumstances is area or time restriction likely to succeed in this objective and by what mechanisms? This is a complex and difficult question, for which we will find no simple answers, especially for permanent area closures in adult fish habitat. That said, some generalisations are beginning to emerge.

Table 8.2 The factors or criteria that have been proposed for deciding whether an area should be included in an MPA or for determining the boundaries of an MPA.[a]

Criteria	Description
Naturalness	The extent to which the area has been protected from or has not been subject to human-induced change.
Biogeographic importance	Either contains rare biogeographic qualities or is representative of a biogeographic 'type' or types. Contains unique or unusual geological features.
Ecological importance	Contributes to the maintenance of essential ecological processes or life support systems. The degree to which the area either by itself or in association with other protected areas encompasses a complete ecosystem. Contains some or all of the following: • a variety of habitats • habitat for rare or endangered species • nursery or juvenile areas • feeding, breeding or rest areas • rare or unique habitat for any species • high genetic diversity, that is diverse or abundant in species terms
Economic importance	Existing or potential contribution to economic value by virtue of its protection. Economic contribution could be delivered through • recreation • subsistence • use by traditional users • appreciation of tourists • important habitat for species with economic importance
Social importance	Has existing or potential value to the local, national or international community owing to its heritage and historical, cultural, traditional, aesthetic, educational or recreational qualities.
Scientific importance	Value for research and monitoring
International or national significance	Has the potential to be listed on the World or National Heritage list or declared as a Biosphere reserve, of other national or international significance, or subject of a national or international conservation agreement
Practicality/feasibility	• Degree of isolation from external destructive influences • Social and political acceptability, degree of community support • Accessibility for education, tourism, recreation • Compatibility with existing uses, particularly by locals • Ease of management, compatibility with existing management regimes

[a] Source: Adapted from Kelleher and Kenchington (1992)

Models of MPAs show that effects on yield depend on dispersal in the larval, juvenile and adult stages, size and configuration of the reserves and the status of the fishery. From these models three generalisations about fishery yields have emerged (Hilborn *et al*. 2006). First, MPAs should increase yields when one cannot control fishing effort and fish populations will

otherwise be overfished. However, they are less likely to be effective when fishing is only light. Second, MPAs will only improve yields most when adult movement rates are intermediate. When rates are too high no reproductive potential builds up in the reserve. When they are too low, adults stay inside MPA boundaries and the benefits remain inside the reserve and do not contribute much to the fishery. A corollary of this is that the higher the rates of adult movement, the larger the area of MPA needed. Last, MPAs reduce variability in catches when random events such as recruitment failure happen. Thus, an MPA can make fisheries less sensitive to uncertain fishing mortalities.

Despite their promise, area and time restrictions do not guarantee success in preserving stocks. The Organization for Economic Cooperation and Development (OECD), for example, reviewed the benefits to fisheries of 52 restricted areas. They found that in 32 cases stocks declined or showed major oscillations and in only 16 had stocks increased or remained the same (OECD, 1997). Importantly, all the successful cases also used limited entry or total allowable catches (TACs) and other input controls such as size or sex selectivity, so the contribution the area closures alone made to the outcome was impossible to determine. This is an important point – regulatory structures that mix effort controls, total catch controls and closed area approaches will usually provide the best combination of economic yield and buffering against uncertainty (Stefansson and Rosenberg, 2005).

Despite this pessimistic OECD analysis, however, there is good evidence that, for many purposes, area and time restrictions have been successful. As noted earlier, one can also find MPAs that successfully conserve stocks by protecting adult fish habitat in coral reef and other tropical systems where the biology of the fish is favourable and other management measures are also in place. One might expect similar positive benefits in temperate systems where the fish species of interest have similar life history characteristics to their tropical counterparts. However, the case for permanent closures is less convincing for temperate continental shelf fisheries, although seasonal closures such as the Plaice Box (see Section 8.4.4) do seem to confer benefits.

How big does my MPA have to be or how long should restrictions run for?

As noted earlier, for temperate demersal fishery management, area closures in adult habitat may need to be especially (and perhaps unfeasibly) large to be effective. This may be especially true in fisheries managed through controls on TAC, where fishers may divert effort to other areas and negate potential benefits (Horwood, 2000). Horwood argues convincingly, for example, that claims for benefits to fish stocks by closing 10–20% of fishing grounds are too optimistic for temperate European demersal fisheries. However, seasonal or other closures to protect juveniles appear to be effective. For coral reefs, McClanahan and Kaunda-Arara (1996) suggest that many small reserves may be preferred from a fisheries perspective. These authors found that small reserves increased the total catch in adjacent areas, but a larger park did not. This effect may be due to the lower ratio of edge to park area in a large reserve. Unfortunately, data for tropical demersal trawl fisheries are lacking and there is little analysis available to guide decision-making for these circumstances.

For more general marine conservation, the idea of a park or reserve is somewhat different to that on land where one usually thinks of a protected area as being separate, with the surrounding areas having little influence within the park. In contrast, for marine parks, there is usually a lot of exchange across the legislative boundaries defined by lines on a map. It

follows that the minimum size needed to meet the objectives for an MPA is often likely to be many times larger than that needed on land. In particular, there is general agreement that to protect areas of high productivity or biodiversity, an MPA must encompass as much of the ecosystem as possible and consider fully the many influences on productivity and diversity.

What are the legislative issues associated with its implementation?

Legislative processes for establishing closed seasons will usually fall solely within the domain of the fisheries manager, with little need to involve agencies or stakeholders other than those with a direct interest in fishing. In contrast, setting up permanent MPAs will probably need inter-agency agreements and negotiations. Of course, the precise legislative environment for an MPA will differ from country to country. Thus, one can provide no general guidance here beyond stressing the value to a manager of fully understanding the legislative issues for their own circumstance.

How will we enforce the measure?

As with all fisheries management measures, the ease with which one can monitor and enforce compliance critically affects feasibility. Unfortunately, for area and time restrictions, there is no straightforward answer to the enforcement question. It is, however, an essential one to ask. An analysis by the OECD in 1997, for example, showed increased enforcement costs or problems for six fisheries, while five reported no difficulties. One could imagine a situation, for example, where one could easily police a short fishing season for boats from a limited number of ports. In contrast, permanent closure of a large and remote area would be almost impossible to control without technological support such as satellite tracking of vessels or air surveillance.

Without doubt seasonal or area closures are likely to be most effective where the fishers themselves agree wholeheartedly with the measure and will police it themselves. Achieving this happy state often critically depends on how effectively one integrates fishers into the discussion and decision to set up the restriction. Effective inclusion may shift perceptions of fishers from one dominated by unhappiness at the loss of access the measure imposes to the enthusiasm for the benefits it provides. It is unlikely that fishers will cooperate without that shift.

Is there a need for adjustment funding?

An important consideration when you wish to restrict access to fishing grounds is the extent to which it will displace fishing effort elsewhere and the likely outcomes of such displacement. If effort displacement is a concern, one may need to consider providing funding for structural adjustments to reduce capacity and compensate fishers for loss of access – in effect moving towards an input control.

8.5.5 Evaluate the need for underpinning research

It is difficult not to be sceptical of some of the bolder claims made for the success of area and time restrictions. In particular, with respect to permanent area closures in adult fish habitat,

it is certainly not axiomatic that they will protect stocks or improve yields. This is not to suggest, however, that one should use uncertainty about their value as a management tool as a reason not to establish them. On the contrary, the case for trying the permanent reserve approach is often compelling. A sensible manager, however, will try to learn from the attempt by making efforts to understand the underlying mechanisms that lead to success or failure. A programme of research to study the effects of the closure and the reasons for them is a prerequisite for doing this. There are also perhaps more politically compelling reasons for mounting research programmes in association with area restrictions when resources allow. Consider the following scenario:

A marine reserve is set up using arguments that benthic habitats will be conserved and fish stocks will be enhanced. This reserve was established in the face of great resistance by fishers, who perceived the measure as an unnecessary constraint on their trade. In the end the fishers accept the measure, albeit grudgingly. Imagine now that after 5 years, there were no detectable improvements in catches. One could imagine at least four reasons:

1. the reserve was not big enough;
2. the area was not closed for long enough;
3. the reserve was in the wrong place;
4. reserves do not work in this system for some other reason.

Reasons 1 and 2 argue for even stricter constraints and reason 3 argues for a rethink. Fishers of course are likely to argue for reason 4 and for a reopening of the region. The point is that without information about the ecological mechanisms that operate in the region, there is no basis for saying which of these explanations is the most likely one. Thus, one is unable to decide whether to make the reserve bigger, move it or abandon reserves altogether. Of course, even with a directed research programme the information will not be perfect, but adopting a Bayesian approach (see Sections 8.4.5 and 13.5.1) is the soundest route towards a sensible decision. Without efforts to monitor the effectiveness of any area or time restriction and understand why they succeed or fail, one may compromise the goal of protecting fish stocks and the marine system in general.

Despite the aforementioned comments, it should be recognised that it will often be difficult to demonstrate the benefits offered by an area or time closure for fishery management over reasonable timescales. Researchers estimate, for example, that using the standard 5% statistical significance level, it would take over 30 years to get a 90% chance of recognising a 20% improvement in mean flatfish recruitment after establishing the Plaice Box (see Section 8.4.4). In many circumstances, therefore, it will probably take more than a decade to show the benefit of a closed area (Horwood, 2000). Similarly, for coral reef fish communities fully to recover from the effects of fishing one may need up to 20 years of a closed area (McClanahan *et al*., 2006).

8.6 Synthesis and outlook

There are many compelling reasons for a fisheries manager to seriously consider closed areas and time restrictions as a complement to other measures. Seasonal restrictions can be effective in many fisheries and are an important tool in the management armoury. In many

respects, justifications for their use (i.e. the benefits that will flow to fishers) and the process of implementation are likely to be relatively straightforward compared to permanent area closures. The political gulf between a temporary loss of access each year and a loss for ever is enormous.

From a fisheries management perspective, the benefits that flow from permanent area closures are usually less easy to predict than that from seasonal closures. Also, even if one accepts that implementation of a permanent reserve will provide higher production levels in adjacent fished areas, there is a danger of wasting the potential benefits. If, for example, the fishery remains open access, the increased production is likely to attract new entrants into the fishery, thereby driving it back towards bio-economic equilibrium. From a wider conservation perspective, however, closed areas have an important and clearly defensible role to play and some form of zoning arrangement will often effectively serve conservation values. Given the increasing trend towards (and pressure for) national and regional networks of MPAs, fisheries managers throughout the world will need to ensure they are familiar with the issues surrounding these approaches. In thinking about their use, however, they should bear in mind that sole reliance on such measures is a mistake if sustainable management of fisheries is the goal.

Sources and recommended reading

Attwood, C.G. and Bennett, B.A. 1994. Variation in dispersal of Galjoen (*Coracinus capensis*) (Teleostei: Coracinidae) from a marine reserve. *Canadian Journal of Fisheries and Aquatic Science*, 51: 1247–1257.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387: 253–260.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. FAO, Rome. 41p.

FAO. 1996. *Precautionary approach to fisheries*. Part 1: Guidelines on the precautionary approach to capture fisheries and species introductions. FAO Fisheries Technical Paper. No. 350.1. FAO, Rome. 52 p.

Fogarty, M.J. and Murawski, S.A. 1998. Large-scale disturbance and the structure of marine ecosystems: Fishery impacts on Georges Bank. *Ecological Applications*, 8: S6–S22.

Gell, F.R. and Roberts, C.M. 2003. Benefits beyond boundaries: The fishery effects of marine reserves. *Trends in Ecology and Evolution*, 18: 448–455.

Hall, S.J. 1999. *The Effects of Fishing on Marine Ecosystems and Communities*. Blackwell Science, Oxford.

Hilborn, R., Micheli, F. and De Leo, G. 2006. Integrating marine protected areas with catch regulation. *Canadian Journal of Fisheries and Aquatic Science*, 63: 642–649.

Horwood, J.W. 2000. No-take zones: A management context. In: *Effects of Fishing on Non-Target Species and Habitats: Biological, Conservation and Socio-economic issues*. Kaiser, M.J. and De Groot, S.J. (eds). pp. 302–312. Blackwell Science, Oxford.

Kelleher, G. and Kenchington, R. 1992. *Guidelines for Establishing Marine Protected Areas*. IUCN, Gland, Switzerland.

Lauck, T., Clark, C.W., Mangel, M. and Munro, G.R. 1998. Implementing the precautionary principle in fisheries management through marine reserves. *Ecological Applications*, 8: S72–S78.

McClanahan, T.R. and Kaunda-Arara, B. 1996. Fishery recovery in a coral reef marine park and its effect on the adjacent fishery. *Conservation Biology*, 10: 1187–1199.

McClanahan, T.R., Verheij, E. and Maina, J. 2006. Comparing the effectiveness of a marine park and a multiple-use collaborative fisheries management area in East Africa. *Aquatic Conservation Marine and Freshwater Ecosystems*, 16(2): 147–166.

Murawski, S.A., Brown, R., Lai, H.L., Rago, P.J. and Hendrickson, L. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges Bank experience. *Bulletin of Marine Science*, 66(3): 775–798.

OECD. 1997. *Towards Sustainable Fisheries: Economic Aspects of the Management of Living Marine Resources*. OECD, Paris.

Russ, G.R. and Alcala, A.C. 1996. Do marine reserves export adult fish biomass? Evidence from Apo Island, central Philippines. *Marine Ecology Progress Series*, 132: 1–9.

Sainsbury, K.J. 1988. The ecological basis of multispecies fisheries management of a demersal fishery in tropical Australia. In: *Fish Population Dynamics*. Gulland, J.A. (ed.). pp. 349–382. John Wiley & Sons, Chichester.

Sainsbury, K.J. 1997. Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. In: *Tropical Snappers and Groupers: Biology and Fisheries Management*. Polovina, J.J. and Ralston, S. (eds). pp. 465–503. Westview Press, Boulder, CO.

Sainsbury, K.J., Campbell, R.A., Lindhom, R. and Whitelaw, L.W. 1997. Experimental management of an Australian multispecies fishery: Examining the possibility of trawl-induced habitat modification. In: *Global Trends: Fisheries Management*. Pikitch, K., Huppert, D.D. and Sissenwine, M. (eds). pp. 107–112. American Fisheries Society, Bethesda, Maryland.

Stefansson, G. and Rosenberg, A.A. 2005. Combining control measures for more effective management of fisheries under uncertainty: Quotas, effort limitation and protected areas. *Philosophical Transactions of the Royal Society of London Series B*, 360: 133–146.

Chapter 9

Input and Output Controls: The Practice of Fishing Effort and Catch Management in Responsible Fisheries

John Pope

9.1 Introduction

Fishery resources are limited. Consequently, if fishing pressure is not controlled in some way, it will increase until at best the fishery just breaks even economically and at worst the stock collapses through being unable to reproduce itself. Conservation of fish stocks is at the heart of the FAO Code of Conduct because if the fish do not exist all other objectives fail (FAO Code of Conduct, Articles 6.2, 6.3, 7.1.1 and particularly 7.2.1). Good management is therefore concerned with preventing this happening in the first case, or with recovering fisheries from bad situations when they have already occurred. Successful management requires attention to all aspects of the problem. For the purpose of this chapter, these aspects may be summarised under the following three headings.

- Firstly, an appropriate institutional, economic and social basis for management (see Chapters 3–6, 10, 11 and 14) needs to be in place. This needs to ensure that appropriate governance structures exist, that fishers have the right economic incentives, that they and other stakeholders feel included in the decision-making process and that all legitimate concerns such as employment stability, operating profit, food security and protection of the wider environment are openly discussed and given appropriate weight in formulating the management process. These form the basic 'hygiene' for fisheries management. With these in place, more detailed prevention or treatment of the disease of overfishing can be considered using the tools in the next two headings.
- Secondly, most fisheries need technical management (controls on the types of fishing gears allowed and restrictions on times and areas of harvest; see Chapters 7 and 8). This is needed to avoid, as far as possible, forms of wasteful harvest such as catching juveniles or of one fishery affecting the production of another.
- Thirdly, and the subject of this chapter, most fisheries require some management of their inputs or outputs. These are the means to limit the total intensity of use of the gear fishers put into the water in order to catch fish (fishing effort management or input controls) or the limits on how much fish they can take out of the water (management of catch or output controls). Collectively we sometimes refer to these as 'direct conservation measures'. This is in order to make it clear to governmental ministers that these measures, like technical conservation measures, are designed to conserve fish and are not just a way of slicing up the pie! They are essentially concerned with limiting the proportion of fish killed each year by fishing, rather than limiting the sizes, areas and times at which fish are captured.

What mixture of conservation tools is chosen for a particular fishery depends on the weight and relevance of various factors such as if

- the primary objective of the management is to meet economic or social goals;
- the management regime is national or multinational and has good or bad compliance/ enforcement;
- the fishery is conducted by a small centralised fleet of large vessels or by a large fleet of small vessels with many landing points;
- the fishery is based upon one or many species;
- the fishery is strongly influenced by historic precedence.

Figure 9.1 illustrates how the relative strengths (indicated by depth of text) of the factors illustrated in the upper panels might influence the choice of mixture of catch limits (output controls), effort limits (input controls) and technical measures indicated in the bottom panel. The final mixture chosen will be a value judgement based upon the where the fishery lays with respect to the various factors and the relative importance given to each factor. For example an international fishery might perforce chose catch controls even if compliance was weak. However, it would be wise to back this up with other measures. It is likely that some form of effort restriction and some forms of technical measures will form part of the management of almost all fisheries. Catch restrictions are more limited in the fisheries to which they can be applied. For example, Figure 9.1 indicates that they would be both ineffective and inappropriate to apply in multispecies tropical fisheries conducted by small boats landing at many small harbours. Where management systems are comparatively weak, it is possible that management may need to rely almost wholly upon robust technical measures such as closed areas or seasons rather than upon detailed input or output controls (i.e. it has most of the characteristics that dominate at the right-hand side of Figure 9.1). However, more generally limiting the intensity of fishing is a vital need of fisheries management (the FAO Code of Conduct, Paragraphs 7.1.8 and 7.6.1). Consequently this chapter describes how this can be achieved by limiting inputs (fishing effort) and outputs (catch) and explains the advantages and problems associated with these tools from the point of view of fisheries managers.

Some fisheries managers may have fisheries that are still developing, though these are becoming fewer as fishing technology becomes globalised. Many will be in the situation of trying to manage fisheries that are effectively fully developed, while some will be faced with the discouraging task of repairing the damage caused by past overexploitation. It is important to recall that the latter fisheries were once undeveloped and that a fishery can easily move from being underexploited to overexploitation over a period far less than a working lifetime. Hence, for managers of underexploited stocks, it is important to be aware of the problems that result from the natural tendency of exploitation to increase and to put measures in place well before the problems become acute. Hávamál tells us '*Byrđi betri ber-at mađur brautu ađ eb sé manvit mikiđ*'[1], so learning from the mistakes of others, avoiding complacency about the state of the management of their own fishery and listening closely and carefully to all opinions and complaints about the fishery are the best luggage any manager of a new fishery can have. For managers with more mature fisheries, hearing what management works or does not work in other jurisdictions is still helpful. For those managers with overexploited

[1] There is not better baggage than common sense.

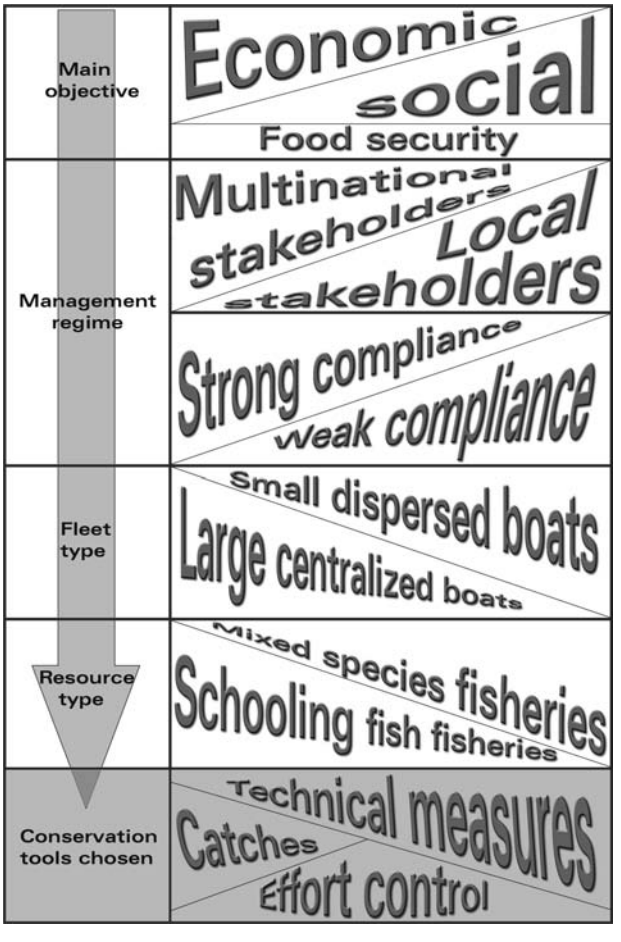


Figure 9.1 The relative strengths of factors which might influence the mixture of conservation tools chosen for a particular fishery.

fisheries I can really only offer Kipling's 'stoop to build 'em up with worn-out tools' as they will know well what does not work!

9.2 What are input and output controls?

9.2.1 Input controls or fishing effort management

As defined above, input controls are restrictions put on the intensity of use of gear that fishers use to catch fish. Most commonly these refer to restrictions on the number and size of fishing vessels (fishing capacity controls), the amount of time fishing vessels are allowed to fish (vessel usage controls) or the product of capacity and usage (fishing effort controls). Often fishing effort is a useful measure of the ability of a fleet to catch a given proportion of the fish

stock each year. When fishing effort increases, all else being equal, we would expect the proportion of fish caught to increase.

For some fisheries, vessels may deploy a variable amount of fishing gear (e.g. those using hooks, pots or gill nets). In these cases, the definition of fishing effort would also need to contain a factor relating to gear usage per vessel. In principle, input controls might also refer to limits placed upon other vital supplies of fishing such as the amount of fuel use allowed, but the commonest form of input controls are those put on the various components of fishing effort. In simpler, less-mechanised fisheries, input controls might relate to the number of fishing gears deployed (e.g. the number of static fish traps) or even to the number of individual fishers allowed to fish.

9.2.2 Output controls or catch management

By contrast, output controls are direct limits on the amount of fish coming out of a fishery (here the term fish is used to include shellfish and other harvested living aquatic animals). Obvious forms of output control are limits placed upon the tonnage of fish or the number of fish that may be caught from a fishery in a period of time (e.g. total allowable catches [TACs]; in reality, usually total allowable landings). Another form of output control used in many recreational fisheries is a bag limit (i.e. a restriction on the number of fish that may be landed in a day). Limiting bycatch might also be seen as an output control. It is worth immediately noting that to limit fishing intensity it is necessary (unless, as is not usually the case, fish can be released alive) to limit the catch (the amount taken from the sea) rather than the landing (which may well contain only a selection of the catch). The unlanded part of the catch (the discards) may be a substantial proportion of the total catch. It may undermine the intent of catch management if it is not restricted.

9.2.3 The need for fishing effort and catch management controls to be generally applied

It is important to note that neither the management of fishing effort nor of catch is likely to be effective unless they apply to all the fishers (or at least the overwhelming majority) engaged in a fishery. Partial controls leave space for the uncontrolled part of a fishery to expand into any gap left by controls placed upon other parts of the fishery. In the past, a number of countries only controlled the effort of the larger fishing units on the basis that they created the most fishing pressure. Small vessel sectors of fishing fleets were left uncontrolled as they were thought to take only a small slice of the catch. This resulted in an uncontrolled expansion of the small vessel sector, which modern technology can render very effective at killing fish. Consequently the FAO Code of Conduct encourages managers to take measures for all vessels under their jurisdiction (Articles 6.10 and 7.6.2).

9.3 Why would you want to use effort or catch management?

9.3.1 How do they link with the objectives of fisheries management?

The quick answer to the title of this section is given in the introduction to this chapter. It is because fishery resources are limited, and if fishing mortality is not controlled, it will

increase until the fishery becomes economically non-viable or the stocks collapse to extinction (Sections 2.3.1 and 4.2). Thus the management of fishing effort or of catch might be seen as pure conservation measures.

Certainly, restricting the amount of fishing by either effort or catch management is one way of protecting fish stocks from becoming overexploited or of encouraging the recovery of stocks that are already depicted. So they are one means of achieving the biological conservation of fish stocks. However, as described in Chapters 3 and 4, fisheries necessarily involve people and therefore have social and economic as well as biological objectives. Thus, viewing these or other management measures purely as ways of achieving conservation is naïve. The social and economic objectives are why people fish and why managers, particularly, wish to conserve fish. Because of this, the FAO Code of Conduct requires managers to take social and economic factors into account when setting objectives and designing management approaches (see Articles 7.2.2 and 7.6.7). Thus, it is important to consider how the management of fishing effort or of catch may affect the social and economic outcomes of the fishery in order that managers may chose approaches that match the outcomes they desire or at least avoid approaches which would result in undesired social or economic outcomes. So,

- choose a conservation approach which suits your fishery and your objectives.

Uncontrolled fishing effort tends to increase until, on average, individual fishers make at best only moderate profits and often no profit at all. In unmanaged fisheries, this tendency often leads to the fishery becoming biologically overexploited by being subjected to too much fishing effort and hence to an excessive annual removal rate of fish. This results in fish being caught at a size before they have realised their full growth potential (see Section 2.3) and often before they have an adequate chance to reproduce. This latter tendency is of course far more dangerous. In single-species fisheries, the imposition of suitable technical conservation measures may be able to prevent the biological overexploitation by protecting young fish and/or spawning fish and/or by making the fishery sufficiently inefficient that the zero profit level is reached before the stock is overexploited. Where the social objective of maximum employment from the fishery is desired this may seem a perfectly sensible approach to management (i.e. adopting a management approach corresponding to the right-hand edge of Figure 9.1). In fact, just stop fishers doing the things that would lead to overexploitation (e.g. depleting the spawning population) and then let them fish as much as they wish to. However, this approach may fail if either the costs of fishing decrease (e.g. fishing gear becomes cheaper or more efficient, or fuel becomes cheaper) or the price of fish increases. Consequently the FAO Code of Conduct encourages the limitation of fishing capacity to prevent uncontrolled increases in the amount of fishing (Articles 7.1.8 and 7.6.1).

There may also be problems with a technical management approach if more than one species is targeted in a fishery or if the fishery takes bycatches of vulnerable non-target species (e.g. marine mammals). What may be a suitable technical conservation measure for a species, which grows to a small size, may be inappropriate for a species that grows to a larger size but which is exploited by the same fishing vessels at the same time. Examples of this are the fisheries for the flatfish species, plaice and sole, caught by the beam trawl fisheries of Northern Europe. Mesh size is smaller than would be optimal for plaice to allow for the catching of the small, lithe but more valuable Dover sole. Thus limiting inputs or outputs from such multispecies fisheries may be a better way of managing them to avoid biological overexploitation. So,

- in rather limited circumstances and if you want to maximise employment, then technical measures alone may suffice;
- But, in most cases, you will need to limit the inputs.

If it is desired to maximise the economic benefits of the fishery, then approaches other than technical measures are required. If the economic benefit is intended to go wholly to the state then it may suffice to use fiscal measures such as taxation. If set at a level appropriate to the economics of the fishery, such measures can both extract rent from the fishery and also lead fishers to reach the breakeven/no profit level point with fishing effort that does not overexploit the stock. However, if it is intended to allow at least some of the profit to devolve to the fishing industry, then it is necessary to stop fishers from increasing their fishing effort at some level short of the zero profit point (see Chapter 4). It will also be necessary to devise ways to prevent them from dissipating their profit by investing in additional uncontrolled inputs, or by engaging in activities such as discarding less-valuable fish in order to high grade their landing. Hence fishing effort or catch management may be used to secure the biological and either the social or economic objectives of fisheries or some trade-off between biological, economic and social benefits. However, how social and economic objectives balance out in practice depends upon the details of how catch or effort restrictions are shared between fishers. So,

- if you have economic objectives you need input or output controls;
- but, the devil is in the detail of the regulation.

9.4 How would you impose fishing effort management and catch management?

9.4.1 Requirement for restrictive licensing

From the previous subsection, we have seen that effort management and catch management might serve the biological, economic and social objectives of a fishery. There are a number of ways that effort or catch management may be established, but the way that they are imposed will determine which, if any, objectives are satisfied. It is common for countries to require fishing vessels to be licensed and, where they fish on the high seas, the UN Fish Stocks Agreement (Article 18) requires the Flag State to control its vessels through licences, authorisations or permits. However, typically such basic registration schemes are not of themselves restrictive, that is traditionally a licence might be had by filling in a form and paying a nominal fee. Although such schemes are useful as a basis for statistics and some forms of fisheries control they do not limit the amount of fishing unless coupled to a limited entry scheme. You might see them as rather similar to issuing driving licences, which are useful for exerting control but which are unlikely to prevent traffic jams.

Clearly, the measures to limit inputs require some form of restrictive licensing which will limit the total number of vessels engaging in a particular fishery together with their fishing power. Often, in order to reduce resistance to restrictive schemes, licensing lists are initially inclusive. They include all vessels, some of which seldom take part in the fishery. Such little-used vessels constitute a latent fishing capacity, which might expand its usage to take a larger part in the fishery, should it become more profitable. Consequently, it may be wise

to extinguish or at least heavily limit these rights if they are not taken up regularly. Failure to do this may force the government to buy out rights when they have become valuable and it is wise to plan for this need when licences are first issued. For the same reason it is also important that the restrictive licence records such characteristics as the size and engine power of the vessel that affects its ability to exploit fish. If these are not fixed then the licence may be transferred to a new, more powerful, vessel or the vessel may be upgraded. Either type of change will allow growth of fishing capacity.

If restrictive licences are in any sense transferable between owners then they are likely to acquire substantial value to the holder and be transferred at high price. In order for a government to avoid claims that they are encouraging dangerous practices or destroying employment, typical licence transfer rules must allow for at least limited transfers from an old to a new vessel or from parent to child. The result is that some value is likely to attach to a restrictive licence giving the government the dilemma that something that they have issued, often for a flat fee, has acquired substantial value that they will probably have to recompense if they wish to rescind the right. In principle this might be overcome by issuing such licences for a fixed term rather than in perpetuity. However, license schemes typically grow from earlier registration schemes, and both socially and politically it may be difficult to deny fishers the right to earn a living in a traditional family occupation without offering them compensation. Even where fishing is not a traditional occupation, short-term licences might further discourage fishers from focusing on protecting the long-term productivity of the fish stock. Such issues are discussed further in Chapter 10. So,

- licences have to be restrictive, so think carefully about what you need to restrict before you need to restrict it;
- Restrictive licences may acquire considerable value and be expensive to buy-back. So plan in advance how they might be rescinded or their scope reduced.

9.4.2 Reducing fleet capacity

In many cases licensing schemes have been adopted after overfishing has occurred. In these cases the fleet is already too large. Even where licensing has been brought in early, it is quite possible that technological advances in vessel and gear design and improvements in fish-finding and navigation equipment may cause the effective fishing capacity of a fleet to increase through time. Indeed technological improvements in efficiency are often 'guesstimated' to increase at least at 2% a year. The actual figure may well be higher, particularly if restrictive licensing puts a premium on vessel efficiency. The rules of compound interest mean that even a 2% annual rate of increase in effective fishing capacity will lead to a doubling in fleet capacity in about 36 years; a 4% annual increase leads to a doubling in effective capacity in 18 years. Moreover discrete increases in efficiency often occur if new forms of gear are introduced or when vessels are replaced or re-engined. These steps can easily be of 10% or more. Hence, it is not uncommon for managers to find that either the fleets they are concerned with already have too high a capacity or they will develop this over time. Thus, if despite licensing, the fleet is too large for the particular fishery then it will be necessary to reduce its capacity. This may be arranged in the following ways:

- by removing vessels from the fleet;
- by reducing the amount of time fished by making all vessels fish for shorter periods;

- by limiting the amount or size of gear that a vessel can carry;
- by reducing the efficiency of fishing effort (e.g. by closing areas where catch rates are high).

Note, however, that none of these approaches will succeed in reducing the amount of fishing unless entry into the fishery is first ring-fenced (restricted by a limited licensing scheme). For example, there is no point in a government buying out vessels if their owners (or proxies) can use the money to buy a better boat and carry on fishing.

Removing vessels from the fleet

Typically, removing vessels from a fleet requires the rescinding of a government licence. In essence this requires removing a right to fish from an individual for the general good and a just system requires there is appropriate compensation. Such vessel removals are typically arranged by adopting a government funded buy-back or decommissioning scheme. If the restrictive licences are freely transferable then the government might simply enter the licence market to buy up excess licences. More usually governments announce schemes for fishers to tender for the decommissioning of their vessels or by announcing a price at which they will buy licences.

A general problem with all such voluntary schemes is that the vessels decommissioned are likely to be the least efficient in the fleet. As a result, their removal will not cause an equivalent reduction in the ability of the fleet to catch fish. A further problem is that fishing communities are frequently tight-knit, and the money paid to an older owner to retire from the fishery may then be recirculated into the fleet capacity, for example by being used to improve the efficiency of a relative's vessel. Indeed as licences become more restrictive there is likely to be a greater incentive to increase vessel efficiency, which may maintain the effective capacity of the fleet and also make successive government buy-back schemes more expensive. Thus, there is probably a need to back up such schemes with fiscal measures such as higher licence fees. One rational approach might be to regard government buy-backs as an investment loan to the whole industry, which would be funded in whole or in part by subsequent loan repayments from the remaining industry. In general, removing vessels from a fleet will tend to increase the profitability of the remaining vessels and thus would serve the economic objective of maximising profit.

Reducing the amount of time vessels are allowed to fish

Reduction in fishing time may be arranged by imposing limits on the days that vessels may spend fishing. But once a vessel is over the horizon it may be difficult to check its precise activities. It is true that satellite tracking has the potential to help with defining the number of days a vessel is on the fishing ground, but unless special sensors are fitted it can only confirm that the vessel was on the fishing ground but not that it was actively fishing. Consequently, fishing is usually more practically reduced by limits on days at sea. This approach was a feature of the UK days-at-sea legislation and also the effort management used by the Faeroes (see boxes below). It now forms a part of the EU's Common Fisheries Policy in the North Sea and other areas, and fishing time (sometimes specific fishing hours) is used to ration opportunities for fishing in some Mediterranean countries.

Direct restrictions on days fishing are of course possible. A vessel could be given a quota of days during which it might fish (interpreted usually as a number of days that it could not fish and had to be tied up in harbour). Such allowances might be transferable and traded between vessels. In this case they might acquire considerable value if the fishery were profitable. Trading would presumably eventually lead to fleet reductions if all the available days fishing becoming concentrated in that efficient subset of the fleet that could best afford to buy up the rights of other fishers. Thus it is an approach which might tend to generate an economically effective fishery rather than one which emphasized direct employment. As with all effective reductions in fishing effort, such schemes may contain the seeds of their own failure by encouraging capital investment in fisheries equipment and/or replacement vessels, which increases fishing capacity. This tendency, called capital stuffing, is always present in any input control designed to increase the profitability of fleets for the benefits of their owners. It might be anticipated and counteracted by legislating for days-at-sea allocations to reduce progressively over time and/or by enforcing reductions in the registered fishing capacity of replacement vessels.

Managers should be aware that unless some transitional compensation is offered, the sudden imposition of days-at-sea restrictions will be seen by the fishing industry as 'decommissioning on the cheap'. Such restrictions will usually be resisted as, until the stock responds to lower exploitation, they will reduce or overturn any profit that the industry might hope to make. Days-at-sea measures (particularly for specified seasons) may be attacked by fisher groups on the grounds that they may encourage people to go to sea to take up their allocation at times when it is dangerous to go out fishing. A general problem with days-at-sea measures may also be that they often accord badly with fishers' self-perception of being free spirits who can go to sea as and when they choose. The success of the implementation of the Faeroes scheme – described later in this chapter – was linked to close consultations with the fishing industry.

The UK attempt at introducing days-at-sea restrictions

The fate of the UK's days-at-sea restrictions proposed in the UK Sea Fisheries Act 1993 should stand as an object lesson to managers of the problems of imposing a days-at-sea scheme. Though this Act was passed by the UK Parliament it was fiercely opposed by the collective fishing industry, subjected to judicial review and to an adverse Parliamentary Committee report. Though it remained available for use, the political will to impose it was lost. Clearly such schemes are better imposed at the beginning of a fishery when they need not be onerous rather than when real sacrifice is required, in the face of severely depleted stocks.

Other restrictions on time at sea are possible. Where a group of fishers are effectively the sole users of part of a resource, they may themselves impose quite heavy restrictions on fishing times. Such restrictions are quite common in EU fisheries of the Mediterranean where fisher groups (e.g. the 'Cofradias' of Spain) impose their own rules. Ports in Catalonia, for example, fish on a daily pattern and have strictly set hours in which vessels may be at sea. Breach of these causes the vessel to be 'fined' additional time the next day.

Other restrictions on time at sea may be arranged with schemes such as no fishing on weekends. In some cases such rules may accord with local customs and be welcome, but

in other cases they may discriminate between different groups of fishers. For example, a weekend ban might favour small vessel day-boat fishers over those who make more extended voyages. In general, reducing the amount of usage of fishing vessels may tend to make the fleet less effective and thus possibly preserve employment, though possibly for shorter working periods. Alternatively, if the time that vessels can be used can be traded between vessels such a restriction might ultimately improve profitability but more slowly than the direct removal of vessels would. As always, managers need to think carefully to determine if a particular regulation will have effects beyond the ones they intend or wish.

Restricting vessels' use of fishing gear

Some fishing vessels (e.g. otter trawlers) tend to use the size of fishing gear that is appropriate to the vessel's size and horsepower, but even for this gear, newer developments (e.g. three bridle twin trawl rig) may increase a vessel's effective fishing power. Restricting the use of such gears may be one way of restricting the increase of the efficiency of fishing effort. For a number of other fishing methods, the amount of gear deployed in a day may have an even less-clear relationship to vessel size or engine capacity. This is particularly the case with static gears such as gill nets, pots and creels. The amount of such gears carried by a vessel (or more properly the numbers deployed) may be increased if restrictions are placed upon other aspects of the vessel's efficiency or use. Thus, when vessels use fixed gear (e.g. gill nets), then days-at-sea restrictions alone may not be sufficient because fishers may leave out gear that is still fishing while they are in port. Moreover, days-at-sea restrictions may give an incentive to using more nets or adopting longer gear soak times, in order to maximise the output of catch within the constraint. Such responses by fishers to the legislation may reduce fish quality and may also increase the loss of fixed gear resulting in an increase in ghost fishing. Ghost fishing is caused by lost gear continuing to kill fish (see Section 7.5). In such cases it may be necessary not only to restrict the vessel's capacity and days of usage but also the amount of gear carried. However, this may be a far less easy factor to restrict and manage than vessel days at sea. One approach is to insist that gear is tended by the vessel and lifted when it goes into port. Such restrictions may also be sensible in order to avoid the dangerous overloading of vessels or unsound fishing practices (e.g. leaving gill nets in the water for too long).

Examples of restricting fishing gear

In southern Newfoundland, where inshore cod fishing is mostly pursued with static gears, measures were introduced in the 2000 fishing season to restrict the use of gill nets to the summer season. This was when they were less likely to catch spawning fish or be left fishing or lost due to adverse weather. More generally there seems a movement amongst some inshore fishers in southern Newfoundland to favour a return to more traditional gears such as hook and line and fish traps.

In Bermuda, there is very tight control of the gear used in their fishery for spiny lobster. The government retains ownership of the standard traps, which are the only ones allowed for use in this fishery, and each year it leases out a maximum of 300 traps to a maximum of 20 licence holders. The traps must be returned to the government at the end of each year for re-allocation.

Generally, trying to restrict innovation in fishing technique is as effective as trying to hold back the tide. New techniques and tools are constantly being developed, and fishers are very skilful at finding legitimate ways around restrictions on their use. For example, the larger Dutch beam trawlers are restricted to a 12-m beam length (for safety reasons) but have responded by using heavier gear and by fishing at faster speeds to cover more ground. Consequently it is usually more sensible for management to anticipate and plan for further increases in vessel efficiency rather than to try to prevent it occurring.

Reducing the efficiency of fishing effort

Closed seasons are often seen as technical conservation measures and are discussed in detail in Chapter 8. However, they may be seen as a way of restricting effort if their intention is to reduce fishing time, rather than to affect selection by protecting fish at seasons when certain sizes are particularly vulnerable. Equally, the decision to close an area to fishing could be regarded as a *de facto* input control, if it were motivated by a desire to restrict vessel efficiency. Such input-restricting closures would be in areas of high catch rates rather than areas where vulnerable ages of fish were found. Obviously, such decisions may well be motivated both by a desire to improve selection (technical conservation) and by reducing the amount of fish removed (direct conservation), and the boundary between these two approaches may become rather fuzzy at this point. Such measures to restrict efficiency will clearly tend to reduce profitability and maintain or increase employment by enabling a greater number of vessels to fish the stock. Such schemes are often adopted by those members of the EU with Mediterranean seaboards where social objectives tend to dominate.

Effort Management in the Faeroes

The Faeroes, a group of Islands lying between Iceland and the Shetland Isles at the north of the United Kingdom, are part of Denmark but are locally autonomous in most matters including fishing. Fishing is of major importance to the Faeroese economy and an important means of employment. Local tradition favours providing employment for all Faeroese but by the early 1990s the need to conserve the local fish stocks particularly those of cod, haddock and saithe was apparent. A TAC system was introduced in 1994 but some fleets misreporting their catches led to the fishing industry rejecting the concept of TACs. Consequently an effort management scheme was introduced in 1996. This imposed limited days at sea, which are transferable within vessel classes, for all but the largest vessels. Larger vessels were restricted from fishing within 12 miles of the coast and a series of area closures was imposed to protect spawning grounds and to reduce the efficiency of fishing. Incentives for fishing beyond the distribution of cod and haddock are also provided by allocating extra days to vessels fishing these areas. There are also bycatch limits of cod and haddock on the larger vessels and on all trawlers. These measures seem to have controlled fishing mortality on the cod and haddock stocks somewhat but have certainly not brought the full reductions intended. They seem generally accepted by the industry as the best compromise possible. Whether the transferable nature of the effort restrictions

will lead to concentration of the effort quotas into fewer hands and thus negate the partly social objective of the measure remains to be seen. It also remains to be seen if technical improvements to vessels will require further reductions in fishing effort and if movements of effort between stocks in response to their relative abundance generate a virtuous or a vicious cycle of exploitation. However, on current experience the tendency to focus effort on the more valuable but less-abundant cod rather than the more abundant haddock may suggest that the latter is the case.

To encourage reductions in fishing capacity, FAO has developed the International Plan of Action for the Management of Fishing Capacity (IPOA-CAPACITY). Details of this initiative including the action plans for several states can be found at the FAO website[2].

Effect on objectives

Ideally, measures of fishing effort are fairly directly linked to the ability of the fleet to kill fish. They may well also link rather directly to the cost of catching fish and the numbers of fishers employed. Thus the size of a fishing effort limit will often have a direct effect on the economic and social outcomes of the fishery as well as the conservation status of the stock. The way the fishing effort is rationed between fishers will have a profound effect on whether the fishery maximises profits or employment. Transferable limits on fishing effort will tend to favour the former objective, while non-transferable limits will favour the later. Hence,

- when limiting effort it is important to do it in a way that matches up to the management objectives;
- it is also vital that it does so in a way that works with the tacit approval of the fishing industry and it is thus important to consult widely before adopting a new scheme.

9.4.3 Limiting catches

Different forms of catch management

Restrictions on catches may take several forms, the most obvious being the limit on the total catch. This is usually called a TAC though catch quota and allowable biological catch (ABC) are used in some areas. This may sometimes be in terms of numbers of fish (particularly for species that are harvested at a fairly uniform size) but most usually TACs are given in terms of tonnage. Strictly, to be effective, they should relate to the catch of fish but for administrative convenience they are often limits on landings rather than catches. However, because some fish may be discarded at sea, in many cases landings and catches are far from being the same thing.

The intention of a TAC is to restrict harvest rates to sustainable levels. In reality such restrictions often also provide for the allocation of the resource between user groups. This

[2] http://www.fao.org/fishery/ipoa-capacity

aspect is particularly important in internationally shared fisheries where some allocation between countries has to be negotiated if a management system is to work. To politicians and to fishers these allocation aspects of TACs may sometimes seem to be more important than the requirements of conservation and both groups tend to be compulsive negotiators! But asking how they would share the last fish may put the emphasis back to conservation requirements.

Bag limits are a simpler form of catch limit designed to restrict certain types of fishery by limiting the numbers an individual person or vessel can catch during a short period, typically a day. Limits on catch per trip and catch per day in commercial fisheries have a similar intention. Such limits do not of course restrict the total catch of the whole fishery. However, they may be effective in restricting sectors such as recreational, first nation or small-scale fisheries that consist of numerous and often dispersed operations that might otherwise be difficult to limit. Such fisheries may have a surprising ability to catch fish. For example, recreational fisheries in the United States are estimated to take sizeable percentages of the total catch of some species which are also subject to regulation of commercial fishing. One virtue claimed for bag limits is the prevention of recreational fisheries and the like from expanding into semi-commercial operations partially financed by the sale of catch. Another is the prevention of commercial fishing masquerading as recreational fishing. This is a potential problem when small-scale inshore fisheries are already heavily restricted by TAC.

Bycatch restrictions may also be viewed as forms of output control as they restrict either the catch of bycatch species or the proportion that these species form of the total catch, often on a trip-by-trip basis. The intention of such limits may be to avoid the targeting of depleted fish species. It may also be needed for species protected under other conservation legislation; for example that concerned with protecting marine mammals or other species at risk. Such rules may at times need supporting by onboard observers particularly if the restricted bycatch has little or no commercial value. Bycatch limits may also be adopted to restrict the catch of permitted small mesh gears to the small species for which they are needed (e.g. shrimp). In these cases the limit is placed on the proportion of larger species that may be caught during a trip using the smaller mesh gear. When used in this fashion, bycatch limits are effectively adjuncts to technical conservation measures rather than intended as an output control as such; the main output control typically remains the TAC. So,

- TACs are the main form of output control;
- but other simpler forms exist that may be useful in restricted circumstances.

How catch limits are estimated

The intention of a TAC is to allow sustainable harvest. So a TAC should act by restricting the harvest to a safe proportion of the exploitable stock of fish. Therefore to be truly effective, such catches must be related to the size of the exploitable biomass of fish and since this often fluctuates annually, so should the TAC. In practice, estimating the size of the exploitable biomass of fish in the sea is a difficult and expensive task (see Chapters 2 and 13). It needs to be done with reasonable accuracy because if, for example, the TACs were set higher than the exploitable biomass it would not act as any limit on the amount of fishing.

Sometimes TACs are set on the basis of average abundance of the stock, and if a stock is relatively lightly exploited this may suffice. However, the effect of average TACs (sometimes

called precautionary[3] TACs) will be to harvest a larger proportion of the stock when it is smaller and a smaller proportion when it is larger. This is of course the wrong way round since the TAC would unduly restrict fishers' activity when the stock is large, and may fail to protect the stock adequately when it is small. TACs are thus a far more effective form of management if they can be modified periodically to accord to the size of the stock. However, if the exploitation rate is low and/or the stock is not very variable, then this may not need to be done annually. However, more commonly TACs will need to be adjusted annually.

Traditionally TACs were estimated using fisheries assessment techniques to first estimate the absolute size of the exploitable biomass of the stock. In principle this allows a TAC to be set which will cause the appropriate proportion of the stock to be harvested. In practice such estimates are rather variable and may be biased. Such bias may sometimes be in one direction, up or down, for a number of years. Worryingly, such estimates have sometimes had a habit of being upwardly biased at times when the stock biomass is in sharp decline and it is vitally important to get the TAC right if the stock is to be saved. This seemed to happen at the time the cod stocks of Atlantic Canada were declining in the late 1980s and early 1990s. Some of the indices of abundance used were based upon commercial catch rate data and seemed to be biased upward due to a tendency of the fleets to focus on the remaining concentrations of fish. There may well also have been environmental changes that caused upward bias. This is an example of the Pope doctrine 'that when things seem bad in fisheries they are usually worse'!

A more recent approach to estimating TAC is to use an approach that is often called a management procedure. This pre-specifies the harvesting rule that will be adopted in various perceived circumstances including exactly how the TAC will be calculated from the available data (see Section 12.4.1). Various ways of doing this can be proposed from the simple to the complex. Simulation studies of how the stock might behave are then used to generate test data and to check carefully which of the proposed rules will on average give the best performance possible against a set of management objectives.

One of the several attractions of this approach is that it may be able to use indicators of the exploitable stock biomass to modify the TAC rather than direct estimates of exploitable biomass. Using principles of feedback control, these may then be used to steer the TAC into the right path. This is rather similar to how the heating system of a house works. This may use a single thermostat to regulate the temperature of the whole house even if the temperature at the place where the thermostat is positioned (say in the hallway) is not the same as the temperature desired somewhere else (say a sitting room). The point being, if it is too warm the heater is switched off and if it is too cool it is switched on. Similarly, the TAC on a stock should increase when the stock increases and be reduced when it reduces. Rules based upon simple indicators, say a survey index, are obviously cheaper to provide and easier to maintain than more complex calculations based upon the age structure of stocks and therefore may make output controls applicable for a wider range of stocks.

In summary,

- Typically catch limits have to be adjusted to the stock size, often this needs to be done annually;
- Estimating catch limits normally requires additional data and scientific interpretation – so can be expensive. It is thus more appropriate to limit catch on stocks with high total value;

[3] Precautionary in the sense that they are adopted as a default and certainly not to be confused with the ideas of precautionary management.

- Such estimates may become biased particularly at crisis points;
- Management procedure approaches which estimate catch limits on changes in catch rate or survey indices may provide a cheaper service.

Ways of limiting fishing by controlling catches

Having set a TAC, there is a need to control the fishery so the TAC is not exceeded. A number of approaches are possible, which include:

- free fishing until the TAC is taken and then shutting the fishery down;
- allocating catch by period and then shutting down the fishery for the remainder of each period when the allocation is caught;
- allocating proportions of the TAC to various sectors and leaving them to manage their own share themselves;
- allocating proportions of the TAC to individuals or individual vessels.

Allowing free fishing until the TAC is taken is the simplest way to administer a TAC since it is only necessary to keep a running total of the overall catch and then to stop the fishery when it is exceeded. However, such a fishery will encourage an intense race to catch fish before the TAC is taken. It will thus encourage excessive capacity and a poor economic performance in the fishery. The classic example of this form of management was in the earlier management of the Pacific halibut fishery where because entry to the fishery was unlimited, fishing capacity became very large and the annual season had to be reduced progressively to a very short period before the fishery was closed. On the plus side such management may suffer less from discarding practices because fishers probably find it better to land everything. However, an intense race to fish is likely to make fish quality a secondary consideration to landing fish quickly. In short, such a system does not have much beyond simplicity to recommend it.

Allocating catch by period and allowing free fishing during each period has some of the advantages of simplicity of the previous approach, in particular the need only to monitor overall catch. However, it would still encourage a series of races to fish. It would also have some advantages in that fish would be landed throughout the year and indeed the period chosen for opening might be aligned with times when fish quality or fish prices were best, but it is still likely to encourage excessive fishing capacity to develop and thus to be economically inefficient.

Allocating proportions of the TAC to various sectors that manage the catch uptake themselves may encourage a more orderly uptake of the fish. To what extent this occurs will depend upon the sector's ability to govern itself. In some cases, producer organisations or co-operative organisations can manage fish uptake between their members very successfully. In other cases such an allocation may just engender a within-sector race to fish.

A problem that sectoral quotas present for management is that catch statistics now have to be collected separately for all sectors. Moreover sectoral allocations would give each sector some incentive to under-report catch. They may be particularly prone to do this if either they feel that they can get away with it or if they suspect, as often they do, that other sectors have been cheating. A further problem may be to decide how to handle a case where one sector is found to have exceeded its allocation. Should management take it from the next year's allocation of that sector? Alternatively, should they penalise the transgressors but balance the excess catch by reducing the remaining in-year allocations of other sectors? If the TAC is

shared between several countries, the latter course may be the only one to take but will be deeply unpopular with the other sectors. In better-managed sectors, there may be a tendency to try to improve quality and price but this may encourage high grading. This is the practice of discarding lower valued catch in favour of its higher valued portions. As there are often differential prices by size, and as, at times, fish may be caught in a state of poor quality (e.g. from having been too long in a gill net) there is considerable temptation for this practice to arise if fishers have a known allocation of catch.

Allocating proportions of the TAC to individuals or individual vessels has the virtues ascribed to the previous approach. It is more likely to lead to an orderly uptake of the TAC and in a fashion likely to be economically efficient. However, such a scheme is particularly vulnerable to the administrative drawbacks. Statistics obviously have to be kept at an individual fisher or vessel level, and the temptation and the opportunity to misreport increases as the allocations are more finely divided. Such problems of reporting often lead governments to develop rather draconian measures to ensure compliance by individuals. Problems of high grading are also likely to be exacerbated when quotas are organised at an individual level.

Effect of catch limits on fisheries objectives

As with fishing effort management, catch management can clearly affect the outcome of the various objectives of fisheries management. The proportion of the stock it is intended to remove annually will affect the biological objectives of yield maximisation, yield stability and conservation. The proportion removed may also affect the overall profitability because the potential for achieving maximum profit will occur at exploitation rates less than those that achieve maximum yield. These are also lower than the exploitation rate where the breakeven occurs between earnings and costs; the point where more fishers would be employed in an unsubsidised fishery. How the TAC is allocated to individual fishers will also impact the achievement of objectives. As an example of this, to provide many individual fishers with a modest living, a quota might be divided into many small non-transferable slices. Such a non-transferable quota would tend to provide maximum participation in the fishery. By contrast, a quota which was transferable would be traded and then tend to be aggregated into fewer but more profitable enterprises. This is the management approach that many fisheries economists advocate because they naturally tend to believe in profit maximisation as the best objective. Notable examples of the use of Individual Transferable Quota (ITQ) management schemes are found in New Zealand and Iceland. Where the fish stocks managed are confined to one country's exclusive economic zones (EEZs), these schemes include some of the better-managed fisheries. This may well be both because they address the economic motivations that most fishers dance to and because a pure economic objective demands a lower harvest rate to be set than would be the case for social or yield objectives.

Increasingly, analogous schemes are to be found in other countries though not always in such a clear form. For example, the United Kingdom has quotas tied to producer organisations rather than vessels. By contrast, Ireland and Namibia use non-transferable quotas to encourage wider employment opportunities. These various approaches are discussed further in Chapter 10.

- As with effort limits, the way that a catch limit is set and allocated profoundly affects the outcome of social and economic objectives.

9.5 What structures do you need for effort and catch management?

9.5.1 The centralised nature of fishing effort management and catch management

By their nature, effort and catch management have to span the whole fishery. Small-sized resources might be managed on a local basis but the larger, more extensive, resources have to have their management agreed centrally. Since the more important resources tend to be the extensive ones, approaches to both fishing effort management and catch management tend to be centralised command and control approaches. There is usually relatively little ability, except on small local stocks (e.g. South African abalone), to devolve the decision-making to the districts where fishers operate. A corollary to this is that they will not work well where the central body has little control over the regions where the fisheries actually operate.

The problem with command and control schemes is that their operation may often seem remote from the interested parties. To fishers, the controls may appear driven by the whims of remote bureaucrats who they perceive, sometimes with justification, as being ignorant both of the fish and the fishing industry. Any attempts to put a more human face on the operation, to increase its transparency and to include fishers in discussing and formulating management is thus to be welcomed (see Chapters 3 and 11). A further problem is that fisheries management may become the shuttlecock of political debate. Since this may focus attention on the short rather than the long-term goals of the fishery, it may work against the goals of conservation and optimal long-term use. Hence, there may be some virtue trying to distance the decisions and operation of effort management or catch management from direct political control and into the care of a benign and transparent public body which is given clear objectives by politicians but then left to do its job. Such bodies can have different levels of delegated power. Some such as the Fisheries Resource Conservation Council (FRCC) of Canada are advisory bodies with the ultimate responsibility resting with the minister they advise.

The Canadian Fisheries Resource Conservation Council (FRCC)

The FRCC provides a partial example of such a body. Its role is to advise the Canadian Minister of Fisheries on resource conservation not to manage the fisheries; but typically its advice is acted upon. It was created in 1993 to form a partnership between scientific and academic expertise, and all sectors of the fishing industry. Together in its earlier years, Council members made public recommendations to the Minister of Fisheries and Oceans of Canada on such issues as TACs and other conservation measures for the Canadian Atlantic groundfish fishery. The Council was also responsible for advising the minister on Canada's position with respect to straddling and transboundary stocks under the jurisdiction of international bodies such as the Northwest Atlantic Fisheries Organisation (NAFO). The Council also provided advice in the areas of scientific research and assessment priorities.

Undoubtedly, the fact that the Council consulted with fishers helped it give advice that 'worked more with the grain' of the industry. However, the immediate economic consequences of advice on annual TAC and short-term management measures resulted in the reluctance of fishers to buy-in to strong corrective measures, while science felt that the

advice might not be objective. In 2004, following a mandate review, the Council main trust was changed to focus on providing long-term strategic conservation advice. Diversified membership and consultations with stakeholders remain key elements of the advisory body's process. The approach adopted by the Council has allowed for a wider definition of sustainability, which includes resource, economic, social and institutional elements. With the focus away from the annual TAC, industry is less reluctant to take part in a process that results in gradual and incremental steps to sustainability of the resource.

The Council consists of members, appointed by the Minister of Fisheries and Oceans, with an appropriate balance between 'science' and 'industry'. Members are chosen on merit and standing in the community, and not as representatives of organisations, areas or interests: 'science' members are drawn from universities, private consultants or international posts, and are of an appropriate mix of disciplines, including fisheries management and economics; and 'industry' members are knowledgeable of fishing and the fishing industry and understand the operational and economic impacts of conservation decisions. Members appointed from the Department of Fisheries and Oceans serve *ex officio*. The four Atlantic Provinces, Quebec and Nunavut may each nominate a delegate to the Council.

The box gives the example of the Canadian FRCC, which is described as an independent body, which provides advice on fisheries management. In practice, its advice is often taken or at least weighed very carefully by the minister and hence its role is a responsible one. Such advisory bodies are also well suited to educating stakeholders on conservation issues as members often share the same backgrounds and experience as fishers. The EU has recently set up rather similar bodies called Regional Advisory Councils. These certainly have helped include the fishing industry and other stakeholders in the advisory process and are a marked improvement in this respect on the dysfunctional bodies that went before. However, they are rather new bodies, which are still feeling their way; so how effective they will prove is as yet uncertain.

Where fisheries are wholly national affairs, they are usually the responsibility of government departments. While the sole ownership of the fishery resource may ease some management problems, the problems of national management are often a microcosm of the problems of international management. Regional governmental bodies often have disparate objectives and different fleets, and may well hold different viewpoints on what are the appropriate fisheries controls. This can lead to disagreements both between different regions and with the central government. In these circumstances, it is not uncommon for agreement to be reached for political rather than conservation reasons. This is particularly the case since the time horizon of fish stock recovery is often longer than the time for which politicians are elected. This emphasizes the desirability of taking management decisions out of the political arena and allowing some involvement of interested parties in the process. What perhaps is required is a fisheries equivalent of the former German Bundesbank. Prior to the advent of the Euro, the Bundesbank, charged with protecting the German Mark from inflation, successfully acted at arm's length from the German Government to make the former German currency a byword for stability. In a similar fashion a fisheries 'Bundesbank' might be given the economic, social and biological objectives for fish stocks and coastal resources by the Government and then given the powers to get on with the job of delivering the objectives. The Australian Fisheries Management Authority (AFMA) seems to be such a body.

The Australian Fisheries Management Authority (taken from its website)

The AFMA was established in February 1992. Our operations are governed by the Fisheries Administration Act 1991 and the Fisheries Management Act 1991. These laws created a statutory authority model for fisheries management whereby day-to-day management of fisheries was vested in AFMA, with the broader fisheries policy, international negotiations and strategic issues being administered by a smaller group within the then Department of Primary Industries and Energy (now the Department of Agriculture, Fisheries and Forestry).

An important feature of the AFMA model is that it enables the minister with portfolio responsibility for fisheries to remain at arm's length from the day-to-day decisions on fisheries management.

Decision-making is passed on to an expertise-based Board. In turn, the Board is advised by a Management Advisory Committee (MAC) structure which draws its membership from relevant stakeholder groups, including the commercial fishing industry.

In summary,

- management structures have to encompass the whole fishery, but
- those that include the industry in discussions and the decision-making processes are more likely to succeed in their aims than remote centralised command and control structures;
- management structures are probably better arranged so that routine decisions can be taken at arms length from the political process.

Where fisheries straddle political boundaries or occur in international waters, there will be the need for some intergovernmental body where fisheries management can be discussed and agreed. (see Section 5.2.4) There will also need to be some corresponding scientific body to provide the agreed scientific advice that the management requires. Such bodies exist for most international fisheries. For example, NAFO regulates fisheries that occur wholly or partly in its convention area outside the national EEZs of the seaboards of West Greenland, Atlantic Canada, France (St Pierre, Miquelon) and the United States (New England), but multinational fisheries may also be arranged by formal or informal bilateral or multilateral bodies (e.g. Argentina Uruguay joint management of Rio de la Plata fisheries, Norwegian and EU joint management of the North Sea).

9.5.2 Monitoring, enforcement and advisory structures

However management is arranged, unless regulations are enforced and complied with, it is unlikely that it will deliver the objectives. Hence these are vital roles. To achieve these, there will clearly be a need to collect data from the fishery in order to monitor the compliance of fishers with effort or catch restrictions and to enforce the management of the fishery in some way (see Chapter 14 for detailed discussion). This can seldom be left to the fishing industry and consequently the government frequently has to act as the referee and to arrange for the fishery to be policed. As a result, there usually has to be some national data collection and inspection service to monitor and to control the fisheries.

Monitoring and enforcement services may be combined since they need similar access to the fishery, and monitoring data provide the essential information on non-compliance with fishing effort and with catch restrictions (see Chapter 14). To be effective they need to be staffed with personnel who understand the workings of and are sympathetic to the problems of the fishing industry but can deal with them fairly yet firmly when the needs arise. In many cases, dockside monitoring and enforcement will not fully meet the needs of either fishing effort restrictions (gears used, areas fished and species caught may all need to be checked at sea) or catch restrictions (discarding at sea may need to be monitored or prevented). Hence monitoring and enforcement staff will usually need to be capable of working at sea, and for senior staff it may be appropriate that they hold some appropriate form of mariner's certification. Most of all they must be incorruptible, which argues that their income must be adequate and they must be carefully selected.

Most fisheries management approaches need some form of scientific advice in order to make informed decisions (see Chapter 13). This is especially the case for fishing effort management and catch management. Both are intended to limit the proportion of the fish stocks being removed each year to a sustainable level. Ideally this requires ongoing information on what proportion of the stock is being removed each year. It also requires a reasonable knowledge of what levels of removals are likely to prove sustainable. These facts allow adjustment to be made either to the fishing effort being applied to the stock or to the catch being removed from it, so as to lead to the appropriate proportion being removed in the future.

Advice on stock status requires some suitable source of scientific advice. Such advice is in fact quite difficult to provide since they require the enumeration of a resource that cannot be directly seen or counted and an understanding of how it will react to exploitation. This might possibly be acquired on an *ad hoc* basis from university departments but if advice is more than minimal it will probably require either a dedicated scientific agency or the ability to commission appropriate scientific advice. The provision of advice also typically requires some scientific as opposed to management data collection since scientific assessment of a stock typically requires a more detailed understanding than is required for routine monitoring, control and surveillance.

In addition to the biological advice that underpins the setting of limits, it will also be wise to have advice on the likely economic and social effects of the management. Since these may well give conflicting signals, all such advice is best integrated so that the trade-offs between each effect can be clearly seen.

- Effective monitoring, enforcement and some biological advice are necessary overheads if fisheries are to be properly managed by input or output controls.
- Data on the biological, economic and social health of the fishery are highly desirable.
- Adequate structures are needed to provide to these services.

9.6 What problems exist with the application of effort management and catch management and how might they be circumvented?

9.6.1 The problem of effort management

A major problem of effort management is defining a reasonable unit measure of fishing effort. For example, for towed fishing gears (i.e. otter trawls, dredges, beam trawls) some

combination of vessel tonnage and engine power often seems appropriate as a measure of the ability to catch a proportion of the stock. As an example of this, the EU effort management system (called the Multiannual Guidance Programme) uses both tonnage and also engine power to define alternative measures of fishing power, both of which must decrease through time to agreed schedules. For static gear fishing methods, other effort measures might be more appropriate as a consistent indicator of fishing power but for some methods no such consistent measure exists. This is because a major requirement of any input control is that a given amount of the input regulated should correspond to a constant ability to exploit fish. This tends to be the case for fisheries based upon gear towed on the seabed. However, for fisheries on schooling pelagic species the proportion of the fish stock caught by a given unit of fishing effort may vary depending on the size of the stock. This is because the schools are the target of these fisheries. If the number of schools of fish diminish as the stock size diminishes then it will become progressively easier to take larger proportions of the stock as its abundance declines since a school will represent a larger fraction of the stock. For such stocks there is thus no link between the fishing effort measured by fishing operations and the proportion caught, and consequently such stocks are clearly not suited to management by input controls.

Where an effort management approach is appropriate then the main problems centre around the increases in technical efficiency that tend to occur as time goes on. The problem of capital stuffing has already been mentioned. It is rather obvious that if fishers cannot expand a profitable operation by increasing the size or number of their vessels, they may try to do so by spending more on capital improvements designed to increase its efficiency. Whether there is an upper limit to possible efficiency improvements is a moot point. However, if there is a theoretical upper limit, it is clear that it has not yet been reached since efficiency still tends to increase. Certainly fishing gear technology has advanced inexorably over the last century and with it the ability of a given size of vessel to kill a greater proportion of the fish available. Consequently restricting fishers' investment in vessel tonnage or engine size by effort management is likely to make technical improvements in vessel efficiency very tempting. Either removing super normal profits by fiscal measures or progressively reducing the fleet capacity seems the most appropriate responses to this. The alternative of specifying fishing vessel characteristics as tightly as those of a class of racing yachts seems inappropriate and stifling of innovation. Moreover, given the ingenuity of mankind, it is unlikely to work since fishers will find ways to improve any unregulated dimensions of the inputs. Thus it is most important to anticipate that such efficiency improvements will occur and how they will be handled when they do.

A particular problem is that licences may frequently specify engine power. Engines may readily have their power output derated by minor technical modifications. Such engines can thus be certified to comply with a licence requirement but after certification their performance may be subsequently subtly upgraded! Periodic certification and inspection is needed to close this loophole.

Other problems concern non-licensed fishing. This may be a particular problem for fisheries in international waters where fleets flagged in countries that are not part of the relevant international organisation may feel inclined to disregard its decisions. They most certainly should not do so. The FAO Compliance Agreement[3] and the IPOA on Illegal, Unregulated and Unreported Fishing[4] both address this important matter.

[4] Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (see Chapter 5).

[5] International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. http://www.fao.org/DOCREP/003/y1224E/Y1224E00.HTM

Multispecies fisheries pose particular problems and are dealt with in a section below. In short,

- fishing effort management is often useful with towed gears;
- it is usually inappropriate for fisheries on schooling pelagic species;
- it may be more difficult to apply effectively to static gear fisheries;
- even where it is useful, always anticipate that efficiency will increase through time.

9.6.2 Problems with catch management

Non-compliance

As discussed earlier with simple output control approaches (when the fishery is closed as soon as the quota is taken), a race to fish is almost bound to develop and may be associated with overcapacity, poor economic performance, poor fish product price and quality, and only seasonal employment. Moreover, a rush to catch fish may cause the safety of crews to be compromised. With more orderly management of quotas with allocations made to groups or individuals, these problems are less likely to occur. The major problem with such a form of output control is the frequent non-compliance or circumvention of the regulation. In many fisheries there is bound to be an economic temptation for fishers to land more fish than their allocations allow. Such illegal landings are often called 'black landings'. If they are extensive they may undermine faith in the management process (see box on Faeroes fisheries management). Moreover, the distortion of catch statistics that they may create may also make it difficult for fisheries scientists to provide accurate estimates of future catches. The reduced ability of scientists to predict catches may lead to a further lack of faith in the management system. The obvious remedy is tighter enforcement coupled with an education program to make fishers realise that they are cheating fellow fishers rather than the government. This is likely to be facilitated by a more open system of governance that includes industry representatives as members.

A more subtle form of non-compliance is reporting one quota species as another species or reporting a species as coming from another management area. Such forms of non-compliance are sometimes referred to as 'grey landings'. The consequences of grey landings in terms of reduced faith in the system can be as pernicious as those of 'black landings'. Indeed they may be worse since they foul the statistics and scientific advice on at least two stocks. Again education and appropriate consultation with the fishers to achieve buy-in to the regulations are the appropriate responses to prevent this happening.

- Non-compliance undermines faith in output controls and also undermines the assessment process on which future catch limits are based.
- Adequate enforcement coupled with close involvement and consultation with the industry should help avoid non-compliance.

Discards

Quota regulations are often specified as levels of legal landings rather than catch. So fishers may chose to discard some of the less-valuable part of their catch in order to get the best

earnings from the quota they have available. Such discarding is often legal and indeed fishers may be required to discard overquota or undersized fish. Such discarding is wasteful and should be minimised. Moreover, such discarding practices may also distort the intention of the regulation and allow exploitation to be higher than the regulation intended. Again this is a practice that may undermine faith in the management system. The prevention of discarding presents a dilemma: if discarding has to be permitted, its extent should be measured by scientific observers (though this is expensive); or if discarding is banned it may help reduce discarding but may also cause it to be conducted covertly and thus, render it unobservable. Some countries (e.g. Norway) require all catches of cod and haddock to be landed and some countries compensate fishers for the cost of landing illegal or unmarketable fish. Compensation is set at a level that encourages landing but provides no real profit to accrue to fishers from catching the fish. South Africa sets a total allowable bycatch for juvenile sardine caught in the anchovy fishery. Other approaches involve the setting up of permanent or temporary closed areas to direct fishers away from the areas where fish that are likely to be discarded are abundant. Temporary closed areas obviously require fast footwork by managers to be effective and are thus more easily achieved when the industry is involved in the details of the management and can provide rapid intelligence. Temporary closed areas are used, for example, in Norway and Iceland, and the pelagic fishing industry in South Africa imposes temporary closed areas on its members as a means of keeping bycatches of certain species within prescribed limits.

- Either ban discarding or at least actively discourage the practice.
- Engage the industry in schemes to avoid catching and discarding unwanted fish.

Problems with providing adequate scientific assessments of catch limits

Fish populations often vary in abundance from year to year and may also be anticipated to change in abundance with respect to changes in exploitation or shifts in ocean regimes. Consequently, effective catch management has to modify the levels of TAC to reflect these changes. Since TACs normally have to be set in advance of the fishing season this means that they must be based on predictions of fish abundance for the next fishing season. This is relatively straightforward when next year's abundance is based upon a population that contains a number of age groups, most of which have been seen during fishing in previous years. However, it may be difficult or virtually impossible when each season's fishery is based upon an incoming brood of fish of unpredictable size. Effective management in these circumstances requires very fast footwork by scientific advisors to provide adequate predictions and this tends to add to the costs. This does make output controls more difficult to apply in warmer waters where fish growth and death rates are generally higher and the populations consequently turn over more rapidly. Moreover, in such waters there is typically a greater diversity of fish species to manage which would multiply these costs. The alternative of adopting an output control based upon a multispecies quota might be one way forward but would, like an input control, suffer from the ability of fishers to cherry-pick the most profitable species from an assemblage. It is also fair to say that the scientific means to make annual modifications to such a multispecies quota are still in their infancy.

- Avoid using catch limits on stocks with high mortality rates.

9.6.3 Effort and catch management in the context of multispecies fisheries

Fisheries are often based upon several fish species, the so called multispecies fisheries. This either occurs because several species of fish are inevitably caught by rather non-selective gears such as bottom fishing otter trawls or catching several species forms part of a fleet's wider economic strategy, its métier. The term multispecies fisheries is also used by scientists where clear biological interactions exist between two or more species even when they are not necessarily caught with the same gear. This aspect of multispecies fisheries is discussed in the next subsection.

The first two meanings are of more direct concern to us here since both imply that fishing mortality on one species is linked in someway to that of the other. It often follows that the fishing intensity on one species (often the larger or more valuable species) can be excessive, while that on the other species could be larger but sustainable if viewed in isolation. Effective fisheries management then needs to find some balance between the conflicting management requirements of both species.

In the case of input controls, fishing effort is not typically designated with respect to particular species. It will tend to be deployed on species in a way which reflects the best bargain fishers can get given the relative ease of capturing different species, their market value and other factors such as the proximity of species concentrations to harbours. Thus, in an input controlled system based on multispecies fisheries, management can specify the total amount of fishing effort to be deployed but not the species it will target. There is a sort of charming simplicity to this; just get the fishing effort or the fleet size (the inputs) right and leave the fishers to use it as they see best. The problem may be though that this might result in low productivity species being fished too hard, while more productive species are less targeted. Where these problems arise there will be a need for technical measures such as gear modifications (see Chapters 7 and 8) to direct fishing away from the less-productive components of the fish assemblage.

In multispecies fisheries there is an obvious risk that fishing effort may switch between the various available fish stocks depending on which is currently the most profitable. To some extent this might be beneficial since fishing effort might tend to move off of stocks which are at low abundance and move onto ones which are at high abundance. However, there remains the risk that the more valuable species will tend to attract more of the fishing pressure than less-valuable species. Moreover, scarcity might cause particularly valuable species to increase in unit price sufficiently to continue to attract effort even when they are overexploited and at low abundance. Such problems might also be addressed by imposing technical conservation measures designed to protect the more valuable and more vulnerable species of an assemblage for example by closing areas or seasons when they are particularly vulnerable, such as spawning times and areas.

A further problem may occur where several different fisheries coexist within an area. In such cases it may be difficult to ensure that a vessel licensed to participate in one fishery is not in fact participating in another.

One interesting suggestion for managing fishing effort on multispecies resources is to zone an area in such a way that effort deployed in areas where the most vulnerable species are more abundant has a higher tariff. For example in the North Sea, two flatfish species (sole and plaice) are the main targets of the beam trawl fishery. It is possible to split the North Sea into temporal and spatial zones where there are more plaice and other zones where there are more sole. Currently the effort tends to concentrate on the areas where the more valuable sole

is most abundant. Hence a scheme that costed double the nominal effort deployed in these latter zones against a vessel's effort quota would probably encourage some redeployment to zones richer in plaice. Satellite tracking devices, which nowadays are often required equipment for fishing vessels, could be used to implement such a scheme. In effect, fishers can still use their effort quota as they choose, but it is used up more rapidly in some areas than others. There is some analogy to this scheme in the congestion charge that is levied on private cars in London to discourage people from driving into central London. Of course it costs money to drive a car anywhere but in London you face an extra substantial daily charge if you drive in the designated central London area.

While input controls provide a coherent approach for multispecies fisheries they do not, in principle, provide strong or appropriate protection for individual species. In the case of output (catch) controls the reverse is the case. In principle they can provide protection for each species to which they apply but they are often not coherent between species. Thus for many years the scientific advice for North Sea cod was that ideally it would have a zero TAC but because of the bycatch of cod in a wide range of other fisheries this was not possible.

Discarding can be a particular problem in multispecies fisheries and is exacerbated when quotas for different species are not compatible. When a quota for one species is exhausted, fishers may continue to catch it and to discard it while fishing for other species in the area. This creates a particular problem if one species is recovering from overexploitation and its quotas have been set to achieve low removal rates, while the quota for another species allows far higher removal rates. The problem is of course exacerbated if both species are caught with the same fishing gear at the same time and in the same place. Allowing the limited landings of bycatches of the more vulnerable species may be one management approach but this may cause a fishing pattern to develop, which utilises any bycatch provision to the maximum extent possible. Suitable technical measures may be another approach but the problem may be that the vulnerable species is larger and more selected by fishing gears than the less-vulnerable species.

A draconian but effective approach is to close the entire fishery once one quota is exhausted or once some specified bycatch level has been exceeded. This is practised in the Bering Sea and Gulf of Alaska fisheries of the United States to protect Pacific halibut and marine mammals. It requires a dedicated observer programme for such an approach to be effective. Where observer programmes do not operate, there is a risk that some fleets might make anticipatory discards of any species with quotas, which if exceeded would lead to a closure of the total fishery.

- Output controls can work in fisheries where only a few species form the bulk of the catch.
- Such fisheries typically need the backup of technical measures to avoid exploiting some species more heavily than others.
- Catch limits are not very practical in fisheries based upon many species.
- For such fisheries a combination of input controls and technical measures is a more practical basis for management.

9.6.4 Effort and catch management in the context of ecosystem management

Traditional fisheries management tends to deal with each target fish species in isolation and assumes that the direct effects on the targeted species are by far the most important. As we have seen in the previous subsection, problems arise when the same fleet catches several

species. Such problems can be particularly serious if the bycatch is of a species that is more susceptible to harvesting than the target fish species. An obvious example of this is bycatch of marine mammals in gill nets. These gears are used to catch a variety of fish species, some of which could sustain harvest rates of 20% or 30% a year. However, these gears (amongst others) may also catch and kill small cetaceans. These species, being slow breeders, can only sustain harvest rates of about 1% per year. Fishing affects the marine ecosystem by this process of killing non-target species. It also affects the marine ecosystem by modifying the food chain, reducing some species and sometimes encouraging others. In particular scavenging species often profit by discarded fish and fish wastes. Bottom fishing can also directly modify the bottom substrate and thus the bottom fauna.

Ecosystem management is shorthand for what is more more properly called an ecosystem approach to fisheries management. It considers the commercial fish, and indeed the fishers as just part of the marine environment. These need to be managed in a way that maintains the health of the whole system. Ideally it would take account of all the impacts fishing might have on all components of the system and take measures which protect the more vulnerable components. Obviously this is a subject that could take up a book by itself but here we confine ourselves to the contribution that input and output controls might make.

What then have input and output controls to offer ecosystem-based management? They offer the only mechanism for directly limiting the broad level of human impacts although other mechanisms, for example fiscal instruments may achieve this indirectly by making excessive fishing unprofitable. They also provide one of the main approaches for assigning rights to fishers. Ideally when rights are assigned so should obligations to avoid damaging the wider ecosystem.

Even without the assignment of obligations, rights-based input or output management are likely to direct fishers' attention more clearly towards maintaining the health of the stocks they have rights to. In principle, if not always in practice, such rights should also act to encourage lower levels of overall exploitation because this provides greater long-term economic payoff for the fishery. Any reductions in exploitation are likely to benefit the wider ecosystem by generally reduced fishing intensity. However, this benefit might be negated if more aggressive gears are used to increase efficiency. It is likely that some ecosystem problems will remain even with reduced fishing. These problems need to be addressed by appropriately targeted technical measures or by broader approaches, such as Marine Protected Areas, designed to protect more vulnerable species and habitats. Thus input or output controls, particularly if harnessed to rights-based management, may help address the problems of ecosystem management but are unlikely to provide the whole answer. Curiously, the objective of achieving a profitable fishery may be more compatible with protecting the wider ecosystem than a social objective of providing yield or employment, since it implies less fishing effort and possibly a focus on the quality of catch rather than its bulk capture. Moreover, where fishers are operating profitably, it may be easier for them to make compromises with environmental concerns than when the bank manager is breathing down their neck.

- Ecosystem-based management is facilitated by lower exploitation levels.
- It is thus more compatible with economic than social objectives.
- Rights-based fishing and co-management with the industry may help reduce the impact of fishing on the marine ecosystem.
- Reducing exploitation levels will reduce the impact of fishing on the ecosystem but this will probably need backing up with measures such as closing areas to fishing where particularly vulnerable biota or habitats are found.

9.6.5 The precautionary approach and fishing effort and catch management

The precautionary approach to fisheries management can be applied at all stages of development of fisheries. It is not particularly associated with any single management approach. However, as fish stocks become progressively more exploited, it is likely they may require the reduction in exploitation rates that effort management or catch management are both intended to provide. An intelligent anticipation of this need may certainly help. This could be achieved by adopting restrictive licensing schemes and detailed catch statistics before the need for them becomes acute. Such intelligent anticipation of future problems by the development of a suitable fisheries management plan is an integral part of the precautionary approach. More detailed interpretation of the precautionary approach becomes possible once a full range of effort or catch management measures is in place. In particular the imposition of target and limit reference points for a fishery may be made more possible if the population dynamics of a stock are known in the detail often required by catch management.

Scientists can help develop recovery plans that are compatible with the precautionary approach. These typically involve progressive reductions in fishing mortality rate as stock sizes diminish. Such detailed management requires effort management and/or catch management for their achievement. The International Council for the Exploration of the Sea (ICES) has been involved in developing such plans for some of the stocks for which it provides scientific advice. The box below shows the text of the full management plan agreed between Norway and the EU for North Sea haddock. Clauses 4 and 5 can be seen as the recovery plan for this stock. They are the actions that are to be taken if the spawning stock biomass (SSB) declines towards the biomass limit reference point (i.e. if SSB is between the precautionary approach biomass, Bpa and the limit reference point Blim, then clause 4 is invoked and if it is below Blim, then clause 5 is invoked). Such plans are best made before such crises occur rather than invented in the panic of a stock decline.

EU and Norway Management plan for North Sea Haddock

The plan shall consist of the following elements:

1. Every effort shall be made to maintain a minimum level of Spawning Stock Biomass greater than 100,000 tonnes (Blim).
2. For 2007 and subsequent years the Parties agreed to restrict their fishing on the basis of a TAC consistent with a fishing mortality rate of no more than 0.3 for appropriate age-groups, when the SSB in the end of the year in which the TAC is applied is estimated above 140,000 tonnes (Bpa).
3. Where the rule in paragraph 2 would lead to a TAC which deviates by more than 15% from the TAC of the preceding year the Parties shall establish a TAC that is no more than 15% greater or 15% less than the TAC of the preceding year.
4. Where the SSB referred to in paragraph 2 is estimated to be below Bpa but above Blim the TAC shall not exceed a level which will result in a fishing mortality rate equal to 0.3-0.2*(Bpa-SSB)/(Bpa-Blim). This consideration overrides paragraph 3.

5. Where the SSB referred to in paragraph 2 is estimated to be below Blim the TAC shall be set at a level corresponding to a total fishing mortality rate of no more than 0.1. This consideration overrides paragraph 3.
6. In order to reduce discarding and to increase the spawning stock biomass and the yield of haddock, the Parties agreed that the exploitation pattern shall, while recalling that other demersal species are harvested in these fisheries, be improved in the light of new scientific advice from inter alia ICES.
7. In the event that ICES advises that changes are required to the precautionary reference points Bpa (140 000t) or Blim (100 000t) the parties shall meet to review paragraphs 1–5.
8. No later than 31 December 2009, the parties shall review the arrangements in paragraphs 1 to 7 in order to ensure that they are consistent with the objective of the plan. This review shall be conducted after obtaining inter alia advice from ICES concerning the performance of the plan in relation to its objective.

This arrangement enters into force on 1 January 2007.
Text taken from ICES Advice 2007, Book 6 *Annex* 6.4.3a.

- Prudent foresight is at the heart of the precautionary approach.
- Input or output controls are likely to be an important component in stock recovery, and how they should be adapted to overcome crises should be agreed before a crisis occurs.

The only realistic alternatives or adjuncts to the use of input or output controls to assist stock recovery would be to

- progressively ratchet up technical conservation measures to increasingly safe levels, for example to progressively increase towed gear mesh sizes to sizes that give fish a chance to spawn several times before they are caught,
- increase fiscal measures such as extraction taxes, or
- alternatively to progressively extending the areas of no take zones until no fishable area remained.

9.7 Where can you see examples of effort management and catch management in action?

Catch management, notably TAC management systems, is particularly common in fisheries where the catch is based upon fewer species. In the case of demersal (bottom living) fisheries, these are more often found in higher latitudes. Most of the major demersal fisheries of the European fisheries of the North Atlantic have TACs as the primary management instrument. The same is true of the demersal fisheries of Canada and in much of the United States (though traditionally in a somewhat more flexible form where overages have triggered management actions other than closure). TAC management is also practised in Argentina, Australia, Namibia, New Zealand and South Africa. One may also find them used on pelagic fisheries which tend to be less mixed than demersal fisheries. Notably, they are used on large pelagic fisheries such as the southern bluefin tuna.

TACs have an obvious appeal when fishing opportunities have to be shared between countries, or communities or fleets since they can be allocated a constant share of the overall TAC. Such percentage shares of catch form the basis of many fisheries agreements between countries. In general it is easier for countries to agree to share catch in some proportion than to agree how to share out fishing effort. This is because fishing effort is measured in various ways for various fleets so that establishing a common currency for an agreement is technically difficult.

It is well known that fishing effort may change in efficiency through time and that changes in efficiency by one partner might well undermine any agreement. Thus percentage shares of catch (so called relative stability) forms the basis of national shares of the EU's Atlantic fisheries. It is also the basis of the share between Norway and the EU in the North Sea; Norway and Russia in the Barents Sea; and between the members of the CCSBT for the southern bluefin tuna. For these reasons, TAC management remains established in these areas even where its track record for achieving sustainable fisheries is anything but impressive, for example in the demersal fisheries of the EU.

While the use of TAC management is widespread in higher latitude demersal and pelagic fisheries, it appears to be more difficult to operate as the number of species increase in a given fishery. There are several reasons for this. Firstly, problems of bycatch are bound to increase as more species occur in the catch and it is more likely that several of the quotas managing such a fishery will be incompatible and lead to discarding or falsified landing declarations. Secondly, the requirement for scientific assessments of stock sizes becomes more difficult and less cost-effective when faced with many small stocks rather than one big one. This is because the amount of sampling needed to effectively sample a small stock is similar to that required for sampling a large one. The cost of scientific advice may thus tend to be lower per unit catch for a large fish stock than a small one. The same is often true of the per-unit costs of management monitoring and surveillance. Therefore, by extension, the species-rich demersal fisheries of tropical regions may be virtually impossible to manage by single-species quotas. The alternative of multispecies quotas of course always carries the risk that the fishery may focus on the more valuable species and perhaps discard the less-valuable species in order to maximise short-term earnings.

Effort limitation is properly a component of management for all fisheries and is found in some form in many legislations. However, it does not always act as the binding constraint on fishers. Pure effort management systems, where it is the main constraint, have a less-systematic distribution. Clearly they may be inappropriate for managing fisheries on schooling pelagic fish whose catchability may increase as stock sizes decrease. They seem appropriate for some single-species fisheries particularly where precise scientific assessment of stock size is difficult but where a reasonable presumption of constant catchability exists. Examples of this are seen in some local shellfish fisheries.

Mozambique deep-water shrimp fishery

This fishery illustrates the potential advantages of effort management but also the problems of success. The fishery on Sofala bank catches two types of shrimp. One species has continuous recruitment while the other recruits to the fishery during November and December. An industrial trawler fishery started in the late 1970s and rapidly became the

most valuable fishery in Mozambique. In the past it was mainly fished by two joint venture fleets from which Mozambique earned licensing fees. However, the stocks became overexploited by the early 1990s. A limited entry scheme and a TAC were introduced but the latter was set at too high a TAC to form a binding constraint on the fishery. In this fishery on short-lived species a TAC is in any case probably very difficult to calculate in an accurate and timely fashion. The Mozambique Fisheries Research Institute (IIP) proposed a closed season for January and February both as a technical measure and also as an effort reduction. This resulted in a rapid recovery of the fishery to profitable levels. The closed season was subsequently extended to also include December. However, the profitable nature of the fishery led to the issue of additional licences. Currently one of the species is regarded by IIP as intensely fished.

Effort management seems appropriate for multispecies trawl fisheries where the ability of the fleets to move their attentions to the most abundant species may help reduce pressure on depleted stocks. However, this is not an automatic benefit. It would certainly depend upon the fleets not being so large that they exhausted one stock before the rested stock recovered. It would also depend upon how separate the distributions of the different fish were and how their relative prices adapted to scarcity or abundance.

Effort management is also used as a backstop for fisheries predominantly managed by TAC. An example is the Atlantic fisheries of the EU where the capacity of the fleet is out of balance with the resources and needs to be reduced. In the case of the EU, an effort management programme called the Multiannual Guidance Programme has been in place for some time. However, it has suffered in that the annual reductions that EU countries could agree are insufficient to stem the typical increases in the efficiency of fishing effort that may be expected and it has had to be backed up with restrictions in the days at sea that some fleets can fish.

Experience suggests that single tools seldom suffice to achieve fisheries management objectives. Moreover, where multiple objectives exist, multiple management tools will certainly be required. However, it is also true that the problems with both fishing effort management and catch restrictions are that concerns for short-term goals and the lack of proper consultation and proper incentives have often clouded the achievement of long-term goals. Where this has been the case, fishing effort and catch management have not been applied with sufficient vigour or with sufficient regard to the precautionary approach to achieve long-term sustainability.

9.8 Synthesis and outlook

Input controls mostly mean the restrictive capping of fishing effort, while output controls mostly mean the restrictive capping of species catch. In some form, one or both controls are likely to form part of the management of well-regulated fisheries; their main virtue being that they provide mechanisms to directly cap human activity.

Input controls, in some senses, are simpler to apply because they tend to be kept constant through time. Moreover they do not apply to individual species. Because they are likely to remain at the same value (or some fixed trend) for some years, they do not require as much

biological data nor as much enforcement information as do output controls. Because of this greater simplicity they are probably more suited to managing trawl fisheries based upon multispecies bottom fish, particularly those of tropical nations. However, they are easier to apply to active towed fishing gears than to static gears because it is often difficult to control the input of gear units (e.g. numbers of pots used) as opposed to the input of vessels. A further problem is that because they are not species based, they may allow fishers to focus too much on certain preferred species. Moreover, since they rely upon the link between fishing effort (vessel usage) and the harvest rate of fish they are generally useless for managing schooling pelagic species.

Output controls are more focused on species but become increasingly difficult in extreme multispecies contexts. The data required to construct the essential scientific indications of stock size make them more suitable for situations where there are comparatively few large fish stocks rather than many small stocks. Thus they are most often used in the management of fisheries in temperate and Arctic regions or of single-species pelagic fisheries. As well as with regard to the problems of providing cost-effective scientific advice, setting a series of species TACs, which are mutually compatible and do not lead to excessive bycatch or discarding, is problematic in very mixed fisheries.

One virtue of both approaches is that they are the most obvious adjuncts to types of rights-based management such as ITQs or effort. These seem one of the brighter hopes for effective management since they address the economic drivers, which are keenly felt by most fishers.

A number of improvements to input and output controls are in prospect. Firstly the wide availability of satellite tracking of fishing vessels allows finer grained measures to be applied to input controls, which were traditionally based only upon days out of port. Thus the possibility of differentially charging of effort by zone of use gives some possibility of sharpening up what has traditionally been a rather blunt instrument of management.

Cheaper means of estimating TACs through Management Procedure type approaches hold some promise of making output and perhaps also input controls both more reliable and more cost-effective and thus more widely applicable. The possibility of multispecies quotas has not been much considered but might be one approach to using output controls in the sometimes very mixed fisheries of tropical areas.

Sources and recommended reading and web resources

General Fisheries Management

FAO. 1995a. Code of Conduct for Responsible Fisheries. Rome, FAO. 41p.

FAO. 1995b. Precautionary Approach to Fisheries. Part 1: Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions. FAO Fisheries Technical Paper. No. 350/1. Rome, FAO. 52p.

FAO. 1996. FAO Technical Guidelines for Responsible Fisheries No. 2. Precautionary Approach to Capture Fisheries. Rome, FAO. 54p.

FAO. 2003–2009. IPOA-CAPACITY homepage. International Plan of Action for the Management of Fishing Capacity. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 30 July 2003.

Jentoft, S. and McCay, B. 1995. User participation in fisheries management: Lessons drawn from international experiences. *Marine Policy*, 19: 227–246.

McGoodwin, J.R. 1990. *Crisis in the World's Fisheries: People, Problems and Policies*. Stanford University Press, Stanford.
Townsend, R.E. 1998. Beyond ITQs: Property rights as a management tool. *Fisheries Research*, 37: 203–210.

Bycatch and discards

Alverson, D.L., Freeberg, M.H., Marawski, S.A. and Pope, J.G. 1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper. No. 339. Rome, FAO. 233p. ftp://ftp.fao.org/docrep/fao/008/y5936e/y5936e00.pdf

Objectives

Pope, J.G. 1983. Fisheries resource management theory and practice. In: *New Zealand finfish Fisheries: the Resources and their Management*. Taylor, J.L. and Baird, G.G. (eds). pp. 56–62. Trade Publications, Auckland.
Hilborn, R. 2007. Moving to sustainability by learning from successful fisheries. *Ambio* 36: 4: 296–303.

Management procedures

Rademeyer, R.A., Plagányi, E.E. and Butterworth, D.S. 2007. Tips and tricks in designing management procedures. *ICES Journal of Marine Science*, 64: 618–625.

Aspects of management in specific areas

Australia

http://www.afma.gov.au/about/who/history/default.htm

Bermuda

http://www.fao.org/DOCREP/006/Y4931B/y4931b08.htm

Canada

http://www.dfo-mpo.gc.ca/csas/Csas/status/2004/SSR2004_019_e.pdf
http://www.dfo-mpo.gc.ca/csas/csas/publications/pub_index_e.htm
http://www.frcc-ccrh.ca/

North East Atlantic

ICES. 1997. Report of the Study Group on the Precautionary Approach to Fisheries Management, ICES Headquarters, 5–11 February 1997. ICES CM 1997/Assess:7. 41p.

EU

http://ec.europa.eu/fisheries/cfp_en.htm
http://eur-lex.europa.eu/LexUriServ/site/en/com/2006/com2006_0872en01.pdf
http://www.nsrac.org/

Faeroes

http://www.ices.dk/committe/acfm/comwork/report/2007/may/cod-farp.pdf
http://www.ices.dk/committe/acfm/comwork/report/2007/may/had-faro.pdf
http://www.fishin.fo/get.asp?gid=d2FF4388C-1FE7-46D5-91F9-943B36D92C0E

Mozambique

http://www.fao.org/fi/fcp/en/MOZ/body.htm

New Zealand

http://www.fish.govt.nz/en-nz/Commercial/Quota+Management+System/default.htm?wbc_purpose=Basic&WBCMODE=PresentationUnpublished%2cPresentationUnpublished

Hersoug, B. 2002. *Unfinished Business. New Zealand's Experience with Rights-based Fisheries Management*. Eburon, Delft. p.246.

United Kingdom

http://www.london-gazette.gov.uk/si/si1993/Uksi_19931196_en_1.htm
http://www.nffo.org.uk/pdf/nffo_august07_screen.pdf

Chapter 10

Rights-Based Fisheries Management: The Role of Use Rights in Managing Access and Harvesting

Anthony Charles

10.1 What is rights-based fishery management?

'Rights-based management' is an approach to fishery management that focuses on the rights (together with the responsibilities) held by individuals, communities, companies and governments relating to fishing. In this chapter, we will explore rights-based management and its role in supporting fishery management, with particular attention to what are known as 'use rights'. In this section, we discuss the idea of 'property rights' and ownership of fish in the sea, we introduce use rights and draw connections with human rights and finally we examine a parallel form of fishery rights, namely 'management rights'.

10.1.1 Property rights: who owns fish in the sea?

Property rights are the relationships between people that arise over various forms of property – whether a fish stock, a fishing boat or a license to fish. Before focusing on rights specifically in fishery management, consider the case of a fishing boat as a form of property. Typically, the rights in such a situation are reasonably clear: the 'owner' of the fishing boat, whether an individual, a community or a company, usually will have the right to use the boat (a use right), the right to prevent others from using it (an exclusion right) and the right to sell it if desired (an alienation right). These capabilities reflect several characteristics of the 'bundle' of property rights – something the owner of the boat usually has, while others do not.

Now consider fish in the sea. Who owns those fish is not always clear. Indeed, there are four property rights arrangements that could apply to fish in the sea.

1. *Non-property* – If no one can be seen to be the 'owner' of the fish, this lack of property rights is a case of 'non-property'. This situation – in which no one can claim ownership and exclude others from a fishery, and thus the fish are simply there for the taking – is typically one of 'open access' (see Sections 3.2 and 4.1.3). As time has passed, fewer and fewer of the world's fishery resources have been exploited in the absence of property rights, but even today the high seas pose a challenge in this regard.
2. *Private property* – Whenever a fisher catches a fish, once it is brought out of the water, that fish typically becomes the private property of the fisher. Even when fish are still swimming in the water, they may be private property, for example, fish in a lake located

entirely on someone's private land. In such cases, only the owner of the resource has the right to decide the use of the resource – subject possibly to societal constraints, such as those that may be imposed to preserve biodiversity.

3. *State property* – In many countries, fish in the oceans within a state's exclusive economic zone (EEZ) are the property of the nation's citizens and managed on their behalf by the government. In such cases, the fish are said to be 'state property'. The fish become private property when caught but remain state property as long as they are in the water. Typically such resources cannot be privatized without legislation or perhaps even constitutional change.
4. *Common property* – Suppose that the fish in the sea are 'owned in common' by a certain identifiable group of people – for example, the set of citizens within a specific local jurisdiction, such as a coastal community, or the members of a native tribe, but not a single private individual or company. In such circumstances, the fish are referred to as 'common property' – a frequently arising situation worldwide. (Note that one also finds the term common property used to refer to the fishery resources of an entire nation or other jurisdiction in which case the relevant 'group' includes all citizens of the nation, as with state property given in point 3.)

These four scenarios reflect the range of situations in fisheries around the world. While those considered to be 'owners' of the fish in the sea clearly vary, it is typically true that those engaged in fishing do not own the resource *per se* – until those fish are actually caught. This is a similar reality to that in other natural resource sectors. In forestry, for example, government-owned forests may be leased to industrial harvesting companies; these companies do not own the forests but instead have the right to use the resources, often subject to certain conditions. Similarly, in the oil and gas sector, the right of a company to use a particular oil field does not extend to ownership of the resources on or in the ground.

10.1.2 What are use rights?

This brings us to the focus of this chapter. While the aforementioned context of property rights and ownership of fish in the sea is crucial to understand, there is little practical day-to-day need to speak of 'property rights' as such. The key elements of rights-based management in fisheries relate to issues of access, harvesting and management, which involve 'use rights' (the focus here) and 'management rights'.

Whenever a fishery is managed by restricting who can have access to the fishery, how much fishing activity (fishing effort) the participants are allowed or how much catch each can take, those with such entitlements are said to hold use rights (Charles, 2001, 2004). Such use rights are simply 'the rights to use', as recognized or assigned by the relevant management authority (whether formal or informal).

Use rights can be viewed in parallel to the many forms of regulation available to fishery managers – such as area closures, limited entry and other input controls (effort limitation) and output controls (quotas), discussed in earlier chapters of this volume. These regulations address a range of fishery issues: Who can go fishing? Where is fishing allowed? How much gear can be used? How much fish can be caught? Suppose, however, that we look at these from a different perspective, not as restrictions but rather as the rights held by fishers or fishing communities to use the fishery resources – these are use rights.

For example, a programme of limited entry licensing may be seen as an 'input control' from the perspective of resource management, but each license also conveys a 'right' to access the fishery. In this sense, certain individuals, groups or communities have the right to 'use' the fishery (i.e. to go fishing) while all others do not have that right. Similarly, limits on the number of traps that are allowed to be used might be seen as a (negative) restriction or as a (positive) use right – the fisher, group or community has the right to use a certain number of traps.

There are many varieties of use rights and a wide variation in the extent to which they are incorporated into fishery management. In all cases, it is important to reiterate that use rights refer to the right to 'use' the fishery, and such rights should not be misinterpreted as implying 'ownership' of the fish resource itself. This crucial distinction has been confused at times with use rights promoted by suggesting that fishers holding these rights will in fact 'own' fish in the sea, just as one may own one's fishing boat. As should be clear from the above, this is not at all what is meant by use rights.

Furthermore, along with rights go responsibilities. As the FAO Code of Conduct (Article 6.1) notes, 'The right to fish carries with it the obligation to do so in a responsible manner. . .'. A key aspect in moving toward responsible fisheries thus lies in developing effective and accepted sets of both rights and responsibilities among fishers.

Use rights options range widely; for example, each of the following approaches to fishery management involves use rights:

- Customary marine tenure (CMT) and territorial use rights in fishing (TURFs) have long been applied by indigenous communities in determining for each member of the community (whether a fisher or household) the location where that member can access fishery resources.
- Limited entry was the initial approach to use rights in modern 'state' management of fisheries, providing a limited number of individual fishers with the right to access the fishery.
- Quota allocations made to individual fishers, companies, cooperatives, communities, etc., to catch a specified amount of fish, are numerical (quantitative) use rights, as are allocations of rights to a certain level of fishing effort (e.g. quantity of gear or days fishing).

While there is considerable diversity in use rights systems, it is helpful to consider two major categories. First, *access rights* deal with participation in the fishery, specifically relating to entry ('access') into the fishery or into a specific fishing ground – a fishing license would be an example of an access right. Second, *quantitative withdrawal rights* involve a numerical right, whether to use a specific amount of fishing effort (effort rights, e.g. to fish for a certain amount of time or with a certain amount of gear) or to take a specific catch (harvest rights or 'catch quotas'). Clearly, a withdrawal right incorporates, or must be accompanied by, an access right but the converse need not be the case – many fisheries operate through access rights without there being any quantitative withdrawal rights specified.

Each use right can occur at various organizational levels, that is rights held by individuals, by communities or regions, or by specific groupings such as fishing vessel or gear sectors. Indeed, the first of these options – individual fisher rights – is often the focus of attention in industrial fisheries, but an important form of use right, both historically and currently, is that held collectively by a community or fishery group.

Finally, it is helpful to envision each use right as being composed of a 'bundle' of rights characteristics, as noted earlier. The characteristics that each right will have may vary from case to case, but some possibilities include: security of the right, durability (longevity of the

right), transferability (ability to transfer the right to someone else) and exclusivity (ability to exclude others from infringing on the right, i.e. enforceability). The presence of each of these characteristics may have both positive and negative implications in any given situation, so the issue of which should be attached to a certain use right needs careful attention. We will be discussing some of these characteristics in detail later in this chapter.

Use rights beyond the fishery

Use rights arise in a multitude of contexts. For example, consider the owner of a home in a setting such as a rural village or an urban condominium (an apartment block in which each unit is privately owned). Such homeowners certainly have the right to 'use' the home. In addition, as will be discussed later, they likely have other rights as well: the right to exclude others from using the home and perhaps the right to sell the home to someone else. Now consider the common areas surrounding the home, and neighbouring homes, such as the village pasture or the garden outside the condominium building. The group of homeowners may well share the use rights over these common areas with no single person having the right to exclude others nor to sell the common area. Similar situations arise in settings where individuals and families hold various rights within their own households, as well as shared collective rights over community property. Alternatively, the cultural context may be such that collective (group) rights predominate throughout a society, a key reality in many nations.

10.1.3 How do use rights relate to human rights?

When most people think of 'rights', it may well be *human rights* that come to mind. There is an important relationship between such human rights and the use rights addressed in this chapter. Unfortunately, this relationship has been neglected in much of the literature on rights-based fisheries management, but it has been raised in recent discussions of the topic.

Recently, in the context of a debate over the nature of 'fishing rights', one analyst has developed a list of five 'fishing rights' that he suggests should be prominent in fishery thinking (Kearney, 2007). The five rights – which Kearney notes reflect more general statements found in the Universal Declaration of Human Rights – are as follows:

1. The right to fish for food.
2. The right to fish for livelihood.
3. The right to healthy households, communities and cultures.
4. The right to live and work in a healthy ecosystem that will support future generations of fishers.
5. The right to participate in the decisions affecting fishing.

If there are some aspects of human rights that can be maintained and enhanced through fishing activities, then this provides a strong link to fishery use rights and a context within which decisions can be made concerning who should hold those rights, how they should be

managed and so on. This connecting of use rights and human rights may be increasingly important to take into account in fishery policy development, at scales from the local to the international.

Indeed, FAO (2007, p. 6), in addressing issues in small-scale fisheries, notes that "A rights-based approach, in defining and allocating rights to fish, would also address the broader human rights of fishers to an adequate livelihood and would therefore include poverty-reduction criteria as a key component of decisions over equitable allocation of rights, including in decisions over inclusion and exclusion, and the protection of small-scale fishworkers' access to resources and markets".

10.1.4 What are management rights?

Use rights serve to specify and constrain who is to be involved in resource use, thereby making management more effective and conservation more likely. There is a parallel need to specify who is to be involved in fishery management, that is, through what are called '*management rights*'. In general, the state has the responsibility for management and indeed holds the liability in case of mismanagement. However, the State can delegate management functions, and the issue here is that of who else should be involved in fishery management whether alongside government or delegated by government.

Management rights and use rights can be seen as parallel forms: the former specify the right to participate in fishery management just as the latter specify the right to participate in the fishery itself. Management rights reflect the fifth 'right' noted by Kearney earlier, as well as the FAO Code of Conduct's call to 'facilitate consultation and the effective participation of industry, fishworkers, environmental and other interested organizations in decision-making with respect to the development of laws and policies related to fisheries management. . .' (Article 6.13).

This call for consultation and participation in fisheries management reflects a shift away from a mode of operation in which management was done by the managers, typically government officials within a commercial fishery context. Over time, it has become clear that fisheries management, practised in a top–down manner, may be unsuccessful because, in such situations, the manager rarely if ever has the time and finances to fully monitor and effectively control the thousands of fishers at sea.

This reality has led to a sense that effective management requires the support (or at least acceptance) of fishers, accompanied by some degree of self-regulation. This in turn has led to new co-management arrangements involving joint development of management measures by fishers, government and possibly local communities. Chapter 11 focuses on this topic, which has been the subject of considerable study in recent years. In the language of fishery rights, co-management requires allocation of management rights, the right to be involved in managing the fishery.

Who should hold management rights? As noted earlier, the government – with responsibility to conserve the resource, to produce benefits from that resource and to suitably distribute those benefits – will certainly be among those holding management rights. Furthermore, the earlier discussion suggests that, if only for pragmatic reasons, fishers (those with use rights) should be among the rights-holders. To what extent should management rights also be held by communities, non-governmental organizations (NGOs) and the general public? This is an important question, the answer to which may vary depending on the level of management under discussion.

At the operational or tactical level of management – involving measures such as closed areas, closed seasons and allowable hook or mesh sizes that affect the fishing process directly – it is particularly important for fishers to hold management rights so as to encourage compliance at sea. However, there may often be less interest among communities, NGOs and the general public to participate in these detailed operational aspects. (An exception may be cases in which ecosystem protection is an issue.) On the other hand, at the strategic level of management, debates over the fishery's overall objectives and policy directions are typically matters of public interest in which the general public, and fishing communities in particular, are legitimate interested parties. Thus, a wide spectrum of interested parties will (or should) hold management rights in dealing with strategic management issues and in setting objectives for use of the fish resources and of the ecosystem as a whole. This is increasingly the case with small-scale community-based fisheries; for example, legislation in the Philippines places management rights over coastal 'municipal fisheries' clearly at the level of the local municipality.

Related to, but distinct from, management rights are two other forms of rights (as identified by Ostrom and Schlager [1996]): exclusion rights (the right to allocate use rights and thereby determine who can access the fishery) and alienation rights (the right to authorize the transfer or sale of other rights). All three rights may be held by both users and non-users of the fishery contrasting with use rights which essentially are held only by fishery users. For example, while a fishing community may not hold use rights *per se*, it may have management rights. Precisely who should hold management, exclusion and alienation rights, and what institutions are suitable to deal with such rights, are becoming major issues likely to receive increasing attention in the years ahead. (See Chapter 11 for further discussion of this matter.)

While the remainder of this chapter focuses on use rights, it is important to keep in mind that those participating in the fishery (holders of use rights) may well be involved in fisheries management as well (as holders of management rights, in the spirit of co-management). Thus, as noted earlier, use rights and management rights may often operate in parallel.

10.2 Why are use rights relevant to fishery management?

Before discussing the various forms of use rights, questions of who can or should hold these rights and policy issues relating both to the choice among alternative use rights systems and to how use rights are implemented in practice, we begin by exploring the rationale for use rights.

The FAO Code of Conduct (Article 10.1.3) makes reference to use rights, not only within fisheries but pertaining to coastal resources in general: 'States should develop, as appropriate, institutional and legal frameworks in order to determine the possible uses of coastal resources and to govern access to them taking into account the rights of coastal fishing communities. . .'. Why are use rights so important?

10.2.1 What are 'open access' fisheries?

Open access fisheries are those in which there are no limits to access, so anyone can go fishing. This is the most unrestricted application of use rights – everyone holds the right to fish. Perhaps, the most famous cases of open access (and, until recently, its most serious

manifestation) have been the high seas fisheries taking place in ocean spaces located outside any single nation's jurisdiction.

It has become accepted wisdom, based both in theory and in the experiences of fishery collapse and stock depletion worldwide, that such open access is likely to produce disastrous conservation and economic problems. Unregulated 'laissez-faire' (free enterprise) exploit-ation of marine resources is among the greatest threats to long-term sustainability of fisheries. Indeed, the threat posed by such open access fisheries was a major factor leading to efforts to regulate fisheries on the high seas, through the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks and the subsequent United Nations Fish Stocks Agreement[1] implementing the relevant provisions of the United Nations Law of the Sea (see Section 5.2.2).

Even if there are regulated limits placed on catches in a fishery, one may still see the term 'open access' used, if there are no controls over the number of boats or the amount of gear. In such a case, the fish stocks may not necessarily collapse (if regulations work) but the fleet may become excessive (over-capitalized), driven by economic incentives to enter the fishery and to invest in larger boats (in a 'race for the fish'). With more inputs used than necessary to catch the fish, the economic health of the fishery may be threatened even if the resource is safeguarded.

It is important to avoid confusing 'open access' with the idea noted earlier of 'common property'; the former refers to unrestricted use rights over fishery resources, while the latter focuses on ownership of fish in the sea. The confusion, fuelled by a famous 1968 'Tragedy of the Commons' article by Hardin, led to common property arrangements being 'blamed' for the evils of open access over-exploitation (see also Section 3.2). In reality, while some common property fisheries are indeed open access, research has shown that this is by no means the rule and that, in many common property fisheries, the rights-holders have collectively developed effective management institutions, including use rights. Indeed, use rights can be implemented under common property just as much as under private property or state property (and to some extent even in the case of non-property, e.g. the United Nations Fish Stocks Agreement [Article 10], provides the capability to prescribe use rights on the high seas).

10.2.2 What is the rationale for use rights?

With open access fisheries having a bad reputation both internationally and within national jurisdictions, the overall need for, and desirability of, restricting use of fishery resources is accepted as a basic premise in fishery management. Informal and traditional use rights have existed for centuries in a wide variety of fishery jurisdictions. Even in cases where direct government regulation of fisheries dominates, use rights are being implemented with increasing frequency.

Use rights are relevant to the fishery manager not only in resolving open access problems but also in helping to clarify who is being affected by management. Some specific benefits are as follows:

- First, an effective use rights system eliminates (or reduces) the need for fishery management as such to deal with one major element of complexity and uncertainty – that

[1]Agreement for the Implementation of the Provisions of the UN Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

of identifying the set of users and regulating that group. Use rights aid management by specifying and clarifying who the stakeholders are in a certain fishery. In an already complex and uncertain management system, this can be a major benefit.

- Second, stakeholders – whether fishers, fishers' organizations, fishing companies or fishing communities – are provided with some security over access to fishing areas, use of an allowable set of fishing inputs or harvest of a certain quantity of fish. If use rights are well established, those involved in the fishery know who can or cannot access the fishery resources, how much fishing individuals and/or communities are allowed to do and how long these rights are applicable. When use rights are clear, fishers and fishing communities can better plan their resource harvesting, with greater capability both to optimize the value of the output within a conservationist framework and to adapt to changing conditions. Related to this, use rights may assist in reducing the magnitude of conflict in fisheries (in keeping with Article 7.6.5 and Article 10.1.4 of the FAO Code of Conduct). These factors are helpful in enhancing the fishery's overall resilience – its ability to 'bounce back' from unexpected shocks.
- Third, fishery management can more easily identify use rights-holders as those needing to meet certain conservation requirements. For example, the FAO Code of Conduct (Article 6.6) states that 'where proper selective and environmentally safe fishing gear and practices exist, they should be recognized and accorded a priority. . .'. This implies that there may need to be changes in the allocation criteria or the specifications of the use rights in order to promote (or favour) certain gear types or fishing practices.
- Fourth, with secure and durable use rights, conservation measures to protect 'the future' become more compatible with the fishers' own long-term interests, which may encourage adoption of a conservation ethic and responsible fishing practices and greater compliance with regulations (FAO Code of Conduct, Article 6.10). As noted earlier, the FAO Code of Conduct (Article 6.1) highlights the necessity of such connections between use rights and conservationist practices. This also points to the need for care in establishing use rights, since it is possible that certain use rights could be accompanied by anti-conservationist incentives that induce actions such as high grading in which low-valued fish is discarded in order to maximize profits.

10.3 What initial considerations arise with use rights?

Before moving ahead to examine use rights in a particular fishery, two key questions must be answered, one relating to the initial use rights situation in the fishery and the other to the overall policy objectives being pursued.

10.3.1 Are use rights already in place?

The first question one must ask is: Are use rights already established in the fishery? In existing fisheries, particularly those with a long history, one needs to understand whether use rights have already developed naturally over time, perhaps put in place by fishers themselves or by their community. This has proven to be the case in a wide variety of fisheries around the world. It is not surprising that use rights would have emerged, since there are clear benefits both for the fishers themselves and for the well-being of the fishing community, to defining

the group of fishers entitled to fish in a certain location. Social scientists have played a major role in documenting not only existing 'indigenous' use rights systems but also systems that had been in place in the past, but which were displaced by 'modern' central management. In many cases, the process of understanding local use rights accompanies that of accessing local knowledge about the fishery and its environment known as traditional ecological knowledge (TEK) (see Section 3.6).

If use rights already exist, and holders of the rights are already specified, the manager's first job may be to develop an understanding of the nature of those rights, how effective they are and whether there are available mechanisms to reinforce them. It will be important also to assess whether the use rights system meets current objectives in the fishery and criteria of equity and sustainability. Certainly, it is likely to be less costly and easier politically to accept and reinforce traditional rights rather than to attempt the development and enforcement of an entirely new regime. Thus, if use rights are currently in place, then only if they are for some reason unsustainable or unsuitable will it be necessary to implement a new use rights system.

10.3.2 What is the underlying policy framework?

Whether the focus is on enhancing and reinforcing existing use rights arrangements or developing a new set of use rights, we need to understand the specific framework for dealing with them. Indeed, whatever the use rights system, there are several policy issues that arise concerning the allocation and governance of the rights. How precisely should the desired use rights option(s) be implemented? How are those rights to be 'managed'? What management institutions will be effective for the various combinations of fishery resources, industry structure and political jurisdictions? Who should be involved in establishing and operating a use rights system? Suitable policies are needed to guide these decisions.

It is important to recognize that the matter of use rights is likely to be a controversial and delicate one. After all, use rights define who can and cannot take part in the fishery. In addition, there is likely to be an element of irreversibility to any decision about use rights; once rights are allocated, it may be very difficult to make major changes. This sensitive nature of use rights is particularly relevant when the status quo set of use rights is seen as inappropriate in the context of policy directions. In South Africa, for example, national policy goals have driven use rights' decisions within the fishery sector, as the transformation from a period of apartheid into one of democracy meant that broadening the right to access the fishery has been a matter of urgency (Cochrane and Payne, 1998). Whatever the specifics of a situation, the task of implementing use rights will be made easier if clear policy directions are laid out in advance, since such policy should provide guidance in terms of which parties in the fishery are to receive priority in obtaining use rights (e.g. small versus large vessels, community versus corporate participants, etc.).

Finally, it is also important to keep in mind that decisions involving use rights can affect not only current fishers but potential participants as well. This implies that despite the broad usefulness of co-management arrangements in which current fishers take part in management, it may be considered unfair to restrict participation in discussions of use rights to only the current fishers. The question of who should be allowed to take part in such discussions (and indeed whether a participatory process is feasible at all) needs careful consideration (see Chapter 11).

10.4 What forms of use rights are there?

This section examines in turn the various forms of use rights, depicted diagrammatically in Figure 10.1. These fit under the two broad headings given earlier.

- Access rights, which permit the holder to take part in a fishery (limited entry) or to fish in a particular location (territorial use rights or 'TURFs').
- Quantitative withdrawal rights, which typically involve numerical limits on resource usage, either through input (effort) rights or output (harvest) rights.

Two points are in order here. First, most of the use rights options to be described here correspond to an input or output control discussed in Chapter 9; they are really the same thing, seen from differing perspectives. For example, as noted earlier, the common regulatory approach of limited entry – seen as an 'input control' from the perspective of resource management – corresponds to an access right from the perspective of fisher management. Similarly, the fisher might see a limit on the number of traps allowed in a fishery as a (negative) restriction or as a (positive) use right. Therefore, there is some overlap between the content of this section and that presented in Chapter 9. The reader is referred to the latter for more details on the various input and output controls that underlie use rights. Note as well that the final part of this section discusses the factors involved in choosing amongst the various forms of use rights.

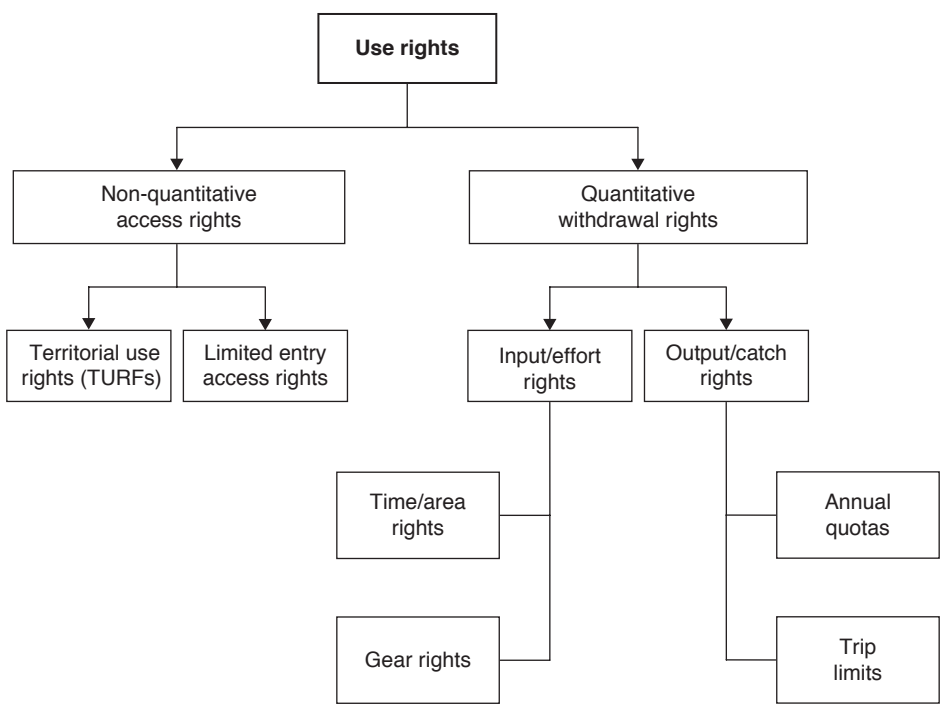


Figure 10.1 The relationships between the different forms of use rights. (See Townsend and Charles [1997] for further details.)

Second, whatever the form of use rights adopted, there are a number of policy issues that arise in implementing the use rights.

- A decision is needed about how the various forms of use rights are to be allocated, whether individually or collectively, that is to operate at the scale of the individual fisher or at that of fishers' organizations or fishing communities.
- The mechanisms by which rights are to be distributed initially must be settled, whether this is to be through market means, through a participatory or community-based process or by some other governing force. Decisions are also needed with respect to which individuals or groups should be allowed to hold the rights, and what should be their duration.
- In managing the use rights system on an ongoing basis over time, decisions must be made about whether rights should be transferable from one user to another, and if so, how rights can change hands (e.g. in a market) or be reallocated (e.g. through community processes), as well as who should be allowed to hold the rights.

For each of these policy issues, decisions between the alternatives are critical from both a policy and a practical perspective; this matter will be explored in detail in Section 10.5.

10.4.1 Territorial use rights (TURFs) and Customary Marine Tenure (CMT)

Among the most important management tools are those dealing with fishing location; these can be considered as arising in two forms. One is the 'closed area' approach in which an entire fleet is affected equally by a blanket prohibition on fishing in certain locations (such as a 'no take' area) (Chapter 8). The other, of interest here, is a rights-based approach involving TURFs and CMT. Both of these are inherently spatial management mechanisms, assigning rights to individuals and/or groups to fish in certain locations (thus the term 'territorial' in a TURF), generally, although not necessarily, based on long-standing tradition ('customary tenure').

A classic reference on TURFs is that of Christy (1982), who noted that 'As more and more study is given to the culture and organization of fishing communities, there are indications that some forms of TURFs are more pervasive than previously thought to be the case, in both modern and traditional marine fisheries'. This point is echoed by others, who note the long-time and continuing operation of 'traditional sea tenure systems' around the world and suggest that these systems hold considerable potential to provide relatively stable socially supported fishery management.

Examples of TURFs are widespread – some examples include lagoon fisheries in the Ivory Coast, beach seine net fisheries along the West African coast, collection of shellfish and seaweed on a coastal village basis in South Korea and Japan and controls over outsiders by fishing communities in Sri Lanka. Two particularly well-known examples are the long-standing arrangement in coastal Japan, where traditional institutions are incorporated in modern resource management, and the lobster fisheries on the north-eastern coast of North America, where fishers have been able to maintain extra-legal control on entry, that is, demonstrating the capability to exclude others. TURFs have a particularly long history in traditional,

small-scale/artisanal and indigenous fisheries. Consider two examples, one in the Atlantic region of Canada, where the Mi'kmaq (aboriginal) people have developed a social process for determining control over fishing territory, and the other in the artisanal fisheries of Chile:

> In the centuries before the arrival of the first Europeans, the Mi'kmaq. . . governed themselves through councils based on consensus in accordance with the laws of nature. District Chiefs were responsible. . . for confirming and reassigning hunting/harvesting territories.
>
> (Native Council of Nova Scotia, 1994).

> Today, artisanal fisheries management measures in Chile consider the allocation of Territorial Use Rights in Fisheries (TURFs) among fishing communities traditionally exploiting benthonic resources. . . Chilean fisheries legislation, the General Fisheries and Aquaculture Law (GFAL) enacted in 1991 allows the establishment of areas especially reserved for the use of specific artisanal fishing communities, through their legally constituted organizations. . .
>
> (Gonzalel, 1996).

A common ingredient in these TURF systems is the local resolution of usage issues. For example, Brownstein and Tremblay (1994) reported on the case of a small community in Nova Scotia, Canada, faced with a lobster poaching problem in the late 1800s. The problem was resolved by the local church minister, who decreed marine use rights based on an extension of property lines out to sea. In addition, if a fisher was unable to obtain a reasonable catch from his or her area, the fisher would be given temporary access to a fishing 'commons', a reserve area designed to enhance equity in the fishery. Notably, this management system has proven workable and is maintained by the community to this day.

Despite the many examples of CMT and TURFs, and the potential value of such systems both in their present form and adapted to other fisheries, such systems are generally poorly understood. As with any management mechanism, CMT and TURFs are not suitable in all cases but, depending on the specifics of the fishery, they may provide an efficient means of fishery management. For example, while some TURFs may involve excessive costs for development and maintenance to make the arrangement work, others may be easily implemented and regulated within the framework of existing social institutions. Even if costly, the costs may be outweighed by the inherent value of the institution involved. The point is that these options need to be examined and compared with the alternatives, particularly since, as Lawson (1984) has noted, such territorial management can be 'the most effective method of control' especially if it can be 'supervised by the fishing community itself or by its elected leaders' (see also Chapter 11).

It is notable that, while some CMT and TURF systems lacking the support of policy measures may have declined over time, there are now moves to maintain or restore these systems. For example, in the fisheries of Oceania, traditional CMT/TURF systems declined as fisheries were 'modernized', but there is increasing recognition of the efficiency of such systems, and initiatives in some nations (e.g. Solomon Islands, Fiji and Samoa) seek to re-establish them. Veitayaki (1998) reported on the case of Fiji, where the principal marine resource management practice of 'ownership of the customary fishing areas. . . by different, but closely related social groups' had been in decline. It was noted that efforts to register the boundaries of customary fishing grounds had the potential to 'return to traditional communities the ownership of their traditional fishing grounds. . .'.

10.4.2 Limited entry

Limited entry is a common management tool in which the government issues a limited number of licenses to fish (Section 9.4.1). Compared to open access, in which everyone has a right to access the fishery, under limited entry, the right to participate in the fishery (the use right) is restricted. Limited entry seeks to prevent the expansion of the number of fishing boats and/or fishers, with the aim of controlling potential fishing effort (fleet capacity). If limited entry is successful, this limit on effort helps to conserve the resource and also generates higher incomes for the license holders (i.e. those holding the use right). Not surprisingly, this can be expected to be popular with those who actually obtain the use rights while being opposed by others.

Limited entry has shown positive results in a variety of fishery management cases. For example, in a limited entry programme for the Alaskan (United States) fishery, the state government reduced the number of active licenses, and license values in many fisheries remained high, indicating a relatively profitable fishery. On the Pacific coast of Costa Rica, where expansion of the fishing fleet in the 1980s led to declining shrimp resources in the Gulf of Nicoya, introduction of a limited entry licensing programme (and a corresponding ban on new boats) was one of the management measures credited with improving the situation (Charles and Herrera, 1994).

However, limited entry cannot be expected by itself to 'solve' all management problems. Limited entry specifies access rights – and thus helps to prevent 'outsiders' from taking part in the fishery – but does not constrain fishing by the existing fleet. This lack of quantitative withdrawal rights means that there remains an incentive for each fisher to try to catch the fish first, before the competitors get it (the 'race for the fish'). This in turn may lead to an over-expansion of vessel catching power, including both physical capacity and technology (and a resulting pressure to over-exploit stocks) – contrary to the FAO Code of Conduct, Article 7 Paragraph 7.1.8 and the FAO International Plan of Action for the Management of Fishing Capacity.[2] Therefore, limited entry, while a reasonable mechanism to assign access rights, is best implemented as part of a 'management portfolio' that also includes measures to limit fishing by the current fleet.

It should be noted as well that the likelihood of success with limited entry will be much greater if it is put in place before the catching power of the fleet (or the number of participants) in the fishery becomes too large. In cases where this has not occurred, it has proven difficult to effectively reduce the number of licenses in relation to the productivity of the resource once the capacity is already excessive. Limiting entry is still important in such circumstances, but it becomes more of a challenge to bring the catching power in line with desired levels.

10.4.3 Effort rights (quantitative input rights)

In situations where the catching power or capacity of a fleet is greater than the fish stock can withstand, there is a need to regulate how that catching power is used in practice, that is, to limit the total fishing effort on the stocks so as to 'ensure that levels of fishing effort are commensurate with the sustainable use of fishery resources' (FAO Code of Conduct, Article 7.1.8) – and perhaps also to spread effort across more vessels than would otherwise be the case, for equity reasons. In addition to controlling the number of vessels, through access rights

[2]The full text of the Plan of Action is available at http://www.fao.org/fishery/ipoa-capacity.

(limited entry), this may involve aggregate restrictions on the activity of the entire fishing fleet, for example with limits on fishing seasons, amount of gear, gear attributes or the total allowable boat days at sea for the fleet, analogous to a total allowable catch (TAC) (see Chapter 9 for further discussion on these topics). Furthermore, it may be desired to limit the amount of fishing by each fisher (or vessel) by prescribing quantitative withdrawal rights for individual fishers – that is, in this case, individual 'effort quotas' (input-based use rights), such as a specific amount of fishing time and gear.

A common example of such an effort-based use rights approach arises in trap fisheries, notably those for lobster, crab and other invertebrates, where each fisher has the right to set a specified number of traps. It may be that all fishers have equal quantitative rights (i.e. to the same number of traps) or it may be that the rights vary from one individual to another, perhaps based on location, boat size or some other criteria. Similar input rights are used with respect to limiting fishing time at sea (e.g. in the United States) and vessel capacity.

The key problem for an effort rights programme is the incentive that will exist among fishers to thwart the input controls, by locating other uncontrolled inputs to expand (Section 9.6.1). This implies the need for a multi-dimensional approach to input rights, by implementing rights over not one but a range of inputs. For example, effort rights in a trawl fishery might cover a combination of days fished, hold tonnage and vessel horsepower. In the lobster fishery of Atlantic Canada, access rights (limited entry) are supplemented with quantitative withdrawal rights limiting the fishing effort (number of lobster pots) per fisher. This has been a relatively effective control for many decades, but in recent years, a trend to more frequent hauling and baiting of the traps has increased the effectiveness of each trap. This expansion in an uncontrolled input has led to a rise in the actual effort over time, a potential threat to resource sustainability. To restore the effectiveness of effort controls, either the allowable number of traps per fisher can be periodically reduced or the set of use rights can be broadened to cover not only limited entry and trap limits but also other dimensions of fishing effort.

Use rights over fishing effort must also deal with the natural process of technological improvement (or 'technology creep') that gradually increases the effectiveness of any given set of inputs over time. If there is no compensation for this effect, conservation impacts of fishing by a given fleet may be under-estimated, leading to over-exploitation. However, an input rights programme can adjust for improvements in fishing efficiency, either by reducing the number of allowable input units over time (to reflect the rate of efficiency increase) or by placing the onus on vessel owners to ensure, and demonstrate, that efficiency increases (e.g. from addition of gear or from construction of new, presumably more efficient, vessels) are compensated for by adjustments elsewhere in the fleet, so that overall catching power does not increase. Note, as well, that if fishers are involved in fishery management decision-making (with effective management rights), reductions in the level of input rights may take place voluntarily, on a collective basis. For example, fishers in a trap fishery may choose to reduce the maximum number of traps allowed per fisher, both for conservation and cost reduction, as has happened in a number of lobster fisheries.

Thus input/effort allocations can be a viable approach to rights-based management if care is taken in defining the rights, if a suitable portfolio of rights is established (cf. Hilborn *et al.*, 2001) and if a plan is put in place to deal with fishing efficiency improvements and capacity control – as noted in the FAO Code of Conduct (Article 7.6.3). Note, however, that any quantitative rights system, whether involving effort rights or harvest quotas (see later) inherently requires certain data collection and monitoring schemes to operate; naturally, the cost and feasibility of these must be taken into account.

10.4.4 Harvest rights/quotas (quantitative output rights)

A TAC is a conservation control but not a use right, since setting a TAC makes no statement about the rights to catch the fish. The situation changes, however, if that TAC is subdivided into quotas allocated to sectors of the fishery, individual fishers or communities in which case these shares of the TAC represent quantitative output rights – collective or individual use rights over the corresponding 'shares' of the TAC. Several variations on these harvest rights may occur.

- The right may be held collectively by a sector of the fishery, with allocations made for small boats or large boats, for hook-and-line fishers or net fishers, etc., through a suitable institution within that sector.
- Rights may be assigned to communities, as 'community quotas', so that fishers within the community regulate themselves, perhaps with the involvement of their community, establishing suitable fishery management plans and dividing up the quota to suit their local situation and to maximize benefits, in a manner that reflects community values and objectives (Charles, 2001).
- Harvest rights may be allocated to individual fishers as trip limits (providing the right to take a certain catch on each fishing trip) combined with a right to a certain total number of trips per year (thereby ensuring that the TAC is not exceeded).
- Harvest rights may be allocated to individual fishers on an annual basis as individual quotas, rights to harvest annually a certain portion of the fish resource (a fraction of the TAC). These appear in two main forms: individual transferable quotas (ITQs) are harvest rights that can be permanently bought and sold among fishers in a 'quota market', while individual non-transferable quotas (INTQs) are rights that are not permanently transferable. (The impact of transferability is discussed later in this chapter.)

Whatever the form of harvest rights, if these are considered certain within a fishing season, the fisher can plan fishing activity as desired. This can (a) potentially provide a better match to available markets and (b) avoid the 'race for the fish', so that catches can be taken at a lower cost and with less incentive for development of over-capacity (a concern noted earlier for limited entry and input rights programmes). This second benefit exists both with trip limits and individual quotas, but more so with the latter, since the fisher can plan fishing activity over the course of a full year rather than on a trip-by-trip basis. Individual quota advocates argue that the above incentives lead to (a) reduction in fishery inputs such as fleet size and number of fishers, (b) increased net benefits in the fishery and (c) increased product value, either through more attention to quality or through development of higher-valued product forms (e.g. fresh fish instead of frozen). Some evidence has emerged supporting these claims, although there is also some questioning of the extent of the benefits (Squires and Kirkley, 1996; Copes and Charles, 2004).

Along with the potential benefits of harvest rights are various social, economic and conservation concerns (e.g. Section 9.6.2). A focus on social considerations is to be found later in the chapter. From an economic perspective, the costs of a quota system can be very high. First, such systems require setting a sustainable TAC annually, by assessing the quantity of fish in the sea – a task that requires extensive financial (and scientific) resources. Even in cases for which such resources have been available, uncertainty typically remains high, creating a significant economic risk element (and indeed, errors in setting TACs have led to serious consequences in the past). Second, a quota system incurs costs in allocating the TAC to

individual fishers, groups or communities, and particularly in the expensive monitoring and enforcement of these individual catch allocations, which is needed both at sea and on land.

Conservation implications include those related to catch controls in general and those arising due to particular incentives that exist to thwart individual controls. Among the most widely discussed examples of these are the following.

- When an individual fisher, or a group of fishers, is allocated or otherwise obtains a certain quota to catch, inherent incentives exist for the fishers to cheat by under-reporting catches, since every caught fish that is unreported is one less that must be deducted from the quota – meaning that additional fish, beyond the quota, can be caught by that individual or group later in the year. The incentives for under-reporting are particularly great under an individual quota system, compared with other fishery rights' arrangements, since the benefits of under-reporting become 'individualized' – directly accruing to the fisher.
- Incentives exist under a quota system to dump, discard and high-grade fish, since this allows the fishers with the quota to directly increase the value of what they land, thereby maximizing profits obtained from the limited quota. Again, this incentive is particularly serious with individual quotas, since a fisher engaging in this anti-conservationist behaviour directly benefits from his/her actions.
- Pressure on decision-makers to increase the TAC beyond sustainable levels can arise in quota systems and particularly with individual quotas. Specifically, this may occur when fishers go into debt to purchase rights (quota) from others, leading to financial pressure on those fishers to increase incomes and pay off the debt. While in the long term, these new quota holders may prefer to limit catches so as to ensure a healthy resource, in the shorter term, financial pressures can lead to lobbying for higher TACs and thus higher individual catches. (This phenomenon will arise especially with transferable rights, as discussed later, and can occur not only with harvest rights but with effort rights as well – including some limited entry licensing approaches.)

The various social, economic and conservation impacts of harvest quotas explain why individual quota systems (in particular) are found in relatively few of the world's fisheries and are particularly rare in developing country fisheries. However, they have been a popular topic of study and promotion, particularly by fishery economists and managers of industrial fisheries, in locations such as New Zealand, Iceland, Australia, Canada and the United States. There are also some instances of their use in industrial fisheries of developing countries, such as Namibia, Chile, Peru and South Africa.

10.4.5 How should choices be made among the forms of use rights?

If, in fact, no use rights system is already in place or alternatively, if use rights do exist, but there is a recognized need for substantial changes, then fishery management is faced with a choice among the various use rights options described earlier. How do we compare output/harvest rights, input/effort rights and territorial use rights? Can any one of these provide the 'best' solution? Several factors must be noted in this regard:

- Given the biological, economic and social diversity of fisheries, no single use rights approach will be applicable everywhere. The choice of use rights must fit into the

culture, the historical reality and the policy directions of the specific fishery and overall jurisdiction.

- Each use rights option has its inherent advantages and limitations, and these will be of varying relevance depending on the specific fishery. Thus what is 'best' will depend on the fishery in question, and it is important to understand how the particular fishery circumstances influence the desirability of certain options over others.
- Given the above two points, it is unlikely that any single use rights approach will produce optimal results. Thus, it may be preferable to pursue a 'portfolio' of rights – a combination that is most acceptable, helps the fishery operate best and maximizes benefits for the given context.

As a result, it should not be surprising that there is neither a clear set of conclusions nor a consensus about which use rights options are most compatible with which fishery features. However, based on experience, some tentative guidance as to the choice of use rights is as follows:

- Sedentary fishery resources may be especially amenable to the use of territorial rights (TURFs) as part of the management portfolio.
- When biomass estimates are unreliable, or when regular catch monitoring is too expensive, management may be best approached through effort rights rather than harvest rights (quotas).
- Management of highly migratory or transboundary stocks, for which the allowable catch must be allocated among nations, may focus on harvest rights.
- Management of fisheries in which the fishing technology is relatively uniform may focus on effort rights, while in fisheries with many different gear types, harvest rights may work better.

Of course, these points do not cover all possible scenarios, and in any given case, the importance of each of the fishery characteristics must be weighed in assessing the pros and cons of use rights options, before arriving at a desired solution.

10.5 What implementation decisions arise with use rights?

This section identifies four fundamental questions that must be addressed in determining how best to implement use rights systems in fisheries, namely (1) Who should hold use rights? (2) How should use rights be allocated? (3) What should be the duration of use rights and (4) Should use rights be transferable?

10.5.1 Who should hold use rights – individuals, groups or communities?

For any given fishery, some people hold use rights and others do not. In a tribal fishery, it may be the Chief who decides who is to have access to the resource; in a fishery with limited entry licensing, the government's fisheries authority may designate license holders. Whatever the situation, the issue arises: who should hold use rights? This is largely a policy-level decision, one that will reflect overall policy in the fishery and beyond. However, some

guidance is provided, for example, by the FAO Code of Conduct, which notes (Article 6.18): 'States should appropriately protect the rights of fishers and fishworkers, particularly those engaged in subsistence, small-scale and artisanal fisheries, to a secure and just livelihood, as well as preferential access, where appropriate, to traditional fishing grounds and resources in the waters under national jurisdiction'.

A crucial choice in relation to who should hold use rights concerns the level at which those rights are instituted, that is, whether allocated to individual fishers or to groups in a collective manner (such as to a community or a fishers' association). If a government authority has designated, for each individual within a certain group of licensed fishers, their right to utilize a certain amount of fishing gear, then in such a case, use rights – a license and an effort right – are at an individual level. If, in another context, use rights are held by a coastal community or a fishers' association, which then determines who is to take part in the fishery at any given time, then the rights are primarily at the group level, even if possibly allocated down to an individual level.

The choice between individual and group/community rights should depend on both the historical context and the fishery objectives being pursued. For example, in the case of a fishery that has developed relatively recently and that has an industrial focus, there may be a natural inclination to an individual rights system, which may be viewed as compatible with the entrepreneurial independence of fishers. However, community rights are historically prevalent and of greatest importance in long-standing traditional fisheries – although such rights have not always been properly understood and incorporated into 'modern' management, leading in some cases to social and conservation problems.

Since the holding of use rights in a community or collective manner is typically less studied than the case of individual rights (cf. Charles, 2006), it is worth paying extra attention to such rights here. In this regard, two points should be highlighted:

- For those cases where community use rights already exist, or where the conditions are conducive to their introduction, this form of rights has the potential to provide considerable benefits, notably in fisheries for which the community has a strong inherent interest. Through suitable management institutions and through moral pressure applied on local fishers, the community can create incentives for resource stewardship (conservation), with increased management efficiency and better implementation of local enforcement tools. In addition, the community could formulate the rights system on a local scale to achieve equity and fairness goals, for example, by allocating rights not only to boat or license owners but also to crew members, and not only to those currently in the fishery but also to others, present and future, who would like to participate in the fishery – whether these were excluded in the past for some reason or are just reaching an age or seniority at which participation is possible.
- While community use rights cannot be expected to work in every fishery, the approach seems more likely to be effective given: cohesiveness of the community involved, experience in and capacity for local management, geographical clarity of the community and a modest overall size and extent (see Chapters 3 and 11 for further discussion on this topic).

Consider the example of 'community quotas' – fishing quotas (portions of a TAC) that are allocated to communities rather than to individual fishers or companies. Community quotas defined on a geographical basis have the potential to bring people together in a common purpose, rather than emphasizing individualism. The group of fishers in a community manage

themselves, perhaps also with involvement of their community. The fishers create fishery management plans (Chapters 15 and 16) and divide up the quota (or, alternatively, another form of rights, such as effort rights) to suit their specific local situation and to maximize overall benefits. Note that this involves use rights at both the community and the individual level. This community quota approach may provide many of the benefits of individual quotas while also supporting community empowerment and enhancing community sustainability by allowing each community to decide for itself how to utilize its quota. For example, one community may decide to allocate its quota through market forces, while another may prefer distributing the quota so as to achieve a mix of social objectives such as community stability, employment and equity. Examples of this approach include Alaska's system of Community Development Quotas and the fixed-gear community management boards in the Scotia-Fundy groundfish fishery of Atlantic Canada (Charles *et al*., 2007).

10.5.2 What mechanism should be used to allocate use rights?

If a use rights system already exists in a fishery, the distribution of the rights among the various participants (and the exclusion of non-participants) has been established. But what if a new use rights system is being implemented or there are to be adjustments to the existing system? Then a critical step in implementation is to determine who is to receive which rights (and more generally, how to allocate or distribute the rights). Furthermore, even if use rights have been allocated initially, there may be mechanisms by which the allocations change over time, such as through transfers. If so, what restrictions should be in place to regulate such changes in allocations?

The allocation of use rights is a key issue in fishery policy debates and is obviously highly contentious. It is important to realize that there is no universally 'correct' way to allocate rights. Perhaps the overall goal is to somehow divide up the total set of rights in a manner that seeks to minimize conflict while optimizing total benefits. This process must be accompanied by some form of appeals process to manage the special cases that arise. While such processes can resolve conflicts over initial allocations of rights, the debates involved at this stage can be so extensive as to delay implementation of rights systems for years.

Among the allocation mechanisms that might be considered are the following.

Auctions

It has been suggested that, to maximize economic efficiency, it may be desirable to auction fishing rights. With such an approach, those willing or able to bid highest will acquire the rights, regardless of historical, social or cultural considerations. Because of this lack of social sensitivity, such an approach is often seen as unpalatable and is little used, although it may be useful in purely industrial fisheries or situations where social factors are considered irrelevant. One example of its use has been the allocation of inland fishery rights in Bangladesh.

History

Political constraints in various cases have led to use rights being allocated to fishers on the basis of their historical participation. This is referred to as a 'catch history' approach, since

it most often focuses on allocating rights in proportion to each individual's past catches (although some other measure of participation in the fishery could be used). This can be problematic, however. What is the best way to define historical participation? Suppose the period over which the catch history is calculated happened to be one of overfishing and stock depletion, then those who contributed most to the overfishing (and in particular, those who may have even fished illegally without being caught) are rewarded, in perpetuity, with a larger quota at the expense of those fishers who fished less and thus had the least impact on the fish stocks. This sends a questionable signal if one wishes to reward conservation and creates inequities that may well lead to social conflict. In an effort to deal with this, hybrid schemes for initial allocations may be used. For example, there is some experience with formulas in which part of the total is allocated based on catch history and the remainder is allocated equally among fishers. Whatever the mechanism, it should be noted that a history-based allocation approach can be adopted in conjunction with either individual or community/group use rights, of the sort discussed earlier.

Markets

With a market-based approach, allocation of use rights is determined through the buying and selling of rights in the marketplace. Who it is that buys, or sells, the rights will depend on the situation at hand. It may be that more-efficient stakeholders buy out less-efficient ones, or that the buyers are those with better access to financial capital (a key issue in many developing countries) or there may be some other factor that dominates. Broadly speaking, a market-based use rights system can be expected to display the various advantages and disadvantages of the overall market system and inspire similar debates to those arising with respect to market mechanisms elsewhere in the economy. For example, depending on one's perspective and the case at hand, markets may (or may not) be the most cost-efficient institutional arrangement to handle transactions between fishers and may (or may not) increase flexibility in fisher operations.

One issue to note is that this mechanism could limit the capability of governments to undertake new policy directions that may imply a change in allocation of rights. Examples could be shifts in governmental policy to favour small-scale over industrial fisheries, or conservationist over destructive fishing gear. This issue has arisen in situations in which there is a politically perceived need to compensate those who have purchased market-based rights, if new policies are contrary to their self-interest.

Note that while market-based rights are typically discussed in the context of individual fishers, there is nothing to prevent an entity operating at a collective (corporate or community) level from buying or selling on a fishing rights' market. However, the actual bundle of rights resulting from such a transaction may differ depending on whether the buyer is an individual, corporation or community – due, for example, to differing regulatory constraints on the various rights-holders.

Community/sector/group allocations

As noted in Section 10.5.1, use rights can be allocated and managed on a group/collective basis, held directly by participating community, fishing sector or other identifiable groups. This is a form of devolution (or an application of the subsidiarity principle) in that use rights

are allocated in a more deliberate manner than with other mechanisms. This can be done through a decision-making process that is typically (a) based on recognizing multiple societal goals, (b) carried out by institutions operating at a suitable scale, whether community-based, regional or national and (c) involving rights specified through a combination of legislation and government decisions, plus traditional/informal arrangements.

Such arrangements have a lengthy history in real-world situations – arising frequently, for example, in the context of cooperatives, marketing boards and indigenous/native communities. Typically, the community or group holding the use rights in common makes subsequent allocations (whether permanently or periodically) to those individuals deemed suitable to receive a part of the group's package of use rights. Of course, this does not eliminate the challenge of how to make the allocations at the individual level, but it does facilitate solutions that can be tailored locally.

Allocation panel/board

Finally, circumstances could arise in which allocation of use rights can only be settled through a special body established for that purpose. Consider a situation in which public policy involves broadening the base of involvement in a fishery to include those who were previously excluded. (A dramatic example of this would be the case of fisheries in South Africa; see Cochrane and Payne [1998]. Incorporation of indigenous peoples into fisheries in locations such as New Zealand, the United States and Canada could be further examples.) Both an auction mechanism and a market approach for allocating use rights are inherently affected by differences in wealth among prospective participants, and a catch history approach is dependent on previous performance in the fishery, so none of these is particularly suitable to deal with such circumstances. In such cases, a special body – an allocation panel or board – may be required to determine allocations of use rights to specific groups or communities.

Summary

Any of the above mechanisms can be utilized whether one is dealing with initial allocations or ongoing processes of reallocation. In either case, what mechanism, among the choices described earlier, should be used for allocation of use rights (e.g. history-based, market-based or community-based) and at what scale should this occur (e.g. individual, collective or community level)? There is no consensus on which characteristics of a fishery favour one or other of these choices, but some analysis has been carried out on this important topic.

For example, the choice between community-based use rights and market-based rights (such as ITQs) has been addressed by Berkes (1986) and Copes and Charles (2004). Berkes proposes that a community-based approach 'provides a relevant and feasible set of institutional arrangements for managing some coastal fisheries', particularly 'small-scale fisheries in which the community of users is relatively homogeneous and the group size relatively small'. On the other hand, he suggests that individual market-based use rights (perhaps including 'exclusive and transferable fishing rights') may be appropriate 'for offshore fish resources and larger-scale, more mobile fishing fleets'. This indicates that a useful differentiation can be made between fisheries that are small-scale/artisanal (with clear ties of fishers to communities and with history and tradition playing a major role) and fisheries that are predominantly industrial and capital-intensive (in which profitability dominates over other

societal goals). However, there are bound to be exceptions to any general direction, and a wide range of intermediate options can be contemplated as well, so allocation decisions must be made with great care.

10.5.3 What should be the duration of use rights?

Within any system of use rights, it is a fundamental matter to decide how long the rights are to last, that is for how much time the holders of rights are able to make use of those particular rights.

This revolves largely around the balancing of two factors: management flexibility and conservationist incentives. On the one hand, short-duration rights give the capability to more frequently reallocate those rights, a flexibility that may allow fishery management to better reflect society's changing objectives over time. On the other hand, longer-duration rights, by providing more security to fishery users, give those users a stake in the well-being of the resource further into the future and an incentive to better 'plan for the future' in husbanding the resource.

Consider two examples. First, suppose government policy is to improve the situation of small-scale fishers but, in a particular fishery being developed, a substantial level of financial investment is needed in order to operate. It may be that at the time of allocating use rights, only a small set of industrial companies are able to make the necessary investments in the fishery. If these parties, the only ones able to fish, are given long-duration use rights, this might prevent the subsequent entry of small-scale fishers even if they develop the financial means to do so, for example, through cooperatives. Shorter-duration rights might have provided management flexibility to facilitate access of artisanal fishers much earlier. (Similarly, if a foreign fleet has dominated in a particular fishery, contrary to the national policy goal of developing a domestic presence, allocating long-duration rights to the foreign fleet may be counter-productive.)

Alternatively, if short-duration rights are allocated in a fishery, what happens as the end of the time period approaches? If the rights-holders know that their rights are about to expire, they may have an incentive to harvest intensively with no regard for the future of the fish stocks. Rights of longer duration (a longer 'time horizon') would mean that incentives to conserve would apply for many more years than would otherwise be the case.

There is no universal 'right answer' in dealing with such trade-offs, and indeed hybrid approaches can be designed to provide intermediate choices. For example, flexibility can be added to systems of long-duration rights (e.g. by allowing transferability of those rights but only in directions deemed desirable by society), while incentives to avoid over-exploitation can be provided in the case of short-duration rights (e.g. conservation performance criteria placed on the option to renew the rights).

In many fisheries, use rights tend to be of indefinite duration. This is particularly the case in small-scale or artisanal fisheries, where access rights may be available to all those in the local community, and those rights may be considered essentially permanent. This may be desired if no particular need exists for the flexibility to reallocate rights, and the idea of having access rights expire after a certain period of time is deemed unacceptable. In particular, it seems unlikely in such a context that a government manager would force a local fisher to leave the fishery after, say, 5 years of fishing on the basis that the person's time had 'run out'. (However, just such an occurrence could be contemplated in the same fishery, if managed

on a community basis – in some tribal fisheries, for example, the community accesses the resource collectively, and there may be utility in alternating those who actually do the fishing for the community.)

Explicit limitations on the duration of use rights seem more common in commercial or industrial fisheries in which leases or other agreements may allow harvesting over a limited number of years. This is especially common with coastal states establishing access rights for foreign fleets, on an annual or multi-year basis, but an explicit duration of use rights also arises in some domestic fisheries. For example, in Bangladesh there has been a practice of auctioning periodic harvest rights for inland fisheries, and in Namibia's quota system, multi-year rights were allocated for terms depending on the company's levels of investment and Namibian ownership. As noted earlier, in such situations one needs mechanisms to reduce the incentive users may have to over-exploit resources when the term of the right nears an end.

It is clear from the discussion earlier, and the range of possibilities described, that there is a close linkage between decisions about the duration of rights and deciding who is to hold the use rights. We turn now to a discussion of the latter issue.

10.5.4 Should use rights be transferable?

Once use rights are allocated, can the rights be bought and sold or handed down in a family from one generation to the next or temporarily transferred to another fisher within a fishing season? This key question is one of transferability of use rights (whether fishing licenses, input allocations or quota rights) and is naturally related to that of how use rights are allocated, as discussed earlier.

On the one hand, if the rights are completely non-transferable, they can only be used by the holder and are no longer valid when that fisher leaves the fishery. On the other hand, if there is to be transferability of some sort, then this can be done through market-based mechanisms (i.e. markets for buying and selling of use rights) or through family or community processes (e.g. handing down the rights from fishers to their children).

Furthermore, several choices arise for how transferability can take place:

- *Non-divisible* transfer of use rights implies that transferability is only done as a complete indivisible package, that is with all a fisher's use rights transferred together, as might typically be the case if the use right is simply a fishing license.
- *Divisible* transfer of use rights allows fishery participants to freely transfer all or any portion of their rights, an option that could apply in the case of a quantitative withdrawal right, in which rights-holders may choose to transfer a certain part of their effort or catch allocation.
- For each of the two options above, if there is a desire to provide greater stability within the fishery sector or the community/region, transferability may be allowed only *within* the particular sector or community in which the use rights reside.
- A hybrid approach could be adopted in which there are differing classes of rights, some transferable and some not, with defined policy measures determining which fishers have which form of licenses (e.g. there could be two classes of license: transferable ones for full-time fishers and non-transferable ones for part-timers).

These options have very different implications depending on whether we are considering temporary or permanent transferability. Consider first the case of temporary transferability in which a

fisher is permitted to rent or lease use rights to another fisher within a fishing season. The rights then revert to the original fisher at the end of the season. This mechanism provides important short-term flexibility (in that a fisher who happens to become sick or whose vessel breaks down one year can still obtain some income by renting out the use rights) while maintaining long-term stability in the distribution of the rights. There would seem to be few long-term negative impacts of this temporary transferability, as long as regulations prevent its excessive use (avoiding, e.g. contracts that enforce a repeated 'temporary' transfer of rights, year after year, from a fisher to a company). On the other hand, with permanent transferability, the implications are more significant, so this will be the focus of the remainder of this section, exploring several key issues relating to efficiency, fishery mobility, social cohesion and concentration of rights.

Efficiency

Transferability of use rights is often promoted as a key means to improve economic efficiency. The argument is typically that with transferability (in a market-based system such as ITQs), the more 'efficient' vessel owners, who can best maximize the profits resulting from a given use right, buy up the use rights of other fishers, who then leave the fishery. This 'survival of the fittest' process, it is argued, produces increasing overall efficiency. This argument is so often made that it is often assumed to be universally correct, but in reality outcomes are not so clear and indeed market-based transferability can actually have negative consequences for fishery efficiency:

- There is no guarantee that efficiency will increase through the market process. For example, if there is strategic buying of quota to gain greater control of the fishery (not unlike the manner by which financial mergers take place), ownership will still become concentrated and participation reduced in the fishery, but the resulting impacts on efficiency are unclear.
- Efficiency – 'doing the most with what we have' – is desirable, but it must be assessed at a level appropriate to the policy goals. While transferability may increase the efficiency of individual vessels (with higher vessel profits), it could decrease efficiency for the fishery as a whole and for the coastal economy. This is because we must take into account (a) all stakeholders rather than just the owner of the vessel and (b) all related monetary and non-monetary fishery benefits not only profits to the vessel owner. These related benefits will depend on the situation but would typically include benefits to crew members, onshore workers, the onshore economy and coastal communities. Such consider-ations are often ignored in looking at the economics of the fishery but must be taken into account to properly assess the desirability of use rights transferability.
- Third, not only must efficiency be seen broadly, in the context of the whole fishery and the coastal economy, it must also be seen as a long-term conservation matter. This has a var-iety of implications. For example, if transferability results in use rights being transferred out of a local area, thereby reducing use of locally based TEK in management, we need to be conscious of possible negative conservation impacts. Conversely, if transferability facili-tates adoption of new conservation-oriented technologies, there could be positive effects.

These points lead to the overall conclusion that increased efficiency does not necessarily come from transferability nor from non-transferability. In fact, which is to be preferred will depend on the specific objectives and the specific fishery.

Fisher mobility

Transferability increases the 'mobility' of those holding the rights. If the use rights are bought and sold in a market, then this allows rights-holders to exit the fishery when the revenue to be gained from the sale of the use right exceeds the expected benefits of remaining in the fishery. This provides flexibility for the fisher and makes it easier for managers to reduce participation in the fishery. However, in the absence of restrictions to keep use rights within the local community, this mobility can reduce the stability of the fishing communities. Non-transferable systems, on the other hand, are better able to maintain community stability by keeping rights locally, but this in turn reduces the mobility of the fishers, making it more difficult to reduce fishing power over time (capacity reduction). In particular, incentives exist to keep non-transferable rights in use as long as possible to maximize the total benefits, and in the hope of a financial windfall should there be a later decision to allow transferability. This may mean that a boat will be used beyond its technological life, which can also create safety problems.

Social cohesion

Transferability can have a major impact on social well-being. First, since rights are often held solely by the vessel owner, the selling of those rights may leave crew members without jobs and without compensation. Second, transferability can lead to a loss of social cohesion in the community as a whole. This is particularly the case when transfers remove fishing rights from the community, resulting in reduced local involvement in the fishery, reduced employment and a corresponding increase in the proportion of 'outsiders' fishing on what had been locally-controlled resources. On the other hand, non-transferable rights may help stabilize the local economy by ensuring that a certain portion of the rights resides in the local communities. It should be noted, however, that in the case of non-transferable systems, there may be inherent pressure to shift to transferability, with all the implications of that change – it seems that this has occurred in many cases to date.

Concentration of rights

In experiences to date, transferability has generally led to the concentration of ownership of use rights in fewer hands (and particularly in the hands of processors or fish dealers). If the goal is to reduce the number of stakeholders with which the manager needs to interact, transferable rights may accomplish the goal. On the other hand, concentration of rights raises social and economic concerns, particularly in relation to potentially detrimental impacts on (a) traditional organizational arrangements of fishers, (b) employment of vessel crew, (c) overall equity in the coastal economy and (d) the stability of fishing communities.

To prevent concentration, rights might be made non-transferable or there might be limits on maximum amounts of rights that can be owned by any person or firm, or an owner-operator requirement might be put in place (so only the vessel owner can be its operator). However, it is important, as well, to be aware that various schemes have arisen to evade non-transferability or the limitations placed on transferability – for example through legal contracts or 'nominal ownership' (by family, relatives and employees). Therefore, if concentration of fishing rights is considered undesirable, mechanisms are needed that 'plug the loopholes' to prevent supposedly non-transferable rights from ending up being transferable in practice.

10.6 Synthesis

Many of the major ongoing debates in fishery management relate to use rights, the right to use (access) a fishery, as well as management rights, the right to take part in its management. This chapter has discussed the rationale for use rights, the range of use rights options, considerations related to implementation of use rights and their relationship with management rights and other forms of fishery rights. It has been noted that the various use rights options – including TURFs, limited entry and quantitative input rights (limiting effort) and output rights (catch quotas) – typically correspond to specific input and output controls, as described in Chapter 9.

From a policy perspective, as well as in operational terms, it should be clear that the choice of use rights can have significant impacts in terms of economic outcomes, social impacts and resource sustainability. At the same time, use rights can be highly controversial. This is due not only to the conflict inherent in any use rights system (where some are excluded and some may have greater rights than others) but also to the lack of consensus on the 'best' path to follow in establishing such systems. One will find that there are advocates of various use rights schemes, but we must be sceptical of any claim that a particular use rights option is somehow inherently superior to others. In reality, there is no single answer to the question 'what is the best use rights arrangement?'

Instead, the key is to follow a desirable process. A flowchart highlighting the sequence of events in such a process of assessing and developing a use rights systems is provided in Figure 10.2. A key point is that if no (acceptable) use rights are currently in place, and we need to develop and implement such a system, fishery managers and planners need to meet together with interested parties (e.g. current or aspiring fishers, vessel crew members, community members or other citizens) to determine a set of use rights that will meet objectives and be feasible in practice. In doing so, it is crucial to be aware of both the positive and the negative impacts that can arise (as discussed, for example, in the case of rights transferability). To this end, we must take into account the structure and underlying nature of the fishery, including:

- societal objectives in the fishery;
- the relevant history and traditions of the fishery;
- the relevant social, cultural and economic environment;
- the key features of the fish stocks and the ecosystem.

To conclude, it is important to emphasize that this chapter represents only an introduction to the idea of rights-based fishery management, and use rights in particular. Among the points raised, here are four that we reiterate in conclusion:

1. Use rights are crucial in the pursuit of sustainable, responsible fisheries, and come in conjunction with *responsibilities* for stewardship and conservationist use of the fishery resources.
2. Use rights in fisheries must be seen in relation to broad social, economic and human rights.
3. Use rights, of various forms, already exist in many long-standing fisheries and these need to be recognized. Only if the current rights system is found to be ineffective or unacceptable should a replacement be developed and implemented.
4. The task of introducing, or reinforcing, a use rights system (or changing the distribution/functioning of rights within an existing system) requires considerable care, with no

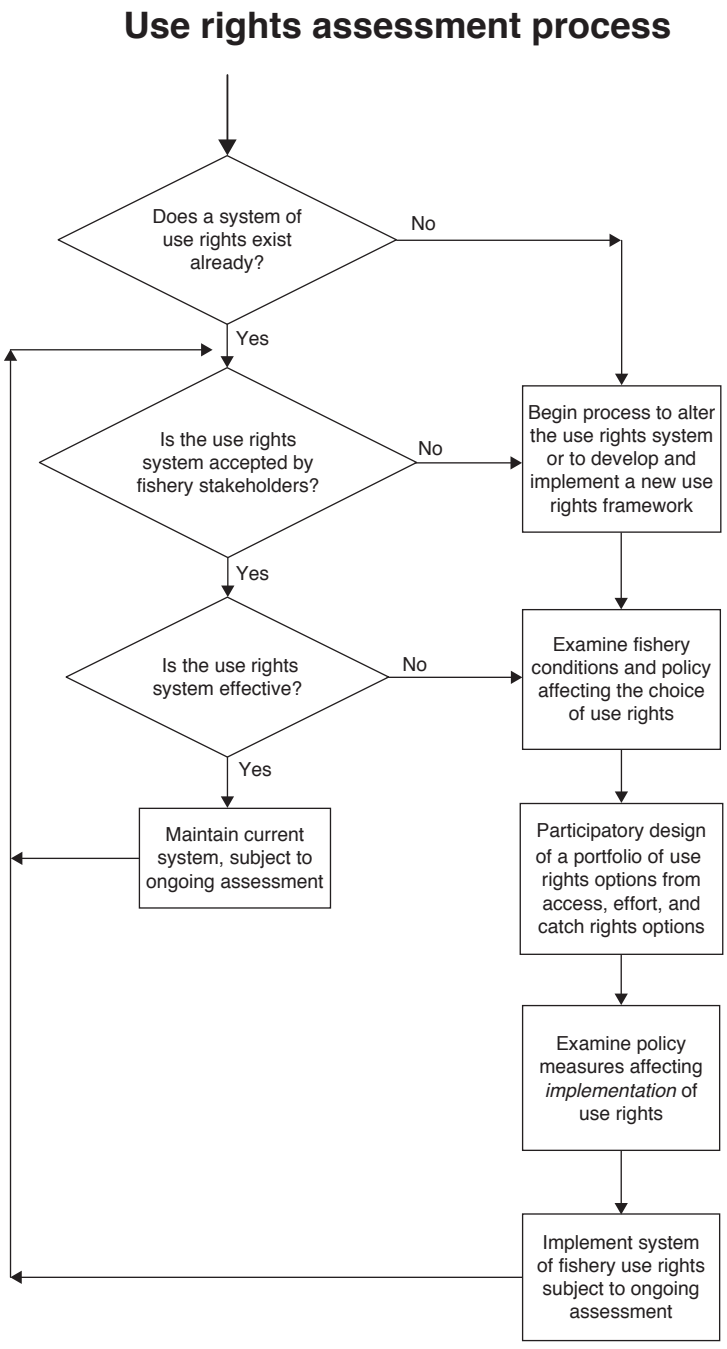


Figure 10.2 Flowchart for assessing and developing a use rights system.

simple 'cook-book' formulas to help; use rights need to be appropriate to the cultural and historical situation, the policy directions and the financial and personnel capacities of the particular fishery.

These realities, and the complexities they imply, ensure that use rights will continue to play a major role in fishery management and in future fishery debates. Indeed, it seems apparent that if both the use rights held by fishers and the responsibilities undertaken by those fishers are clearly identified and widely accepted, success in achieving responsible fisheries will be that much more likely in the future.

Acknowledgments

An earlier version of this chapter appeared in the first edition of the Fishery Manager's Guidebook. The chapter draws on work with a number of colleagues; I am grateful to Ralph Townsend, Melanie Wiber and Parzival Copes for many helpful discussions, but any errors remain my responsibility. Helpful comments were provided as well by the editors and anonymous referees. Financial support was provided by the Natural Sciences and Engineering Research Council of Canada.

Sources and recommended reading

Berkes, F. 1986. Local-level management and the commons problem: A comparative study of Turkish coastal fisheries. *Marine Policy*, 10: 215–229.

Brownstein, J. and Tremblay, J. 1994. Traditional property rights and cooperative management in the Canadian lobster fishery. *The Lobster Newsletter*, 7: 5.

Charles, A.T. 1998. Fisheries in transition. In: *Ocean Yearbook 13*. Borgese, E.M., Chircop, A. McConnell, M. and Morgan, J.R. (eds). pp. 15–37. University of Chicago Press, Chicago, U.S.A.

Charles, A.T. 2001. *Sustainable Fishery Systems*. Blackwell Science, Oxford, U.K.

Charles, A.T. 2004. Rights-based fishery management: A focus on use rights. In: *Who Gets the Fish? Proceedings of the New England Workshop on Rights-Based Fisheries Management Approaches*. Petruny-Parker, M.E., Castro, K.M., Schwartz, M.L., Skrobe, L.G. and Somers, B. (eds). pp. 3–5. Rhode Island Sea Grant, Narragansett, RI, U.S.A.

Charles, A.T. 2006. Community fishery rights: Issues, approaches and Atlantic Canadian case studies. *Proceedings of the 13th Biennial Conference, International Institute of Fisheries Economics and Trade. Portsmouth, UK*. International Institute of Fisheries Economics and Trade, and CEMARE, University of Portsmouth, Portsmouth, U.K.

Charles, A.T., Bull, A., Kearney, J. and Milley, C. 2007. Community-based fisheries in the Canadian Maritimes. In: *Fisheries Management: Progress toward Sustainability*. McClanahan, T. and Castilla, J.C. (eds). pp. 274–301. Blackwell Publishing, Oxford, U.K.

Charles, A.T. and Herrera, A. 1994. Development and diversification: Sustainability strategies for a Costa Rican fishing cooperative. In: *Proceedings of the 6th Conference of the International Institute for Fisheries Economics and Trade*. Antona, M., Catanzano, J. and Sutinen, J.G. (eds). IIFET/ORSTOM, Paris, France.

Christy, F.T. 1982. *Territorial Use Rights in Marine Fisheries: Definitions and Conditions*. FAO Fisheries Technical Paper No. 227. Rome, FAO.

Cochrane, K.L. and Payne, A.I.L. 1998. People, purses and power: The role of policy in directing fisheries management as indicated in the debate surrounding a developing fisheries policy for

South Africa. In: *Reinventing Fisheries Management*. Pitcher, T.J., Hart, P.J.B. and Pauly, D. (eds). pp. 73–99. Kluwer, Dordrecht.

Copes, P. 1997. Social impacts of fisheries management regimes based on individual quotas. *Proceedings of the Workshop on Social Implications of Quota Systems in Fisheries*. *Vestman Islands, Iceland, May 1996*. Nordic Council of Ministers, Copenhagen, Denmark.

Copes, P. and Charles, A.T. 2004. Socioeconomics of individual transferable quotas and community-based fishery management. *Agricultural and Resource Economics Review*, 33: 171–181.

Dewees, C.M. 1998. Effects of individual quota systems on New Zealand and British Columbia fisheries. *Ecological Applications*, 8 (Suppl.): S133–S138.

Dyer, C.L. and McGoodwin, J.R. 1994. *Folk Management in the World's Fisheries: Lessons for Modern Fisheries Management*. University Press of Colorado, Niwot, U.S.A.

FAO. 1998. Report of the FAO technical working group on the management of fishing capacity. La Jolla, United States of America, 15–18 April 1998. FAO Fisheries Report No. 586. Rome, FAO.

FAO. 2007. Social issues in small-scale fisheries. Report prepared for the twenty-seventh session of the committee on fisheries (COFI), 5–9 March 2007. COFI/2007/6. Rome, FAO.

Gimbel, K.L. (ed.). 1994. *Limiting Access to Marine Fisheries: Keeping the Focus on Conservation*. Center for Marine Conservation and World Wildlife Fund, Washington, U.S.A.

Gonzalel, E. 1996. Territorial use rights in Chilean fisheries. *Marine Resource Economics*, 11: 211–218.

Grafton, R.Q., Arnason, R., Bjorndal, T., Campbell, D., Campbell, H.F., Clark, C.W., Connor, R. and Dupont, D.P. 2006. Incentive-based approaches to sustainable fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, 63: 699–710.

Graham, J., Charles, A.T. and Bull, A. 2006. *Community Fisheries Management Handbook*. A publication of Turning the Tide: Communities Managing Fisheries Together. Gorsebrook Research Institute, Saint Mary's University, Halifax, Canada (available at www.coastalcura.ca/links/).

Hanna, S. and Munasinghe, M. (eds). 1995a. *Property Rights and the Environment: Social and Ecological Issues*. Beijer International Institute of Ecological Economics and World Bank, Washington, U.S.A.

Hanna, S. and Munasinghe, M. (eds). 1995b. *Property Rights in a Social and Ecological Context: Case Studies and Design Applications*. Beijer International Institute of Ecological Economics and the World Bank, Washington, U.S.A.

Hardin, G. 1968. The tragedy of the commons. *Science*, 162: 1243–1247.

Hilborn, R., Maguire, J.-J., Parma, A.M. and Rosenberg, A.A. 2001. The precautionary approach and risk management: Can they increase the probability of success of fishery management? *Canadian Journal of Fisheries and Aquatic Sciences*, 58: 99–107.

International Institute for Rural Reconstruction (IIRR). 1998. *Participatory Methods in Community-Based Coastal Resource Management*. International Institute for Rural Reconstruction, Silang, Philippines.

Jentoft, S. 2007. Sizing up: Property rights and fisheries management. A collection of articles from SAMUDRA Report. ICSF. pp. 92–93.

Kearney, J. 2007. Fulfilled, healthy, secure? SAMUDRA Report No. 46 (March 2007). pp. 18–21.

Lawson, R. 1984. *Economics of Fisheries Development*. Frances Pinter Publishers, London, U.K. 283p.

Native Council of Nova Scotia. 1994. *Mi'kmaq Fisheries Netukulimk: Towards a Better Understanding*. Native Council of Nova Scotia, Truro, Canada.

Neher, P.A., Arnason, R. and Mollett, N. (eds). 1989. *Rights Based Fishing*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

OECD. 1993. *The Use of Individual Quotas in Fisheries Management*. Organisation for Economic Co-operation and Development, Paris, France.

Ostrom, E. and Schlager, E. 1996. The formation of property rights. In: *Rights to Nature: Ecological, Economic, Cultural and Political Principles of Institutions for the Environment*. Hanna, S., Folke, C. and Mäler, K.G. (eds). pp. 127–156. Island Press, Washington, U.S.A.

Pinkerton, E. and Weinstein, M. 1995. *Fisheries that Work: Sustainability through Community-Based Management*. The David Suzuki Foundation, Vancouver, Canada. 199p.

Pomeroy, R.S. 2001. Devolution and fisheries co-management. In: *Collective Action, Property Rights and Devolution of Natural Resource Management: Exchange of Knowledge and Implications for Policy*. R. Meinzen-Dick, R., Knox, A. and Di Gregorio, M. (eds). pp. 108–145. DSE/GTZ, Germany.

Ruddle, K. 1989. The continuity of traditional management practices: The case of Japanese coastal fisheries. In: *Traditional Marine Resource Management in the Pacific Basin: An Anthology*. Ruddle, K. and Johannes, R.E. (eds). pp. 263–285. Contending with Global Change Study No. 2, UNESCO/ROSTSEA, Jakarta, Indonesia.

Ruddle, K., Hviding, E. and Johannes, R.E. 1992. Marine resources management in the context of customary tenure. *Marine Resource Economics*, 7: 249–273.

Shotton, R. 2000. Use of property rights in fisheries management. *Proceedings of the FishRights99 Conference. Freemantle, Western Australia, 11–19 November 1999*. FAO Fisheries Technical Paper No. 404/1. 342p.

Squires, D. and Kirkley, J. 1996. Individual transferable quotas in a multiproduct common property industry. *Canadian Journal of Economics*, 29: 318–342.

Symes, D. (ed.). 1998. *Property Rights and Regulatory Systems in Fisheries*. Fishing News Books (Blackwell Science), Oxford, U.K.

Symes, D. (ed.). 1999. *Alternative Management Systems for Fisheries*. Fishing News Books (Blackwell Science), Oxford, U.K.

Townsend, R.E. 1990. Entry restrictions in the fishery: A survey of the evidence. *Land Economics*, 66: 359–378.

Townsend, R.E. and Charles, A.T. 1997. User rights in fishing. In: *Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse*. Boreman, J., Nakashima, B.S., Wilson, J.A. and Kendall, R.L. (eds). pp. 177–184. American Fisheries Society, Bethesda, U.S.A.

Veitayaki, J. 1998. Traditional and community-based marine resources management system in Fiji: an evolving integrated process. *Coastal Management*, 26: 47–60.

Chapter 11
Partnerships in Management

Evelyn Pinkerton

11.1 Introduction – partnerships solve problems, but are little known by managers

Chapter 1 outlined the global problems facing fisheries managers, especially overfishing and habitat loss, and the related local problems of poor data and data analysis, the low legitimacy of regulations, and the consequent poor enforcement of regulations. This chapter outlines how new forms of partnering between local communities, non-governmental organizations (NGOs), and government regulators can address many of these global and local problems, and analyses examples of such partnerships. These examples, and many others in the literature, demonstrate that users can be usefully involved in *all* the functions and responsibilities of fisheries management identified in Figure 1.1, from information gathering to analysis, to plan formulation, to rule-making, to enforcement and compliance. If decision-making is currently highly centralized, the notion that users can and often should be involved at all stages of management, rather than consulted by government regulators as an 'add on' when fishing plans and regulations are mostly complete, can involve a substantial change in the conception of management.

This chapter addresses not only the classic partnerships between government and small fishing communities, but also more complex and innovative ones between parties operating at different scales. For example, small communities and large fishing enterprises can be involved in co-management agreements together. Examples of multiple-scale partnerships are rarer but equally important for solving problems, especially where there are interactions between offshore and inshore fisheries.

But if partnerships are so useful, one might ask, why don't we have them already? The short answer is that partnerships have to be carefully designed to be appropriate for the situation, as well as accountable and effective. Not all situations are ripe for partnerships, nor will partnerships be successful under all conditions. The good news is that we now have some good success indicators. In the last 20 years, social scientists have assembled a rich body of documentation which allows us to identify the conditions and situations which are good predictors of successful partnerships. This chapter summarizes some of this literature.

Unfortunately, knowledge of the existence of partnerships, as well as what it takes for them to succeed, has been largely absent from the training and experience of fisheries managers, as well as from the management agencies in which natural scientists work. Despite this, many natural scientists have recognized the need to integrate 'human dimensions' into our management systems. Peter Larkin reminded us a decade ago that in focusing on fish, we often forget that we manage fish mainly through managing people. As we shall see in this chapter, managing people means understanding how human organizations and human values can work towards, rather than against, the goals of fisheries management.

Indeed, our failure to manage people effectively has turned out to be the main limiting factor in fisheries management today. No matter how well-designed fisheries harvest regulations or habitat protection measures appear to be, if fishers or polluters can find a way around them, management efforts are frustrated. But when communities or organizations of fishers are included as partners in the planning, design, and implementation of the regulations, when they participate in protecting habitat, and even more, when they are part of the crafting of the very policies which underlie management decisions, they grant full legitimacy to the regulations, and are the strongest advocates, monitors, enforcers, and implementers of management decisions. Community and NGO partners may even help agencies re-conceptualize a problem and develop a better strategy for attacking it. Recognition of the importance of these kinds of partnership roles in fisheries management is reflected in Paragraphs 6.13 and 6.16 of the Code of Conduct for Responsible Fisheries.

Involving communities or NGOs in management may also be the only way that enough resources can be mobilized to manage effectively. In some cases, this means resources to make even basic stock abundance assessments. In other cases, it means resources to consider species interactions and ecosystem values in management. Our understanding of natural systems has evolved to the point that we know we need to develop management systems which reflect the complexity and diversity of what is being managed. Yet we lack the flexible governance structures and resources to achieve this. We know governments will never be able to achieve this ambitious task alone. A growing literature shows how important aspects of this challenge are already being met through partnerships.

Partnerships vary in the scope of their activities, in the geographic scale of the marine or freshwater areas involved, in the types and number of parties involved, and in the degree of power held by the non-governmental parties. The next few sections explore examples of different types of partnerships along these four spectrums and the costs of developing them.

11.2 Partnerships of small and large scope

At the smallest scope, a government manager may partner with a local group to collect data on a local stock or sub-stock, or monitor pollution, or habitat loss. Much of the most exciting recent research on local or traditional ecological knowledge is based on this type of arrangement (Neis and Felt, 2000; see also Section 3.6). Local fishers may already have extensive knowledge of the behaviour and abundance of a local stock. Managers may work with local fishers simply to record their knowledge and annual observations of changes; or they may actively incorporate the fishers into the work of controlled monitoring of the stock (see Paragraph 6.4 in the Code of Conduct). Often such work provides the only information government has on a local fish population. Since many species are made up of smaller distinct local sub-stocks, such information may be the most critical data informing management of the entire species.

Alternatively, knowledge of the sub-stock may reveal a spatial or temporal pattern which is masked by survey data taken on a larger scale and within a different time frame. Local monitoring of lobster on the Magdalen Islands provided species-wide information on their spatial distribution, use of habitat, and interactions with other species, data which was heretofore missing (Gendron *et al.*, 2000). Local fishers usually have developed hypotheses about these relationships based on decades of observation. They often suggest factors which should be considered, often ones which would not occur to managers.

In summary, the benefits of such a small-scope partnership can be multiple and unobtainable without a partnership with local fishers.

The partnership may

- provide reliable data on the abundance and composition of a local stock or sub-stock (which might be used as an indicator stock, if a species is composed of many stocks);
- help managers interpret large-scale changes in abundance and the environment;
- suggest hypotheses about relationships which scientists can then test;
- assist scientists with the most effective sampling techniques and sites for ongoing monitoring or research.

Suppose that, in addition to collecting and interpreting data, the fishers also assisted in interpreting the effect of regulations on fishing behaviour, and even assisted in crafting more effective regulations. Thus local knowledge would be used to analyse regulatory failures and to proactively design more successful approaches. This was done on Magdalen lobster, where local fishers helped managers interpret the meaning of catch data, helping them understand that fishing efficiency had increased despite tighter regulations. This led managers to consider that reducing fishing effort through time and area closures might be a less effective method of reducing mortality than, for example, reducing licences or traps (Gendron *et al.*, 2000).

Partnering in this slightly larger scope of management:

- checks the validity of managers' interpretation of catch data;
- suggests alternative methods of regulating catch.

The foregoing types of small-scope partnerships can be very low cost if fishers are willing to volunteer time and the use of pre-existing equipment, and if government can provide some start-up staff time to develop a relationship with fishers who become identified as reliable monitors. Volunteerism is likely in situations which are already part of a work day or pleasurable activity for fishers, or where the fisher is learning something new and interesting, or is being made part of an activity which offers greater access to information or power. However, long-term willingness to volunteer is likely to persist only if managers are able to recognize the value of fisher's expertise and treat their fisher partners with appropriate respect. Ideally managers will perceive that many fishers have a passionate interest in the health of the resource and have much to offer as interpreters of data if they are given access to the data and an opportunity to reflect on its possible meanings. A valuable relationship of mutual respect and trust is likely to occur if the most knowledgeable and reflective fishers are treated as colleagues whose knowledge and opinions are valued. In such a relationship, they would be given open access to government data and an opportunity to participate in both data analysis and the design of regulations based on the data, activities which are discussed in some detail in Chapter 13.

In many cases, NGOs can contribute small amounts of staff time or funding to support a key monitoring activity. Volunteerism and NGO donations are more likely to be forthcoming if the management agency is forthcoming about its own budget situation, and/or is able to contribute some modest financial support of its own. To do this, managers often need to overcome deep-seated attitudes that fishers are incapable of acting in anything but their own short-term, narrow self-interest. They need to remember that fishers will often act in the long-term and broader public interest if they see that they also will benefit in the long run. In other words, fishers and communities will invest in their future if they have assurances that they

will share part of the benefits to accrue from present restraint or volunteer effort. (A more in-depth discussion of the conditions which produce this occurs later).

Small-scope projects that are low cost are most effective if they can make a tight connection between the sense of or identification with place which often exists in fishing communities and the objectives of the monitoring or other small-scope activity. For example, better data on a particular local stock will enable more sensitive and appropriate fishing plans on that stock and a better understanding of what other factors affect its abundance in the local area. Regulations based on such improved data will be considered more legitimate and will be better obeyed, and fishers are likely to continue volunteer monitoring, if they are assured they will have the first access to recovered stocks (Pinkerton and John 2008; see also Section 10.2.2).

Partnerships of the largest scope are those which include fishing communities or NGOs in all aspects of management, even the identification of policy issues and the making of policy. A highly developed example of a large-scope partnership is the system in Washington State, USA, in which the treaty tribes co-manage the salmon fishery with the Washington Department of Fisheries. The tribes meet with the state governor's council alongside all the departments managing natural resources, to identify policy issues of concern and to develop approaches. In other words, the tribes have a government-to-government relationship with the Department of Fisheries, even though they do not have equal resources. This type of partnership is explored later under 'different levels of power'. In the evolution of their relationship, the tribes and the state have developed transparency of data arrangements through the University of Washington computer, and divided up management tasks to avoid duplication.

Large-scope partnerships normally involve extensive staffing and capacity building of the NGO partners, and are normally funded through multiple government agencies. In the United States, the tribal managers are funded largely through the Bureau of Indian Affairs. Canada, however, is experimenting with funding large-scope regional organizations through the Department of Fisheries and Oceans (DFO), as an interim measure while NGO support is being identified. This usually happens after long-term conflicts result in the building of cooperation, and the Department believes management will be better served by funding regions on an experimental basis, institutionalizing them in the long term if they are successful. These organizations have accessed funding from private foundations and multiple government departments in their start-up phases. The research initiatives of these organizations are also attracting interest from universities, as well as government researchers, and can often become hubs of funding and activity from multiple private and public sources (Pinkerton *et al*., 2007). The advantages of large-scope partnership can be summarized as follows:

- Small-scope partnerships may attract volunteerism, contributions-in-kind, and small cash donations, while requiring only part-time staff attention from government.
- Large-scope partnerships need substantial external funding sources, but may attract at least some funding from foundations or NGOs, due to their innovative nature and their capacity to conduct integrated research on ecosystem linkages. They may eventually be NGO funded or self-funding if they become non-profit membership-based organizations.
- The use of volunteer labour and contributions-in-kind (use of vessels and equipment) will be sustainably offered if a relationship of trust and mutual respect can be established.
- Data transparency and openness to varying interpretations of data are highly desirable as a mechanism for building trust and mutual aid.

It is important to note that in many developing countries and island states, there are fishing communities that informally regulate their fishing effort, based on their observations of fish

abundance and their reading of indicators which predict fish abundance over time. These cases have been documented, summarized, and synthesized by many geographers, anthropologists, political scientists, and biologists, including Johannes (1978, 1981), Klee (1980), Spoehr (1980), Ruddle and Johannes (1985), Cordell (1989), Dyer and McGoodwin (1994), Wilson *et al*. (1994), Schlager and Ostrom (1993), Wilson *et al*. (2003). Japan has achieved the most 'complete' and integrated set of partnerships, in that it has integrated ancient local systems of management into fisheries planning at all levels of local, regional, and national government (Yamamoto and Short, 1992; Pinkerton and Weinstein, 1995). A reading of these cases suggests that an important challenge for developing countries may be to identify whether such home grown systems already exist and, if so, to support and integrate them into regional and national management through co-management agreements. Funding to support such systems' start-up phase is sometimes accessible through international research organizations or universities (Stoffle *et al*., 1994).

But dependence on legitimation or funding by external bodies such as NGOs can be unhelpful or even a disadvantage if a developed country NGO does not have adequate experience with the community in a developing country it is attempting to assist, and if there is no internally generated effort and strong desire to develop co-management. If external NGOs offer funding to communities to experiment with and adopt co-management processes, goal displacement may occur. A community may discontinue all efforts towards co-management after the external funding is exhausted (Hara and Nielsen, 2003). In this situation, the community's goal in the co-management project becomes to secure funding rather than to develop co-management relationships and management rights that would contribute to conservation and livelihoods. In such a case, the community may have lacked the capacity, vision, or will to take on the responsibilities of co-management (as discussed under condition 4), and the mere provision of funding and legitimation by external NGOs was not sufficient to overcome the absence of these conditions and allow the development and assertion of management rights.

11.3 Partnerships of small and large scale

The foregoing examples of partnerships of small scope were also ones of small scale, since the geographic area is small (but note that temporal scale could be extensive in a small area). Ames *et al*. (2000) point to the need to incorporate multiple spatial and temporal scales in the analysis of how fishing alters ecological processes. This aspiration is contrasted with the conventional approach to management decisions, based on measuring the fishing mortality of a single stock at a single spatial scale, the range of the fish,and at a single temporal scale, one year. Scientists have long noted that overfishing is often a function of unrecognized habitat degradation. Of course, the need to protect fish habitat will not be addressed unless managers understand how to monitor habitat and species linkages. Thus analysts argue that overfishing is often undetected unless managers monitor the species composition of the ecological community to which the fish belong and the gradual removal of patches or subsystems in a progressive manner. The management implication of this argument is that local groups may be the best placed to protect the small-scale components of an ecosystem. Thus the management actions of local fishers or local partners should be integrated into an adaptive multi-scaled governing institution to match the multiple scales of the ecological system (Ames *et al*., 2000; see also Section 3.6).

Some of the most successful partnerships function at a regional scale, around a common interest in a watershed or sub-basin. A small-scope regional-scale partnership, as exemplified in the Kuskokwim River in Alaska, is data collection on the same stocks by different communities located at different points on the river as the stocks swim upstream. By combining their data on a real-time basis, as well as their traditional local knowledge of the migration patterns of different stocks under different conditions, the various communities on the river are able to work with the Alaska Department of Fish and Game and the US Fish and Wildlife Service to produce a more reasonable assessment of stocks and species abundance than the government agencies could produce alone. This is effective because a regional-scale partnership can cover a larger range of conditions and factors than the single test fishery or counting fence which was formerly operated by government. The partnership arose out of controversy over the accuracy of the government's abundance index. With the regional-scale partnership, the abundance estimate is now considered far more legitimate, and government has a far richer database to inform its decisions (Pinkerton and Weinstein, 1995). The partnership was also based largely on volunteer monitoring by fishers, with donations-in-kind by a regional association, a federal government agency, and a fish processing company. The Alaska Department of Fish and Game contributed staff time during the first season to train a community-based monitor, who thereafter became a highly trusted partner, and staff time for in-season meetings to compile and interpret the data in collaboration with community-based partners. This process has continued to evolve constructively and regulations devised by the Kuskokwim River Management Working Group have never been overruled by the statewide Board of Fisheries, even though it has the authority to do so. The mandate of the Board of Fisheries is to allocate fishing opportunity and to resolve allocation disputes among fishing groups. Apparently, it considers that it could not improve on the decisions of the Kuskokwim Working Group. This example illustrates the fact that partnership arrangements do not need to be recognized in law to be effective.

A larger-scope, regional-scale partnership might factor basin-wide habitat affects and enhancement activities into its fishing plans, as it did in the Skeena Watershed Committee in British Columbia and in the Mitchell River Watershed in Australia. This means that multiple community parties and multiple government agencies make decisions based on multiple criteria. From the community perspective, fishers more readily accept curtailment of opportunity to take less abundant species if they participate in the planning process to increase the abundance of other species and the planning for the restoration of the depressed species. The planning in this case includes improving habitat protection, engaging in habitat restoration, and engaging in activities to enhance the productivity of freshwater production of fry and smolts. Perhaps most important is that the involved fishers and community representatives on the committee see a broader picture than their own narrow self-interest and feel part of a grander scheme to restore the health of the watershed. Being able to get beyond geographic isolation and cooperate on a regional scale can have a powerful effect on the parties. This occurs because they perceive that by cooperating, they can have the power to effect positive change on a more meaningful scale, at the same time that they improve or at least stabilize their own position. They also perceive that improvements in the fishery will not occur unless all differently situated parties contribute to the solution. Because of this, they are often willing to 'give to get', even delaying their own 'pay-off'. Government agencies may be likewise enabled to get beyond turf battles and make trade-offs in the interest of getting a better outcome in the long run (Pinkerton and Weinstein, 1995).

Depending on human resources available, it would not be impossible to develop regional-scale cooperation without major funding. In sum,

- small-scale large-scope partnerships may be part of the multi-scaled forms of management necessary to monitor and analyze the dynamics of progressive habitat loss and species interactions;
- regional-scale small-scope partnerships may combine multiple sources of data to create a more accurate real-time picture of stock abundance and the effect of fishing pressure;
- regional-scale large-scope partnerships may enable an analysis of fishing/habitat interactions;
- regional-scale large-scope partnerships may enable cooperation and greater pay-off flexibility among differently situated sectors when they collaborate to increase fish abundance for their mutual benefit.

11.4 Partnerships with dual or multiple parties

The simplest partnership is between one government agency and one community or NGO. But whatever the scope of management decisions shared, or the geographic scale of the management unit, partnerships often include multiple 'communities' and multiple government agencies, as in the watershed management examples given earlier. Such partnerships are being modelled in Canada on both coasts. On the west coast of Vancouver Island in the province of British Columbia, a partnership between aboriginal First Nations and adjacent non-aboriginal communities, alongside regional governments, local environmental groups, and community development agencies has been developing since the early 1990s. It was formalized in 1997, received approval of its terms of reference in 2001, and in 2002 became an operational government-sponsored regional management board. In its final government-sponsored form, it includes aboriginal, recreational, commercial, aquaculture, major processor, tourism, labour, and environmental sectors, in addition to four governments: federal (DFO), provincial (Ministry of Agriculture, Food, and Fisheries and Ministry of Sustainable Resource Management), regional district (Alberni-Clayoquot Regional District and Comox-Strathcona Regional District), and First Nations (Nuu-chah-nulth Tribal Council). First Nations are thus represented both as a regional government and as a resource sector. The Aquatic Management Board (AMB) brings these parties into a respectful dialogue around one table covering most of the west coast of Vancouver Island. The AMB's importance stems especially from its work in building a collaborative planning process with a wide spectrum of stakeholders and sectors at the Coastal Management Area (CMA) scale (approximately 360 kilometres of coastline and 29,750 square kilometres of land). Thus it uniquely explores the role of cross-sectoral consultation (as a partial alternative to current multiple single-sector consultations) at an ecosystem-relevant planning scale. This scale is small enough for meaningful human interactions and consensus building, and large enough for meaningful oceans planning. The value of the work these parties can achieve together includes policy development and modelling how to link local or watershed processes with larger-scale coastal and ocean processes. Detailed information about board activities and an evaluation of its first 3 years of operation as a pilot project are available on their web page www.westcoastaquatic.ca. This web page also contains an extensive internet-accessible marine-oriented atlas (an integrated geo-referenced database) and a linked document database integrating the extensive body of information from multiple sources on the resources of the region.

In southwest Nova Scotia on the east coast of Canada, multiple gear groups and community representatives have formed boards along county lines to create fishing plans and to monitor fish deliveries. John Kearney, an anthropologist who participated actively in the formation of the boards and also served as CEO of one of them for several years, provides a comprehensive account on which this is based (Kearney, 2005). In the mid-1990s, in response to groundfish conservation crises and the move of federal managers toward market-based approaches (individual transferable quotas, ITQs), leaders of fishing organizations, working with DFO, developed separate local inshore groundfishing plans, reflecting the various situations of different gear groups and communities. License holders signed contracts with their organizations to obey the plans, and the organizations monitored their compliance through the fish deliveries and reports of their departure and return from fishing trips. The democratically elected representatives of gear groups formed boards in each county which produced fishing plans each year for each gear group and monitored compliance with the plans. Quotas of cod, pollock, and haddock are allocated to the boards each year based on their collective catch history. Gear-specific fish committees on the board make in-season adjustments to the plans in response to real-time developments (see also Bigney, 2005). The board on the Nova Scotia side of the Bay of Fundy also reached out to the communities to form a support organization, resulting in the creation of the Bay of Fundy Marine Resource Centre, providing facilitation and research services. This Centre now plays a leading role in various community development projects and has spawned the creation of other centres in the region (Kearney, 2005; Graham and Guieb, 2006; Bull, 2007; Charles *et al.*, 2007). The Bay of Fundy Marine Resource Centre has helped fishers map the historical shrinkage of haddock spawning areas and to document their hypothesis that there are several stocks of haddock deserving special management and protection, contrary to the DFO hypothesis of one stock with one total allowable catch (TAC). Armed with this information, the fishers can develop plans aiming to restore spawning areas.

These local planning bodies are nested within broader regional organizations of multiple local parties, communities, and environmental organizations which are guided by a broad public interest. The Bay of Fundy Fisheries Council has articulated principles supported by all the fisher organizations, including: protect reproduction, juveniles, critical habitat, food chain relationships, local stocks; establish and recognize effort controls; promote owner–operator fishing; diversify fishing livelihoods; retain fish as a public resource; make management decisions at the local level (Kearney, 2005; Bull, 2007).

On both coasts, the benefits of multiple parties being able to collaborate are enormous. From government's perspective, there is a conflict-resolution benefit, which often solves allocation problems among warring sectors: sport, commercial, and aboriginal sectors, whose struggles were damaging to good management. The prestige of government is enhanced when it is perceived as successfully mediating such a conflict in a way which serves public values (Poncelet, 2001). From the community/NGO perspective, collaboration means that the chances of developing and implementing a long-term vision and developing a sense of stewardship around that vision are greatly increased. The fact that the vision has input from multiple perspectives and that some of the partners are often communities (who have a general interest in the long-term health of the region, as opposed to fishers, who may have a vested interest in particular stocks) means that the vision has broad support and is likely to be sustainable. There is increasing support for the concept that the right to fish a single species should not include the right to negatively impact the food webs or damage the habitat of other species. 'Integrated management' will thus necessarily mean that governments must listen to these multi-sector constituencies and not allow themselves to be captured by stakeholders

with rights to single species and operating under fishing plans which do not include a broader perspective (Rose, 2002; Tietenberg, 2002). The importance of developing such partnerships is addressed in, for example, Paragraphs 6.13, 7.1.2 and 7.6.6 of the Code of Conduct.

11.5 Partnerships with different levels of community empowerment: accountability

The larger the scope of management activities in which a community or regional board is involved, the more likely it is that the level of power held by the NGO is high. However, since power-sharing is usually negotiated, it is possible that a community/NGO might hold significant power in one area of management and little power in another. For example, an agreement to co-manage a fishery could involve equal power in developing a fishing plan, but no community/NGO power in deciding who had access to the fish, or no community/NGO power is making general policy about the direction or vision of future management goals.

In other words, there are different levels of power, or power over different levels of decision-making, whatever the scale of decisions. Equal partnership in deciding how to collect and analyse data is an important, but still a relatively weak, form of power compared to the power to decide how the fishery will be conducted or to decide who has the right to participate in a fishery, how much they get to take, etc. We might think of a hierarchy of levels of power. At the bottom of the hierarchy are decisions about operations or activities, which can themselves be arrayed in order of ascending importance. At the next level are decisions about who gets to make the operational rules, and who is excluded from the management area affected by the decisions (membership). At the top of the hierarchy are decisions about how the rules at the other two levels have to be made, and what groups may participate in making them (Ostrom, 1990). The treaty tribes in Washington State hold co-equal status with the Washington Department of Fisheries at each level of decision-making, and thus hold the maximum possible partnership power, as well as the maximum scope in decision-making (in all areas of management). In contrast, the geographic scale of the territory over which each tribe has authority is relatively small, so the tribes coordinate their negotiations through a body with no legal authority, the Northwest Indian Fish Commission.

All of these levels of power can be contrasted with the mere advisory status that is often granted to fishers' associations by government managers. It is important to recognize how advisors differ from partners, and that the advisory relationship does not garner the benefits of the partner relationship. If advisors perceive that they have little power and influence, they will revert to the usual divisive client politics. This points to the major benefits of power-sharing: conflict resolution and the mobilization of energy to solve problems in critical parts of the system. This applies equally to conflict resolution between government and communities and among competing parties, who may participate in regional co-management through regional partnerships.

It is often not appreciated by government that human resources are a valuable form of energy, which may be mobilized and utilized only under the right conditions. Sociologists tell us that people will 'go all out', contributing far beyond what is formally required of them when they: (a) believe in the goal of a partnership, (b) feel they are part of a working team on which there is mutual respect and concern for the welfare of all partners, (c) feel that they are able to make a contribution to the team which is respected and honoured by the other partners

(Senge, 1990). These three conditions apply in fisheries management partnerships where there is a situation of accountability between and among partners. Accountability requires

- transparency of data;
- an ability to discuss differing interpretations of the data;
- an ability to agree on what the basic problems are and what approach is most promising;
- clear agreements to share decision-making;
- clear articulation of the standards being used to evaluate decisions and their results;
- an ability to have timely feedback on outcomes of decisions.

When accountability is lacking, human resources are not mobilized. Furthermore, energy flows in the opposite direction. Instead of working overtime to solve problems, fishers and communities actively subvert management plans and actions by managers which they do not feel are accountable.

11.6 Unusual partnerships solving particular equity problems: linking offshore fisheries to coastal communities

In addition to accountability, one of the necessary conditions for successful partnership is equity. Equity normally refers to the democratic representation of different gear groups or differently situated fishers or community representatives on co-management boards which share power with government.

Most nations also face another perplexing equity dilemma. How should they balance the operation of highly capitalized offshore fleets (which are highly efficient when resource abundance is high) with the access needs of coastal communities which support many small-scale artisanal or subsistence fisheries (and which are very efficient when resource abundance is low)? This dilemma has been well captured in a documentary film about the nationwide strikes of inshore fishers and small-scale fish marketers in India in the 1990s. The government of India wanted the offshore trawl fleet as an important source of cash and foreign exchange. The inshore fishers and marketers, however, noted that species of fish which they used to take in their artisanal inshore fisheries were being wiped out. They staged national protests and eventually succeeded in having the offshore fleet shut down, or at least its non-Indian components (Thalenberg, 1998).

In some cases, it may not be realistic or even desirable to shut down the offshore fleets completely or at all. In some cases these fleets may take species which are not available in inshore waters. However, it is often the case that these fleets not only depend on migratory species which are also taken inshore, but that they take as bycatch many other species on which inshore fishing communities depend. So there is usually a policy dilemma in how to balance these two needs. An innovative partnership in Alaska called the community development quota (CDQ) programme has been used to address important aspects of this dilemma.

In Alaska, about 10% of a billion dollar fishery on Bering Sea pollock, halibut, sablefish, crab, and other groundfish that had been taken mainly by offshore fleets (based in centres of production distant from Alaska), was allocated to six coalitions of villages (comprised of 62 villages in total) in Western Alaska. The villages, which had been traditionally dependent on inshore fisheries (but not pollock), were geographically isolated and had limited access to sources of cash income. The goal of the programme, begun in 1992, was to help the communities to develop the infrastructure and have personnel necessary to support long-term

participation in the industry, and thus build a stronger economic and social base (National Research Council, 1999). The programme aimed to address the exclusion and marginalization of these communities from the industry, and from access to all fisheries. This was considered key, because even the original licences in salmon, herring, and halibut allocated to these villages tended to be sold into urban centres or larger communities elsewhere in Alaska. In some cases, the villagers had never received fishing licences, having fished only for subsistence.

The community coalitions are organized as non-profit corporations which set goals and objectives, and submitted annual business plans to the Alaska Department of Community and Regional Affairs. Reports on their performance in meeting these goals are reviewed by the state, which has exercised considerable oversight. The state has the authority to reallocate quota among the six corporations, based on their performance, and has already exercised this authority.

The communities do not have a direct role in fisheries management decisions in the pollock fishery (the major large-scale offshore fishery), but their presence in the fishery as partners or deckhands means that they are likely to assert their interest in the bycatch and habitat destruction by this fleet where it affects species they take in community-based fisheries (mainly halibut and salmon). And they do have a management role in the smaller-scale community fisheries on other species which most villages have created from the proceeds of the pollock fishery. The communities essentially receive a royalty from the industrial fleet, which they use to develop their own participation in the fishery or for education. These activities are overseen by the National Marine Fisheries Service, the federal agency which has jurisdiction outside 3 miles from the Alaska coast. The communities may receive the royalty as cash; negotiate jobs for community members on board pollock vessels to which they lease their catch share; use the cash for scholarships, or to buy gear or vessels or licences; lease a quota share to community fishers; or create a local halibut skiff fishery.

Where communities created a local fishery, they used season and trip limits to spread opportunities among fishers. They used primarily skiffs up to 36 feet in length, and the CDQ organizations kept track of the harvest levels and controlled the pace of the fishery (Langdon, 1999). These new CDQ fisheries have not created a new 'race for fish' nor overcapitalized vessels, but have remained largely small scale. One village association has constructed a few larger vessels, but makes them fish 5 miles outside the village so that the local skiffs have a territory reserved for themselves. Some villages have added value and kept jobs in the community by constructing small processing plants. Some for-profit plants held by the non-profit organizations have also withheld 20% of fishers' landings to ensure that start-up loans are paid off in a timely manner. In short, the villages have had a vision of how to integrate a commercial fishery into their subsistence economies through a development plan (Langdon, 1999).

The Alaska CDQ programme could be applied more generally to any fishing-dependent communities with limited economic opportunities. The community partners may have rights to make decisions only about their own membership, and how to conduct their own fisheries in inshore areas. Such partnerships can address difficult policy issues around equity, however. They illustrate how

- partnerships can be used to create co-ventures between capital-intensive fleets and community-based fisheries which offer greater opportunity to communities otherwise forced out of the fishery by economic conditions and forces;
- partnerships can focus attention on the need to reduce bycatch by industry fleets of species that are also taken by inshore fisheries communities;

- partnerships between the state and fishing-dependent communities can be used to foster wise development of new community-based fisheries that are not overcapitalized and that are within the means of the community to plan;
- community quotas can be used as mechanisms for allocating non-transferable fishing opportunities to communities; flexibility in allocation can be created, however, if the state can transfer quota based on performance of community-stated goals;
- community quotas are also a mechanism for dealing with the power differential between large and well-organized economic actors and small, dispersed economic actors which are nonetheless a large sector of the economy and the welfare of many nations;
- if it is recognized that this sector does not compete well for access rights to fisheries, yet plays a key role in the social and economic diversity and well-being of a country, then a country can use this mechanism to assure the continued role of communities in the fishery.

11.7 Power differentials of diverse actors on regional boards

Another special case of equity involves the dilemma of how to represent powerful non-local interests on regional boards, where these external actors have fishing rights in the region that will be affected by regional board decisions. The problem is that external actors cannot be expected to have the same level of concern as does the community about protecting local habitats, ecosystem linkages, or the sustainable harvesting of local stocks. This is because external actors are less identified with the region, have less opportunity to develop a stewardship ethic, and are more likely to have other diversified opportunities (are less dependent on the local stocks and their habitats). They could be characterized as having an economic interest in the region but not a stewardship interest. The West Coast Vancouver Island board is solving this problem by having such actors represented on committees including local fishers which develop fishing plans but not represented directly on the board which makes overall policy. This leads to the following important corollary.

> ***Condition***: External economic interests can be represented on community or regional boards, as long as they do not have an opportunity to dominate them

Another effort to model the linking and creating of equity between offshore fleets (of large vessels) and nearshore or inshore fishing groups (using smaller vessels) is the Northwest Atlantic Marine Alliance (NAMA), founded in 1997 in Saco, Maine, USA. NAMA is currently drawing support from fishers' organizations in the states of Maine, New Hampshire, Massachusetts and Rhode Island as well as Maritime, Canada. NAMA is a non-profit umbrella coalition, promoting collaborative research in order to provide education about ecosystem linkages and selective fishing. Its history and current efforts are documented in Crocker (2008). NAMA also facilitates efforts by stakeholders to craft regulations which do not disadvantage inshore vessels, or transfer fishing effort from offshore areas to inshore ones, thus threatening the historical allocation balance and geographic spread of fishing effort. Because fishing regulations by the New England Fishery Management Council can be insensitive to local conditions, NAMA promotes the rights of local areas to develop regulations for their local areas which are more appropriate than the generic ones made by the Council. Many of the latter tend to increase fishing effort by offshore fleets and increase bycatch and wastage through regulatory discards due, for example, to very low daily trip limits. NAMA advocates balance and communication between offshore and inshore within

a vision of ecosystem-oriented conservation based on community linkages, increased awareness about fishing practices destructive to ecosystem values and linkages, and the need to enhance stocks. It seeks to include all relevant and affected marine resource interested parties in its membership (http://www.namanet.org; interviews 2000 and 2007). The existence of NAMA is another illustration of the fact that conservation initiatives within industry often emerge from the inshore, more community-based sector, but that this sector is capable of reaching out to and integrating the offshore sector under the right leadership and conditions. NAMA enjoys the support of high-profile public figures, and an ideology in the state that fishing-dependent coastal communities should not be the first to be pushed out of the industry. The non-profit organization is funded through foundation grants, individual and corporate contributions and membership. NAMA employs three staff and receives the equivalent of two more staff positions through the volunteer work of board members.

Recently NAMA organized a coalition to support the concept of area management, and developed a framework proposal for multi-species area management for the inshore fleet which has been praised by environmental groups such as the Nature Conservancy, Earth Justice, and Conservation Law Foundation as the most environmentally advanced regulatory proposal in New England in the past 20 years. Other organizations involved in the coalition include The Island Institute, Penobscot East Resource Center, The Ocean Conservancy, Mid-Coast Fishermen's Association, Independent Fishermen Investing in Sustainable Harvesting (IFISH), Maine Department of Marine Resources, University of Maine, Maine Sea Grant, Cooperative Extension and over 75 commercial fishers spanning four states. This proposal was submitted to the New England Council for consideration in December 2006 (Area Management Coalition, 2006). Fishers in NAMA were the first and only, so far, to propose a definite cap on fishing in the form of a TAC limit, and real-time community-based monitoring for prompt feedback and continuous learning about stock abundance. The area management proposal aimed to design conditions which would allow a finer scale mapping of local stocks and their habitats, rebuilding of overfished stocks, and a retention of all or most species caught to avoid waste and to increase knowledge and management capacity on stocks as assemblages or ecosystem components. It also proposed mechanisms for dealing with the complexities of movement between areas, allocation to areas, accountability and mortality controls, local multi-scaled governance structure, mechanisms for creating fishing plans, and operational fishing rules. Rules would be designed to address how, when, and where the fish are caught, giving local people the ability to address ecological and community concerns. Although gear restrictions are rarely given credit for conservation at the federal management level, fishers are very supportive of rules such as no fishing at night, smaller gear, elimination of ground cables, closing areas for spawning and juvenile protection. Such rules could be made locally faster and more effectively than through a 3-year debate at the federal level. Real-time data collection is also a conservation tool encouraging such local rule-making. As fishers see the quota being caught, local governance structures could quickly rally the participants and adaptively address TACs or unacceptable bycatch.

This framework can be seen as the major alternative to the proposal of offshore fleets to regulate through transferable days-at-sea. Offshore fleets have been buying up days-at-sea and now hold an overwhelming majority of the active groundfish days-at-sea allocation. NAMA members are concerned that days-at-sea will be converted into ITQs, a system favoured by the current US administration, which has generally not proved to create incentives for investments in local area and ecosystem management (Tietenberg, 2002; see also Section 10.5). Advocates of the days-at-sea approach have so far been able to exercise more influence on the New England Council, and the Area Management Coalition proposal led by NAMA has not

been accepted. Alternative management proposals such as this one will be considered after May 2009. At that point, ITQs will also be added to the alternative approaches considered.

> ***Condition***: Organizations which increase communication and education among different sectors and gear types of the commercial fleet can promote a stewardship ethic in all sectors and increase cooperation and appropriate regulations of different sectors.

11.8 Conditions for effective partnerships

So far I have discussed conditions enabling partnership design which affect accountability and equity. In this section I focus on conditions that are good predictors that a partnership will be effective. Some of these conditions pertain to the characteristics of the partners; some pertain to the characteristics of the partnership or the institutions created through the partnership; while some conditions pertain to the characteristics of the resource or resources being managed through the partnership. Social scientists are not able to state categorically which conditions are necessary in all circumstances, or in what combinations with each other, but only that the more conditions that are present in a particular case, the more likely it is that success can be predicted. It should be noted that these conditions for effectiveness need to be considered together with the conditions for accountability and equity discussed earlier.

11.8.1 Characteristics of the partners

- Communities or regions which have a high level of dependency on the resource have a greater incentive to develop sustainable use patterns, and are more oriented towards learning how to do this. This is because they are very vulnerable to non-sustainable use.
- Communities or regions which are highly identified with their geographic area, and are thus unwilling or unable to transfer access rights out of the area, are more likely to develop a stewardship ethic.
- Communities or regions whose membership can be readily defined have the potential power to exclude non-members and retain at least some of the benefits of management with the membership. This allows the development of incentives to invest in management.
- Communities or regions where committed and credible leadership exists, and where an energy centre or sparkplug is able to push the agenda forward, are more likely to sustain an effort to overcome the barriers to innovation.
- Communities or regions where a core group of people are willing to invest enough time in building the agreements to address the problems which are required to see the process of creating partnerships and then operating them.
- Communities or regions where some homogeneity of values, customs, norms, activities already exists, and/or where important sub-groupings have already built some degree of trust and understanding are part way down the road to partnership already. It is possible to build agreements from scratch, but far easier if some social capital already exists in the form of shared understandings.
- Communities or regions where sufficient local knowledge of the resource exists among people who are willing to share it offer far greater incentives to government to share power, and provide a basis from which to design more appropriate regulations.

- Communities or regions where skills exist for building consensus or agreements among community members will more readily mobilize their communities and build solid problem-solving local co-management bodies.
- A government agency which is oriented towards learning will more readily negotiate an adaptive and flexible agreement with partners.
- A government agency containing at least key individuals who have the political will to make the partnership happen, and who will work behind the scenes to overcome obstacles.
- A government agency with some willingness to delegate or decentralize enough decisions to make partnerships possible.

11.8.2 Characteristics of the partnership or the institution created through the partnership

- Permits common access to data and data analysis on the status of the resource.
- Permits the making of appropriate regulations for the local or regional situation (regarding both fishing and habitat protection).
- Permits the monitoring of compliance to these regulations by both government and community partners.
- Permits the enforcement of the regulations.
- Permits assurances that investments will be rewarded: improvements made in the resource by the management work of the fishing partner will benefit, at least partially, the partner who invested the resources to make the improvement.
- Permits the resolution of conflict in a timely manner, through informal or formal means, and with agreed appeals to a higher body if conflict is not resolved.
- Permits access to sufficient start-up monetary resources, where these are required by the scope of the partnership.

11.8.3 Characteristics of the resource(s)

- The resource is amenable to boundaries defining resource management units. In the case of migratory stocks, amenable to agreements being made horizontally or vertically with other regions sharing the management of the passing stock.
- The resource occupies or uses habitat or territory adjacent to the community or frequented by community members or fishers.
- The resource is capable of being monitored by community fishers or members.
- The resource is currently or potentially of sufficient abundance and value (or to supply some key ecosystem service) to be of interest to the community.

11.9 Community partners may add value to the resource

An increasing portion of the world's fish are harvested and processed using mass production strategies which miss opportunities to add value. That is, far more fish are sold in their lowest-value form than is required by market demand, simply because this fits the production strategy of large firms (Pinkerton, 1999).

Mass production at the fishing stage also encourages overfishing, because the capital-intensive vessels require high volumes of fish to cover operating costs, especially considering market fluctuations in fuel and fish prices. Boom and bust market cycles force vessels with frequently high operating costs to take more fish to cover costs, and the fisheries they target are degraded (Clapp, 1998).

Community-based fisheries are smaller scale, less capital intensive, less sensitive to changes in operating costs (labour, fuel), and hence more flexible in adapting to fluctuations in world fish prices, or to changes in fish abundance. Because they are smaller scale and more labour intensive, they have more opportunities – at least in the presence of appropriate preservation technology – to capture the fish live, or to preserve the quality of the fish longer, and to process it into a higher-quality (more value added) product (deYoung *et al.*, 1999).

11.10 Conclusion

This chapter has discussed the conditions under which the following problems may be addressed through partnerships: poor data and data analysis; low credibility of data and data analysis; inappropriate harvest regulations; low legitimacy of regulations; inadequate enforcement of regulations; overfishing; lack of attention to species interactions and habitat/ecosystem linkages; bycatch; habitat destruction; and failure to capture the full value of the resource. Four dimensions of partnership were discussed: their scope, scale, number of parties, and degrees of power-sharing. Partnerships were characterized in terms of their accountability, equity, and effectiveness, and conditions were identified which are predictors of successful partnerships which have these characteristics. CDQs were analysed as a mechanism for partnering offshore and inshore fisheries, or of simply allocating fisheries access to communities which are otherwise disadvantaged in the marketplace. Umbrella regional organizations and regional boards were also discussed as ways of integrating offshore and inshore fisheries and promoting stewardship. Although small-scale fisheries will doubtless be under increasing pressure in the future, mechanisms such as certification and selective fisheries which reward or even allocate fishing opportunity based on best practices and innovations contributing to conservation may assist in their survival.

Acknowledgements

I am grateful to the Social Sciences and Humanities Research Council of Canada for supporting my research on co-management institutions over many years.

Sources and recommended reading

Area Management Coalition. 2006. *Local Area Management of Groundfish. A Framework for Moving New England Forward*. NAMA. 200 Main St. Suite A., Saco, Maine, USA 04072.

Ames, E., Watson, S. and Wilson, J. 2000. Rethinking overfishing: Insights from oral histories with retired groundfishers. In: *Finding Our Sea Legs: Linking Fishing People and Their Knowledge with Science and Management*. Neis, B. and Felt, L. (eds). pp. 153–164. Institute of Social and Economic Research, St. John's, Canada.

Bigney, K. 2005. *Co-managing Troubled Waters: Community-Based Co-management in the Scotia-Fundy Groundfishery*. Master's thesis. School of Resource and Environmental Studies. Dalhousie University.

Bull, A. 2007. *The Fundy Fixed Gear Council 1996–2006: Ten Years of Community-Based Management*. Unpublished MSS available at http://www.coastalcura.ca/

Charles, A.T., Bull, A., Kearney, J. and Milley, C. 2007. Community-based fisheries in the Canadian Maritimes. In: *Fisheries Management: Progress Toward Sustainability*. McClanahan, T. and Castilla, J.C. (eds). pp. 274–301. Blackwell Publishing, Oxford, UK.

Clapp, R.L. 1998. The resource cycle in forestry and fishing. *The Canadian Geographer*, 42(2): 129–144.

Cordell, J. (ed.). 1989. *A Sea of Small Boats*. Cultural Survival Inc., Cambridge, MA. 410p.

Crocker, M. 2008. *Sharing the Ocean: Stories of Science, Politics and Ownership from America's Oldest Industry*. Tilbury House, Gardner, Maine [with Photography by Rebecca Hale].

deYoung, B., Peterman, R., Dobell, R., Pinkerton, E., Breton, Y., Charles, A., Fogarty, M., Munro, G. and Taggart, C. 1999. *Canadian Marine Fisheries in a Changing and Uncertain World*. Canadian Special Publication of Fisheries and Acquatic Sciences, Ottawa. 129: 199p.

Dyer, C. and McGoodwin, J.R. 1994. *Folk Management in the World's Fisheries*. University Press of Colorado, Niwot, CO. 347p.

Gendron, L., Camerand, R. and Archambault, J. 2000. Knowledge sharing between fishers and scientists: Towards a better understanding of the status of lobster stocks in the Magdalen Islands (Quebec). In: *Finding Our Sea Legs: Linking Fishing People and Their Knowledge with Science and Management*. Neis, B. and Felt, L. (eds). pp. 56–71. Institute of Social and Economic Research, St John's, Canada.

Graham, J. and Guieb, B. 2006. *Resource Centres as Communities of Practice: A Preliminary Investigation*. Catalyst Community Consulting, Halifax. Online http://www.seedwiki.com/wiki/coastal_governance

Hara, M. and Nielsen, J. 2003. Experiences with fisheries co-management in Africa. In: *The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects*. Wilson, DC., Nielsen, J.R. and Degnbol, P. (eds). pp. 81–97. Kluwer, Dordrecht,

Johannes, R.E. 1978. Traditional marine conservation methods in Oceania and their demise. *Annual Review of Ecology and Systematics*, 9: 349–364.

Johannes, R.E. 1981. *Words of the Lagoon*. University of California Press, Berkeley, CA. 245p.

Kearney, J. 2005. Community-based fisheries management in the Bay of Fundy: Sustaining communities through resistance and hope. In: *Natural Resources as Community Assets: Lessons from Two Continents*. Child, B. and Lyman, M.W. (eds). pp. 83–100. Aspen Institute, Washington, DC.

Klee, G.A. (ed.). 1980. *Word Systems of Traditional Resource Management*. John Wiley & Sons, New York, NY 290p.

Langdon, S. 1999. *Communities and Quotas: Alternatives in the North Pacific Fisheries*. Presentation to the Pacific marine states fisheries commission. Semiahmoo, Washington. 35p.

National Research Council. 1999. *The Community Development Quota Program in Alaska*. National Academy Press, Washington, DC. 215p.

Neis, B. and Felt, L. 2000. *Finding Our Sea Legs: Linking Fishing People and Their Knowledge with Science and Management*. Institute of Social and Economic Research, St. John's, Canada. 313p.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, New York, NY.

Pinkerton, E. 1999. Factors in overcoming barriers to implementing co-management in British Columbia Salmon fisheries. *Ecology and Society*, 3(2) Online http://www.ecologyandsociety.org/vol3/iss2/art2/

Pinkerton, Bedo, Hanson 2005 with Pinkerton, E. 2007. Integrating Holism and Segmentalism: Overcoming Barriers to Adaptive Co-Management Between Management Agencies and Multi-Sector Bodies. pp. 151–171 *in* Armitage, D., Berkes, F., Doubleday, N. eds. *Adaptive Co-management: Collaborative Learning and Multi-level Governance*. Vancouver, BC: University of British Columbia Press.

Pinkerton, E.W. and John, L. 2008. Creating Local Management Legitimacy: Building a Local System of Clam Management in a Northwest Coast Community. *Marine Policy* 32 (4): 680–691.

Poncelet, E. 2001. The discourse of environmental partnerships. In: *New Directions in Anthropology and the Environment*. Crumley, C.L. (ed.). pp. 273–291. Altamira Press, New York, NY.

Rose, C. 2002. Common property, regulatory property, and environmental protection: Comparing community-based management to tradable environmental allowances. In: *The Drama of the Commons*. Ostrom, E., Dietz, T., Dolsak, N., Stern, P.C., Stonich, S. and Weber, E.U. (eds). pp. 233–257. National Academy Press, Washington, DC.

Ruddle, K. and Johannes, R.E. (ed.). 1985. *The Traditional Knowledge and Management of Coastal Systems in Asia and the Pacific*. UNESCO, Jakarta Pusat, Indonesia. 313p.

Schlager, E. and Ostrom, E. 1993. Property-rights regimes and coastal fisheries: An empirical analysis. In: *The Political Economy of Customs and Culture: Informal Solutions to the Commons Problem*. Anderson, T.L. and Simmons, R.T. (eds). pp. 13–42. Rowen & Littlefield Publishers, Lanham, MD.

Senge, P. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization*. Currency Doubleday, New York, NY. 413p.

Spoehr, A. (ed.). 1980. *Maritime Adaptations: Essays on Contemporary Fishing Communities*. University of Pittsburgh Press, Pittsburgh. 161p.

Stoffle, B.W., Halmo, D.B., Stoffle, R.W. and Burpee, C.G. 1994. Folk management and conservation ethics among small-scale fishers of Buen Hombre, Dominican Republic. In: *Folk Management in the World's Fisheries*. Dyer, C. and McGoodwin, J. (ed.). pp. 115–138. University Press of Colorado, Niwot, CO.

Thalenberg, E. 1998. *Fisheries Beyond the Crisis*. Canadian Broadcasting Company documentary film. 55 minutes. Box 500, Station A, Toronto, Ontario M5W 1E6.

Tietenberg, T. 2002. The tradable permits approach to protecting the commons: What have we learned? In: *The Drama of the Commons*. Ostrom, E., Dietz, T., Dolsak, N., Stern, P.C., Stonich, S. and Weber, E.U. (eds). pp. 197–232. National Academy Press, Washington, DC.

Wilson, J.A., Acheson, J., Metcalfe, M. and Kleban, P. 1994. Chaos, complexity, and community management of fisheries. *Marine Policy*, 19(4): 291–305.

Wilson, D.C., Nielsen, J.R. and Degnbol, P. (eds). 2003. *The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects*. Kluwer, Dordrecht.

Yamamoto, T. and Short, K. (eds). 1992. *International Perspectives on Fisheries Management*: *With Special Emphasis on Community-Based Management Systems Developed in Japan*. National Federation of Fisheries Cooperative Associations and Japan International Fisheries Research Society, Tokyo. 527p.

Part IV

Scientific Information and Advice

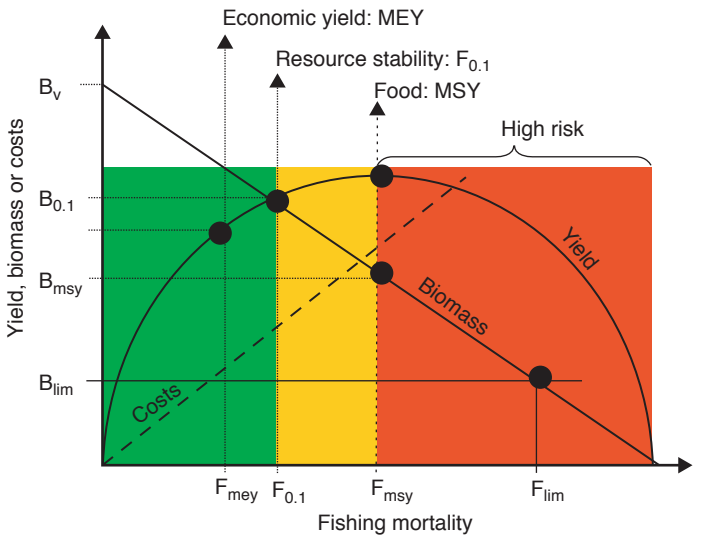


Plate 1 Conventional sustainability framework for fisheries based on the production model. Indicators are yield (in weight or value), biomass, cost and fishing mortality. Reference points are MEY, MSY, $F_{0.1}$, various values for the biomass (B_v to B_{lim}) or for fishing mortality (F_{mey} to F_{lim}).

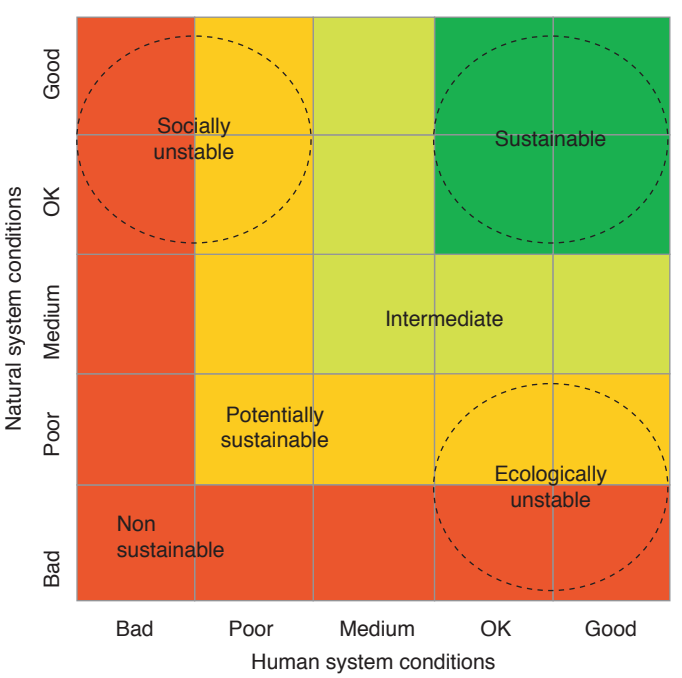


Plate 2 The sustainability barometer. (Modified from Prescott-Allen, 1996.)

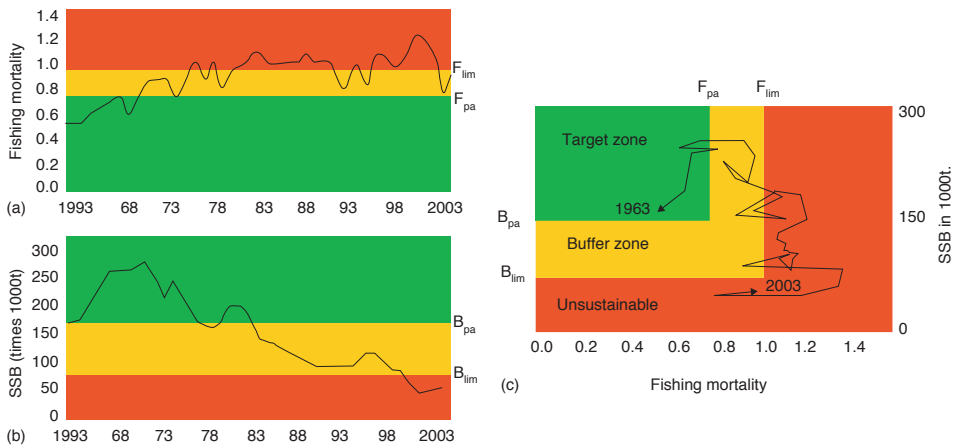


Plate 3 Indicators for Cod in the North Sea, Eastern Channel and Skagerrak. (a) and (b) Fishing mortality and spawning stock biomass indicators time series with their limit and precautionary reference points. (c) Co-representation of the two indicators. (ACFM Advice report Autumn [2004]. Colour coding added.)

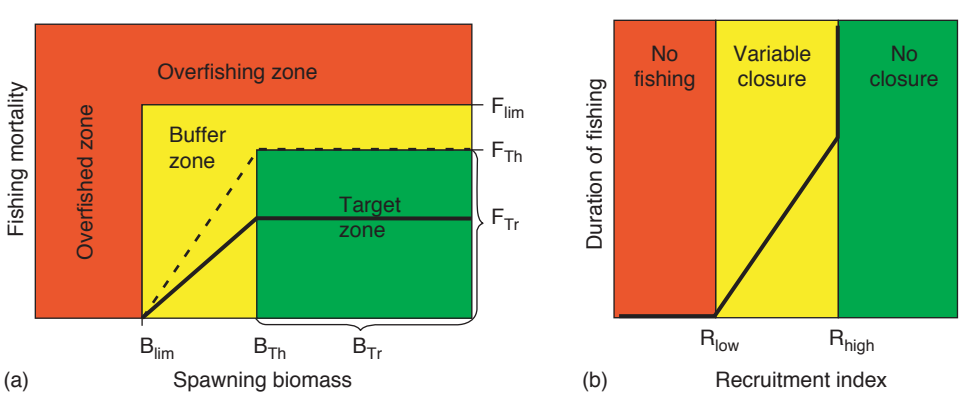


Plate 4 (a) Control rule for regulating fishing mortality (and hence harvest) as a function of spawning biomass. (b) Control rule for regulating the duration of the fishing season as a function of the pre-recruitment index. (From Garcia, 1995.)

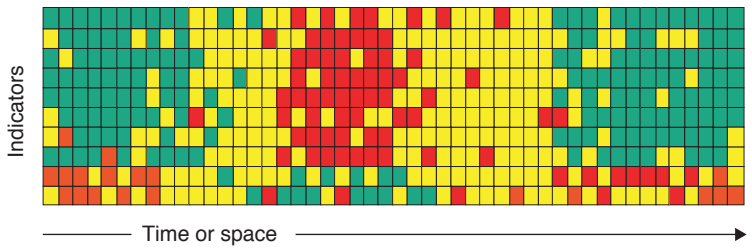


Plate 5 Co-evolution of 10 colour-coded indicators across time or space.

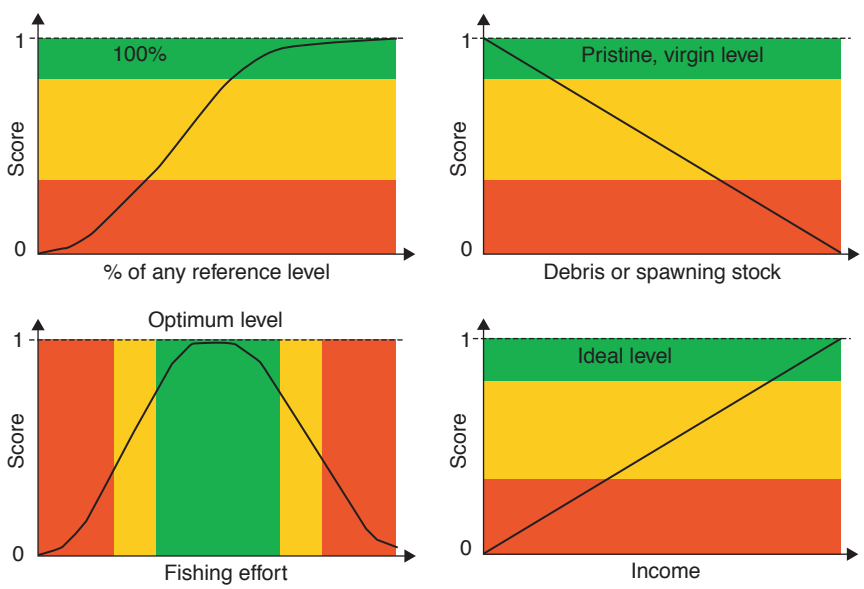


Plate 6 Theoretical examples of rescaling. The value of the variable, shown on the *x*-axis (horizontal), is replaced by the corresponding value on the *y*-axis (vertical). (Modified from Chesson and Clayton, 1998.)

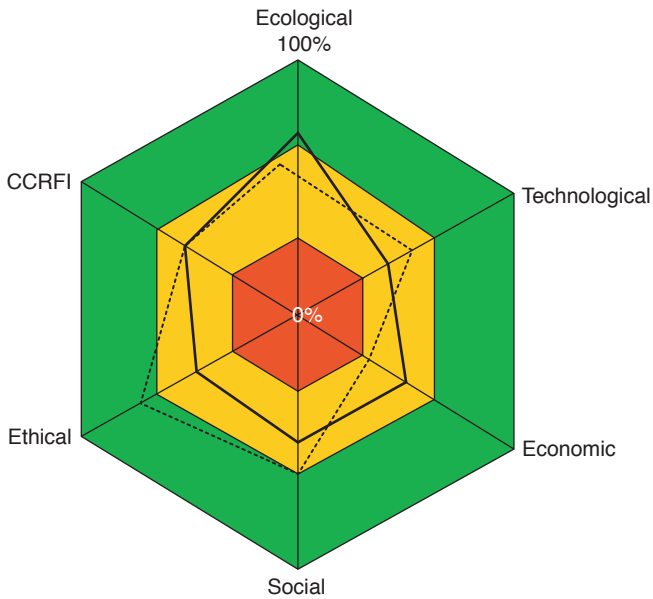


Plate 7 Kite diagram of a set of indicators covering key dimensions of two Canadian fisheries. The polygons refer respectively to the East coast (dotted line) and West coast (continuous line) fisheries. Source: Pitcher (1999) (by courtesy of FAO). A colour scale has been added to show levels of risk.

Chapter 12

Which Indicators for What Management? The Challenge of Connecting Offer and Demand of Indicators

Serge M. Garcia, Hélène Rey-Valette, and Clotilde Bodiguel

12.1 Introduction

Fishery indicators are qualitative or quantitative variables, pointers or indices, the fluctuations of which reveal the variations of key elements of the fishery system in space or time. In a fishery development and management process, indicators measure magnitudes of interest such as inputs, outputs, effects, immediate results, medium-term outcomes and longer-term impacts providing the elements of information needed for monitoring. In addition, their values and trends can be compared with the preferred values or trends (e.g. corresponding to stated objectives), expressed in terms of reference points or reference values (or preferred trends) providing concrete elements for judging to what extent the system operates according to expectations.

The modern societal demand for indicators as policy and management instruments is usually traced to chapter 40 of the 1992 UNCED Agenda 21 and to the call by the first and second session of the Commission on Sustainable Development (in 1993, 1994) for a 'menu of indicators' as a basis for (a) establishing cost-effective data collection systems – identifying most relevant data and appropriate resolution for their collection; (b) monitoring conditions and trends; (c) making informed decisions and (d) developing early warning systems. In fisheries, an extended review of concepts, principles and usage of indicator systems can be found respectively in the Technical Guidelines provided by FAO (1999) and Garcia and Staples (2000). The demand for using indicators has been enhanced by the adoption of the Precautionary Approach to Fisheries (PAF, FAO, 1996a) and the Ecosystem Approach to Fisheries (EAF, FAO, 2003). As an illustration, potential operational objectives, related indicators and data requirements for an EAF are shown in Annex 1.

Indicators have always been used by fishery stakeholders, for the elements of the fishery and at the scale of direct interest to them. For example, indicators have been used by scientists in their assessments; by governments to illustrate their policy and its outcomes; by NGOs for their advocacy; by the industrial fishery sector for monitoring its own objectives and by the media for their communication. Albeit less visible and documented, qualitative or semi-quantitative indicators have also been developed by small-scale fisheries' stakeholders as an integral part of their traditional knowledge. They are called to play a larger role in the more participative, transparent and result-based governance called for in fisheries in the 21st century. In the stormy change process, indicators are confronted with inherent conceptual

constraints, conflicting demands, over-expectations, cultural resistance, hidden agendas and poor or biased communication.

This chapter starts by reviewing the evolution of fisheries management and the related changes in the demand for information. It examines briefly the typology of indicators and in particular their functions, nature and quality criteria. The process of development of a system of indicators is described and examples of such systems are given. The main issues and challenges faced in establishing and maintaining systems of indicators are reviewed before presenting a brief synthesis.

12.2 Evolution of the demand

The present emphasis on the role of indicators for managing fisheries has emerged from the evolution of fisheries management itself and the implications of that evolution of the demand for information in decision-making.

12.2.1 Evolution of fisheries management

Fishery management science developed from the quantitative ecology used in wildlife management in the early 1900s with the view to rationalise harvesting, gradually integrating mathematical modelling of the relation between single species stocks biomass, catch and fishing effort (see Chapter 1). Constrained by data and computing power, it considered initially only a few elements of the fishery system (stock dynamics, catch and effort). It assumed the existence of simple cause–effect relations (e.g. between biomass and effort), the existence of a long-term equilibrium and the reversibility of stock and fisheries trajectories by management. It failed to distinguish and account simultaneously for the known impact of natural oscillations – a problem aggravated today by the perspective of climate change. Originally developed for strategic purposes, to design fishing regimes (optimal mesh size and harvest rates), the models were progressively used for tactical control of fishing operations through annual catch and effort restrictions (see Chapter 9). The numerous management failures of the last three decades indicate that, in most cases, the practice overestimated the predictive power of the assessment, the accuracy of the advice, and the willingness and capacity of governments and industry to really implement 'science-based decisions' with non-assessed economic, social and political costs. The last point is illustrated by the gap, in many fisheries, between the scientific recommendations and the policy decisions in which the social dimension usually looms large. It underlines the importance of co-development of information systems in support of integrated development and co-management.

During the last 15 years, the 'fisheries crises' metamorphosed from a sectoral technical problem to a societal environmental and ethical problem (Chapter 17). The management paradigm evolved progressively towards a more precautionary and systemic approach to fisheries development and management, recognising the complexity, the natural variability, the impact of global climate and economic changes, the pervasive uncertainty, the need for precaution, the importance of resilience and adaptability, and the importance of participative and adaptive decision-making processes for social learning and improved efficiency. The trend is formalised by the adoption of the EAF by FAO in 2001 and in the World Summit on Sustainable Development (WSSD) in 2002.

This evolution resulted in significant changes in the leading management paradigm (with a shift towards more democratic mechanisms of decision) and in the related demand for information (with a parallel shift towards more democratic knowledge building in support of those decisions, see Chapters 3 and 11).

12.2.2 Evolution of the demand for information

The implementation of the complete EAF[1] adds substantial specification to the conventional principles of fisheries sustainability provided by the 1982 UN Law of the Sea Convention (LOSC) in the environmental, socio-economic and institutional (governance) aspects. Furthermore, WSSD underlined the insufficient accounting of institutional and social aspects of sustainable development, accelerating the trend towards a transparent, structured and documented integration of the diversity of stakeholders' opinions and objectives, recognising *the reality of a world based on negotiation, persuasion and compromise* (Gates 1989). The extension of 'the fishery systems' representation to social and institutional aspects has underlined the role of negotiation, participation, compromise and consensus in decision-making and their impact on management performance.

While the conventional population-based quantitative assessments fall short of EAF requirements, their systemic equivalents are more complex, require more data, are more difficult to parameterise and to understand by managers and stakeholders. They are, therefore, not ideal for the highly participative and transparent approach needed for improved governance and societal communication. Indicators have, therefore, been proposed as potentially useful 'proxies' for essential fishery system properties, from which a transparent management 'dashboard' could be constructed,[2] and around which debates with stakeholders and the public could be organised, bridging formal and informal knowledge (Garcia, 1996; FAO, 1999). In addition, the systematic use of indicators can help rationalise data collection, focus performance assessment, monitoring and evaluation of policies and management strategies facilitating the task of the managing authority. Their public communication enhances transparency and accountability and may help connecting more clearly fisheries policies with management plans and fishing operations.

Indicators are therefore potentially required for the human and natural fishery sub-system, for its governance and for its drivers. In addition to conventional population indices, they could cover environmental factors, ecological relationships, biodiversity, ecological economics, fleet capacity and dynamics, social variables and dynamics, trade, etc., responding to a much larger set of fishery-related and societal objectives. These indicators may need to cover a range of nested scales from the household to the fishery, the community, the exclusive economic zone (EEZ) and the ecosystem, to track cross-connected resources and fisheries often indifferent to jurisdictional and political boundaries. Seen from that angle, the indicator

[1]The complete EAF, as defined by FAO, requires simultaneous consideration of the human and natural components of the fishery systems. In some countries, however, EAF and Ecosystem-Based Fisheries Management (EBFM) strategies are often reduced to their ecological components, failing to correct the most conspicuous flaws in fishery science and management.

[2]The problem raised by the 'dashboard' metaphor, implying effective, top-down, close to full control by a central pilot will be addressed further later.

'solution' leads to a long list of indicators (potentially several hundreds) that would scare the most ambitious and gifted manager.

Fortunately, the difficulty is mitigated by a number of considerations including (a) sharing costs with environmental agencies; (b) using qualitative indicators; (c) using rapid appraisal and participative assessment methods, and traditional knowledge; (d) aggregating information in a manageable set of indicators that produces recognisable patterns; (e) using adaptive processes and promoting social learning and (f) reducing the frequency of the systemic assessments to better match the frequency of changes in the systems. Furthermore, societal expectations should adjust to the situation too, and scientists and experts operating in a complex and uncertain environment should no longer be expected to produce the optimal solution, but to analyse and propose a broad range of options arising from participatory processes that take into account the limited rationality[3] of the actors, the less than perfect distribution of information and the logic of collective action.

12.3 Development of a system of indicators

Because indicators already in use in fisheries are numerous and a score of others could be identified, particularly in a systemic approach, the rational use of indicators for management requires the development of a framework for the selection, construction, organisation and visualisation of indicators and their related reference values (targets and limits). Because of their strong connection to sustainable development, these frameworks have been called Sustainable Development Reference Systems (SDRS) (Garcia, 1997; FAO, 1999). In practice, the development of an SDRS involves a number of steps shown in Figure 12.1 and briefly described later.[4]

12.3.1 Defining the scope and detail of the system

The first task in developing a system of indicators is to decide on its scope, characterising the domain to be covered, for example, in terms of geographical boundaries, time and space scales (grain), components (structure) and relations between them (complexity), the key issues (clarifying the demand) and the potential sources of data. A perception of the value (economic and otherwise) of the system will help in adjusting the system to a reasonable cost–benefit ratio. The scoping phase is more effectively undertaken in close collaboration with the stakeholders, employing participative surveys and discussion groups, with the view to establishing, from the onset, a common frame of reference and an agreed set of jointly identified issues.

[3]The idea is that human rationality is goal-directed but of limited information-processing capability. According to H.A. Simon (1916–2001), the consequence is that, in making decisions, instead of scanning all possible alternatives choosing the one that maximises expected utility, people tend to choose the first alternative that looks 'good enough'. An additional difficulty is that, in multiple stakeholder negotiations, the understandings (limited rationality) of the various groups and individuals only partly overlap, and processes are needed to elaborate a common knowledge base.

[4]More details can be found at http://www.fao.org/docrep/004/x3307e/x3307e00.htm

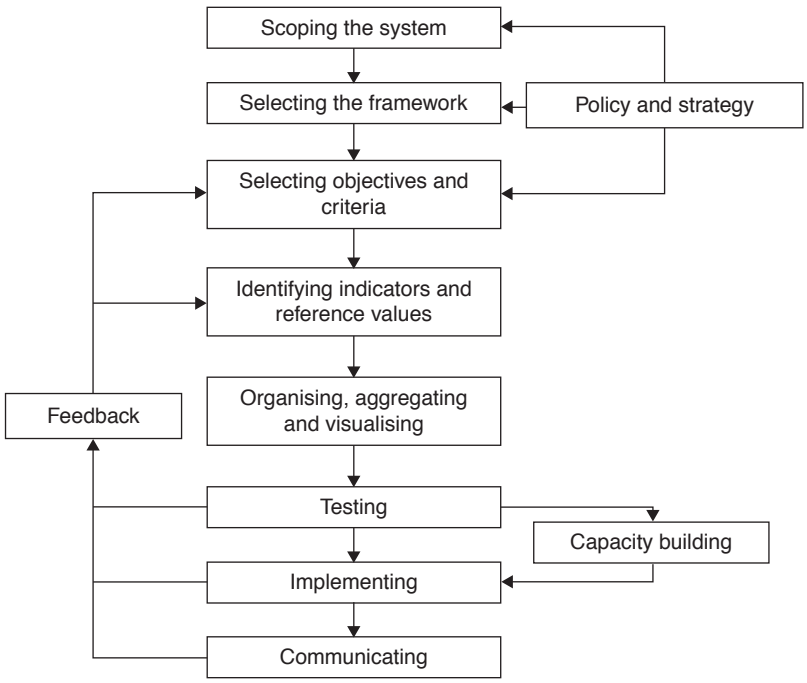


Figure 12.1 The building process of a system of indicators.

The selected geographical, political or ecological boundaries and scale determine whether the system is established at the local level of a community in a small bay or at the national level of a whole sector within the EEZ and beyond. The selection of the main components or dimensions (e.g. target resource, non-target resources, habitat, small-scale and large-scale components, fishers, processors and traders) establishes the complexity of the system and its degree of detail. The identification of key issues affecting the system (e.g. resource depletion, habitat degradation, user conflicts) helps in deciding on the necessary components and level of detail. With the adoption of a systemic approach, a broader range of issues and hence of components needs to be identified in the human and natural sub-systems, increasing complexity and the requirements for information and analytical capacity.

Systems of indicators may be developed at various levels of complication, with different degrees of detail or integration of the elementary variables. At any level, there will usually be a tension between the desire to have as comprehensive and detailed a system as possible and its practical feasibility (in terms of available data and analytical capacity) and affordability (in terms of maintenance cost). Considering the high number of potential components and issues in the natural and human sub-systems, and the need, often, to have more than one indicator per component and issue, the list of candidate indicators is usually very long, requiring careful selection (see later).

Systems of indicators may also be developed at various scales. FAO has developed a system of global and regional fishery indicators for its various reviews of the state of world fishery resources (see for example Maguire *et al.*, 2006) and its report on the State of Fisheries and Aquaculture (FAO, 2007). The constitutive elements include annual production

(by species, countries, etc.), status and trends in main resources (by stock and regions), employment (by sub-sector), utilisation (by type of product) and trade (by commodity and country). Regional Fishery Management Organisations have developed regional systems for the resources under their jurisdiction in which catch, effort and stock characteristics such as biomass and recruitment indices are the main variables. National systems used by fisheries departments tend to hold the disaggregated data submitted to regional and global institutions in an aggregated form and used for regular or occasional national reporting on the state of fisheries as well as for individual fisheries management.

12.3.2 Selecting the type of framework

The selection of the framework on which to organise the indicators and their interrelations is an important step. Because the framework imposes a structure, its selection may be undertaken, in many cases, together with the scoping exercise. Many types of SDRS are available and are mentioned in the FAO Guidelines (FAO, 1999). Other frameworks can be considered. The important point is that the structure of the indicator framework should preferably match that of the policy and decision-making framework to ensure that the information system is adequate for decision-making. A framework elaborated through an intense collaborative process will have more chances to be successfully implemented.

The conventional production model framework

Historically, the analysis of fisheries' sustainability has been undertaken using model-based frameworks, in the context of decision-making, for development and management. The surplus production and yield-per-recruit models have been used as sustainability frameworks (Plate 1 and see Section 13.4). Catch has been used for decades as an indicator of development and management, using maximum sustainable yield (MSY) as reference value. Used originally as a development target (as an UNCLOS standard), to be reached on average, biomass at MSY (Bmsy) has more recently been established as a limit to avoid, as a minimal standard for stock size and as minimal value to reach in a stock rebuilding process (1995 UN Fish Stock Agreement). Rent – the difference between revenue and total costs – has been proposed as an indicator of economic state with the maximum rent (i.e. the maximum economic yield [MEY] or point of maximum return to society) as reference level (see Chapter 4). These have rarely been formally used for decision-making. These frameworks have been used for 50 years – the first for management, the second mainly by academics. Applied in an open access context, the frameworks could hardly succeed in ensuring sustainability and the management model within which they were used, contributing to the failure. While the single stock models are still used at single fishery level, with due precaution, a much broader system of indicators is needed to give effect to the extended management paradigm reflected in the FAO Code of Conduct and EAF, more clearly connected to new objectives, processes and societal expectations.

The sustainability barometer

One of the earlier representations of a sustainability indicator reference system was the sustainability barometer proposed by Prescott-Allen (1996, 2001) working for IUCN (Plate 2). Used to represent human as well as ecological conditions, the barometer was conceived as an

instrument visualising performance scale against two scales related to the well-being of the human and ecological sub-systems. The traffic light colour coding made the value judgements on each scale very explicit and has been used since then intensively in many papers dealing with indicators, in fisheries and elsewhere. Garcia (1997) and Garcia and Staples (2000) have shown direct applications of the barometer concept to fisheries. The main use of the barometer is to combine indicators, enabling users to draw broad conclusions from an array of often confusing and contradictory signals. As such, it can be employed in a wide variety of assessment methods. All that is required is to arrange indicators hierarchically, so that they can be combined into progressively more aggregated indicators culminating in the highly aggregated indices of ecosystem well-being and human well-being. The ESD hierarch-ical component tree mentioned below, in the ESD section, could produce the aggregated indicators needed.

The Pressure-State-Response framework

The Pressure-State-Response (PSR) framework and its variants (Figure 12.2) were developed in the context of the UN Commission for Sustainable Development and the Organisation for Economic Cooperation and Development (OECD) in the mid-1990s (Moldan *et al.*, 1997). Sustainability is represented as resulting from the interaction between the pressures exerted on the system, the resulting state of the system and the institutional response implemented to correct the effects. In this simple framework, indicators are organised as

1. indicators of pressure and intensity of use such as climate, pollution, fishing effort or market demand;

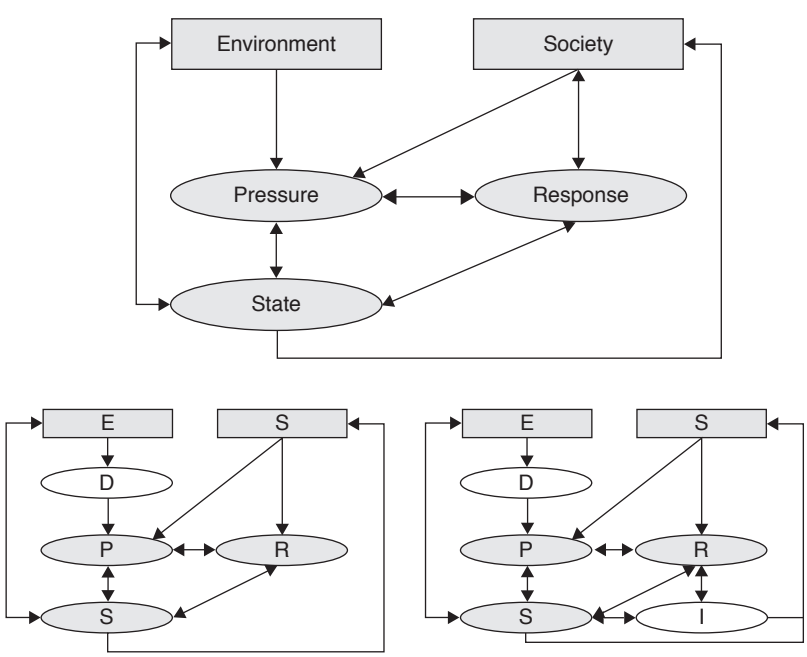


Figure 12.2 The PSR framework (top) and its variants, DPSR (left) and DPSIR (right). (Modified from FAO [1999].)

2. indicators of state such as biomass, percentage of habitat that is still functional or value traded;
3. indicators of institutional response such as regulations of fishing capacity, elaboration of environmental norms and adoption of eco-labels.

In the Driving force-Pressure-State-Impact-Response (DPSIR) variant of the framework, the driving force corresponds to drivers generating pressures (e.g. demand for food, investments) and impact correspond to measures of changes through time.

Despite its potential, direct applications to fisheries are scarce but one can be seen in Rey-Valette *et al*. (2005). It can be noted that institutional response indicators are presently the least developed[5] despite their utility in measuring the capacity of a management system (in human, institutional and financial terms) to reach objectives. These indicators are guided by governance principles such as openness, participation, accountability, effectiveness, coherence, subsidiarity and proportionality.[6] Deeply embedded in societal functioning, they require a high level of participation in their definition. The potential responses of the system itself (through self-organisation or adaptation) are not accounted for.

ESD

The ESD framework, sketched in Figure 12.3, was developed in the early 1990s in Australia to formally and continuously assess if the objectives of the country, within its ESD policy,

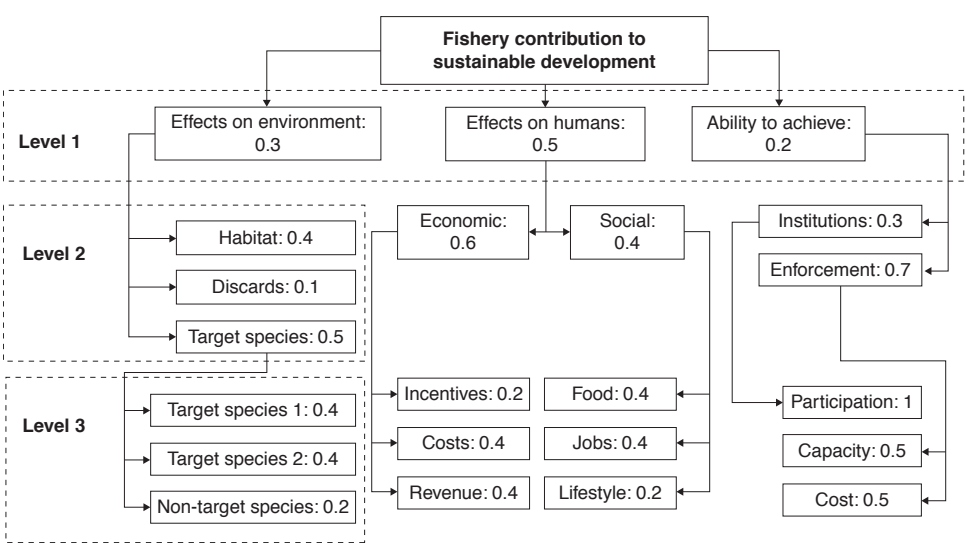


Figure 12.3 Hierarchical subdivision of an ESD framework. The values of the weighting factors are only indicative (Modified from Chesson and Clayton [1998].)

[5]An example related to indicators of management cost is available in OCDE (2003).

[6]These principles were developed in the context of the European Community reform of its governance system. More details can be found in EU (2001) *European Governance, a White Paper*, COM(2001) 428 Final.

were being achieved (Chesson and Clayton, 1998) as well as for the assessment and management of the risks associated with fisheries, in Australia and in some Pacific island countries (Fletcher *et al*., 2002). The framework is also used in South Africa and in FAO as the framework of choice for implementation of EAF.

In the highly participative implementation, the components of the hierarchical 'tree' structure are identified. For each component, the objective (and/or constraint) must be identified and given a 'weight' corresponding to its priority. The sum of all weights within a level of a branch equals 1 (see Figure 12.3) and is used for a simple multi-criteria analysis. The weighting factors represent social preferences and value judgements and are determined through formal enquiries, discussion groups and/or expert knowledge, as appropriate. For each component/objective, a criteria and related indicator is then identified and scaled (standardised) between 0 and 1. The shape of the relation between the observed value of an indicator and its standard score (which could be either a straight line, a sinusoid, a parabola, etc.) depends on the indicator. A particular value or trend of the indicator is identified as the preference playing the role of a reference level (target or limit) or direction.

Trends in scores over time can then be examined for each objective separately or for a set of objectives, aggregating their scores at the higher level using the weighting factors. These trends, relative to the corresponding reference levels or directions, inform on the performance of governance in reaching or failing to realise the objectives. The procedure can be used also to study the possible consequences of different options for action.

The components of the ESD framework are directly related to the PSR framework in that the components dealing with effects (on environment and humans) are indicators of state and pressure, while the components dealing with the ability to achieve are indicators of institutional response.

Other frameworks

In practice, the indicator framework may be naturally imposed by the organisational framework used, for example, to facilitate monitoring and evaluation. The Large Marine Ecosystem projects, for example, are structured around five modules within which variables are collected: (1) ecosystem productivity; (2) fish and fisheries; (3) pollution and ecosystem health; (4) socio-economic dimension and (5) governance. In each component, indicators are collected. In particular, three types of indicators are proposed: (1) indicators of process, (2) stress reduction and (3) environmental status (Duda, 2002).

The Sustainable Livelihood Approach (SLA) to fisheries is structured around five components: (1) the vulnerability context within which fisheries operate; (2) the livelihood assets of the fishworkers; (3) the policies, institutions and processes affecting fishworkers' lives (PIP); (4) The livelihood strategies adopted by fishworkers and (5) the outcomes they wish or achieve.

This chapter does not intend to describe these frameworks in any detail and more can be identified. The important point is simply that monitoring and evaluation of the effectiveness of any framework can best be achieved by collecting indicators in all the components of that framework. Another point is that despite being organised in apparently different structures, the indicators will most likely fall into the DPSIR generic categories established for monitoring sustainable development in general.

12.3.3 Selecting objectives, criteria and indicators

An effective system of indicators does not exist in a vacuum, and the long lists of candidate indicators (several hundreds have been identified) produced in the academic literature have little chance of being implemented. Operational fishery management indicators (and reference values) have usually been integrated into governance process which they reinforce and from which they draw legitimacy. The most successful ones have been enshrined in international legal instruments establishing them as a norms or standard (e.g. MSY in the Law of the Sea).

Indicators can be identified following the Principle-Criteria-Indicators (PCI) model in which indicators are derived from high-level policy principles (see also Figure 1.2) such as those found in the FAO Code of Conduct and national fishery and environment policies. The process is described in the following list and Table 12.1 illustrates part of the sequence.

1. *Identification of the issues* (e.g. overfishing, endangered species or poverty) that may signal a discrepancy with a fundamental principle (e.g. sustainability, conservation of emblematic species, equity).
2. *Translation into objectives* (targets) that can be adopted to mitigate or eliminate the problem (e.g. rebuilding stocks, reducing capacity, improving self-enforcement or increasing revenues). In order to efficiently use the limited resources available, ranking of objectives will be necessary. If the objectives have not been explicitly stated in the development or management planning, or have only been loosely formulated (e.g. improve ecosystem 'health' or maintain 'fair standard of living'), a participatory mechanism can be set up to agree on the operational objectives, reducing the margin of interpretation.
3. *Translation into constraints* (limits) imposed by the system, that is in terms of stock reproduction (minimum spawning biomass), enterprise viability (minimum profitability) and community livelihood (minimum employment). Biodiversity conservation (maximum allowable bycatch); promotion of bycatch excluder devices; area of habitat to be protected.
4. *Identify the criteria and variables* corresponding to objectives and constraints. Many such criteria are mentioned in brackets in the two sections given earlier. The corresponding variable or set of variables is identified together with the source of the data. If more than one variable is needed for an objective, it is advisable to split that objective.
5. *Elaborate the indicator* that best represents the changes in the variable (either quantitatively or qualitatively), either on the basis of pre-existing norms (or best practices) or through a participative process. Formalise the estimation procedure and its recording. More than one indicator might be needed for a variable.
6. *Establish the reference level* (or value or direction) for the objective, which is the value or the trend of the indicator that corresponds to the objective (target level) or constraint (limit level). They will serve to interpret the changes in the indicator. A threshold reference level could also be established, before the limit, which will trigger precautionary action aimed at reducing the probability of inadvertently crossing the limit. Alternatively, the limit could be made more precautionary.
7. *Establish the scale value judgements* corresponding to the indicator scale, for example, define the range in the indicator value corresponding to a situation considered as excellent, good, risky, very risky, unacceptable. This scale could be elaborated through a risk assessment based on mathematical modelling, expert group discussions, etc.

Table 12.1 Examples of the connection between scales, dimensions, components, criteria, indicators and target references. Limit references could also be inserted when relevant.

Scales	Dimension	Components	Criteria	Indicators	Example of Target reference[a]
World	Biological	Stocks	Abundance	Spawning biomass	50% of virgin biomass
Region	Ecological	Species	Richness	Numbers	Number at historical time
LME		Environment	Integrity	Habitat	Previous state Rebuilding plan
Country				Pollutants	Sanitary norms
EEZ		Goods/Services	Fish Tourism	Tonnes Value Numbers	Previous state Adopted target
Ecosystem					
Community	Economic	Fisher, household	Welfare	Income Rights	Maximum revenue % having rights
Fishery					
Household		Vessel, Enterprise	Profitability	Revenue Profit	Maximum revenue Maximum profit
Vessel		Fishery	Efficiency Performance	Rent generation Contribution to GDP	Maximum rent (MEY) Adopted targets
Individual					
		Sector	Viability	Rent Subsidies Export	Maximum rent Zero subsidies Adopted targets
	Technological	Catching sector Processing sector	Fishing capacity Processing capacity	Vessel tonnage Tonnes processed	Optimal capacity (modelled) Optimal landings (modelled)
	Social	Fishers	Employment	Total employment Employment multiplier	Adopted target
		Fishery sector	Benefits distribution	Equitable rent sharing	Balanced participation?
		Customers	Access Availability Health	Relative price Contamination Consumption per capita	Norms Retail price index
		Representation	Consultation Stakeholders	Stakeholders diversity Consultations	
	Institutional	Organisations	Participation Accountability Openness Coherence Effectiveness	Representation Cost-effectiveness Publicity Conflicts Implementation level	Adopted targets or trends
		Instruments	Effectiveness	Implementation degree Compliance level	Adopted targets
	Legal	Laws	Capacity of response	Proposal to decision time lag	Adopted targets
		Regulations	Capacity of response Effectiveness	Proposal to decision time lag Level of implementation	Adopted targets Numbers planned Previous state

Notes: [a]: Reference values (or points or directions) should reflect objectives and constraints. Those indicated are only indicative.

12.4 Typology of indicators

Indicators are often grouped by categories corresponding to the component or phenomena of the system that they measure. For stocks, relevant indicators include, for example, spawning biomass and fishing mortality. For fisheries they include fishing effort, cost or catch. For the ecosystem, the indicators will refer to numerous goods and services, food web structure and environmental variables. The potential list is therefore system-specific and practically endless. Indicators may also be usefully grouped according to their main function (measurement, control, communication), the type of indication they give (e.g. level, change, direction), the method used to obtain them (direct measurement, calculation, modelling, group discussion), etc. Some of these are reviewed in the following sections.

12.4.1 The functions of indicators

Going from their most obvious to their least obvious function, indicators have a number of purposes: (1) representation; (2) audit and control; (3) measurement and (4) communication and reporting. The functions presented here as distinct, in reality, often interact and overlap.

The function of representation

A system of indicators is developed to represent the fishery system. The choice of a suite of indicators (e.g. in an ecosystem approach) and their articulation is never neutral, reflecting the conceptual representation of the system by those who propose it. It implies a more or less conscious ranking of phenomena and issues, selecting the one(s) considered as most 'important'. Selecting an indicator of pressure or impact points naturally to a culprit and to corrective measures. For example, selecting the trophic level (TL) in the catch as the indicator of biodiversity degradation points to fisheries as the main stressor and calls for a biodiversity management instrument. Selecting contamination by heavy metal or dioxin in fish as an index of degradation would point to totally different culprits calling for different corrective instruments. Selecting indicators only because data are available (e.g. fisheries stocks) reflects a street lamp syndrome[7] and does not ensure relevance. Therefore, while structuring the decision field, constraints on availability of indicators, necessarily, reduce it. The problem can be partly mitigated by using a suite of indicators covering the most important components of the system.

The important point is that the selection of indicators is strongly influenced by the conceptual representation of the system. It reflects a preconception of the hierarchy of phenomena and of the relations between them that may be backed up by scientific analysis and formalised through mathematical modelling or emerging from empirical observations, and embedded in personal or social conceptions of the system. Prescribing the use of indicators as a way to deal with complexity without having to use complex models is therefore a fallacy. Models (whether mathematical or mental, explicit or implicit, conscious or unconscious) are omnipresent. In a multiple stakeholders' environment, however, the various groups may

[7]This facetious syndrome refers to looking for lost car keys, at night, under the only street lamp available, because it is the only area with enough light.

have different preconceptions, and it will be necessary to facilitate the process of interaction between stakeholders (including scientists) to co-elaborate the common and legitimate representation, aggregating the different forms of knowledge (and ignorance) available[8] (Section 3.6). From that angle, co-developed systems of indicators are a fundamental instrument of co-management.

Last but not the least, when a system of indicators is used as a control rule (see the section The function of audit and control), it must be kept in mind that the system 'freezes' the moving reality of the complex fishery system into a convenient instrument of prediction and control, the effectiveness of which depends on the variability of the real system, its long-term changes (e.g. regime shifts), and the governance capacity to assess the first and track the second.

The function of measurement

The most obvious function of an indicator is to reflect changes in the system properties of interest such as biomass, catch, values, rent, trade, compliance or customer satisfaction. Catch, employment, trade and many other statistics compiled by FAO and published in the FAO fisheries yearbooks are examples. The indicators may reflect state (e.g. a level), dynamics (e.g. rate and direction of change) or structure (e.g. the average trophic index of the catch). The measurement may be quantitative, absolute or relative to some reference level. It may need to be standardised for comparisons (e.g. between 0 and 1). It may also be qualitative and expressed as a colour (e.g. from green to red, to express risk) or in words either reflecting abundance (e.g. none, few, many), trends (e.g. fast, slow; increasing, decreasing) or quality (e.g. poor, acceptable, excellent). When a reference value is introduced into a chart showing the variations of an indicator, the control and communication functions start.

The function of audit and control

Auditing and control are different but connected functions, in which information is used for decision-making on different timescales.

In the medium term, collecting and arranging indicators for monitoring of the main fishery components and evaluation of trends is an important element of auditing and strategic performance assessment in any adaptive management framework (cf. Chapter 13). Plate 3 provides an example of a situation in which the observed trends can only raise serious concern and call for urgent corrective action. If the objective was to maintain the stock and the fishery in a healthy state, the conclusion of an auditor could only be that management has failed and a new strategy is needed. Indeed, one function of auditing is to assess the effectiveness of the control rules described later.

On a shorter term, yearly or within a fishing season, specific parameters of the fishery can be monitored to decide on 'real-time' interventions aiming at controlling the fishing activity. This has been done in the past, and is still done in many countries, using the production

[8] Arias and Fisher (2000) identify two useful postulates in that respect: (1) the symmetry of ignorance underlines that no actor, alone, can have all the information needed to deal with a collective issue and (2) the need for participatory processes that free knowledge from cultural barriers and allow for debate on collective issues.

model framework (section The conventional production model framework). In more advanced nations, control rules or control laws are used to make decisions in a semi-automated way. For example, harvest control laws (HCRs), graphically described in Plate 4, are used to estimate the amount of fishing mortality – and therefore of harvest – that should be allowed for various expected values of the spawning stock abundance. Combining indicators of biomass and fishing mortality with limit and target reference levels of activity or harvest, and accounting for some uncertainty, HCRs establish in advance the 'rules of the game' institutionalising total transparency and anticipation in decision-making. The same procedure can be used, for example, to decide on the dates for opening or closing a fishery (Plate 4). HCRs formalise and clearly communicate the management strategy. In line with the precautionary approach, they prescribe future courses of action, potentially reducing the reaction time of management to unexpected events. Some of the known uncertainties in the information available are in-built in the definition of the precautionary boundaries and the parameters of the control curve. HCRs could be established rather simply in data-limited situations and can be revised as data improves. They can also be parameterised and formally tested for robustness by simulations using a more or less complex model of the fishery and/or the ecosystem in a formal Operational Management Procedure (OMP) (Butterworth and Punt, 2003) or a Management Strategy Evaluation (MSE) (Fulton, 2005).

The control function has powerful social and economic effects. It can directly affect the relationships between actors and condition to some extent their response (e.g. compliance, under-reporting, technological substitution). Control indicators must therefore be easily collected, carefully crafted and tested, and they should rather be negotiated with the concerned stakeholders (for enhanced legitimacy). The present use of HCRs may reflect an overly confident reliance on indicators and reference points and on the semi-automatic response provided by HCRs (Hilborn, 2002). The problems reside in (a) the uncertainty in the exact values of indicators and in the model-based reference values generally used[9]; (b) the risk of increasing the frequency of undetected errors with time; (c) the approximations introduced in data-limited situations when using proxies from other areas or species; (d) the lack of regular performance assessment of the system and (e) the lack of transparency. Reflecting historical information, HCRs could become dangerously misleading in the case that a regime shift changing the fundamental functioning and productivity of the system is not detected in time (Mohn and Chouinard, 2006). The risks could, in principle, be examined and minimised through thorough simulations (as mentioned earlier for OMPs and MSEs) if such capacity is available. The risk could also be reduced by monitoring and interpreting a much larger suite of indicators than a single predictive HCR (Trenkel, 2007). A significant safeguard is in the adaptive process of elaboration, validation and testing of the control rules in a highly participative environment. The issue underlines the dangers behind the convenience of reducing a complex fishery system to a very small number of parameters.

The function of reporting and communication

Indicators should be part of formal monitoring, evaluation and decision-making. The measurements can be elaborated and organised (e.g. in charts, time series or maps) for

[9]Hilborn recommends the use of observed reference values and indicators as much as possible in order to avoid non-transparent modelling effects.

the purpose of reporting and communicating about issues of interest. Indicators should also be an important component of the communication strategy towards the stakeholders involved and the public at large, contributing to transparency and oversight. Such reports should include as a minimum: (1) a description of the system, the framework, methodology, oversight; (2) indicators snapshots and trends with their confidence limits and (3) the interpretation of changes observed, in relation to objectives. Ideally, stakeholders should be involved in the preparation of the report to increase legitimacy and confidence in its objectivity.

The adoption of a common system of indicators can help simplify, formalise and harmonise common factors, for example at national, regional or cross-sectoral level. Well-organised indicators can convey messages and show progress or aggravation, combining many elements in a few measurements. They have the risky function of simplifying complex information in understandable signals. They contribute to transparency, accountability, awareness raising, education and social learning. They are also an effective support for advocacy (from all stakeholders) and, because of this, run the risk of being manipulated. Communicating key indicators before management negotiations helps stakeholders' representations to converge. It facilitates the process of establishing common conventions, priorities, and inventories of variables and decisive factors. Plate 3 is particularly relevant in that respect, showing the very concerning trajectory of a cod stock during the past 40 years.

Particular attention must, therefore, be given to the formulation and dissemination methods, which must be designed so as to effectively share and convey the information and improve understanding and participation.[10] To avoid misinterpretation, indicators need to be accompanied with explanatory keys, for example clarifying the significance of trends. To facilitate interpretation, the same indicator may be expressed in various forms – as a quantitative statistical indicator and a range of colours. It should be noted in that respect that, because scales matter a lot in complex systems like fisheries, indicators developed at one level (e.g. for national-level policy making or accounting) may not be effective in informing or mobilising attention at lower level (e.g. at the community or single fishery level). Scales will need to be adapted to the communication target audience.

12.4.2 The nature of indicators

The terms used to describe indicators relate to a number of criteria:

1. *The system component or property it describes*. For example, a fleet size indicator and a pressure indicator.
2. *The method used to obtain it*. The indicator can be directly observed, measured in the field (e.g. number of vessels, average size at landing) and used with little processing of the primary data (e.g. averaging, smoothing). It can also be calculated from a model (e.g. risk of recruitment failure). Measured indicators carry statistical errors that may be estimated. Modelled indicators are less transparent, and their validity depends on assumptions behind the models used for their generation.
3. *The phenomenon described*. Indicators of level are the simplest ones and reflect the spatial and temporal evolutions of the key variables of the system (e.g. fishing capacity,

[10]For an example, see the future European guideline INSPIRE (Infrastructure for Spatial Information in Europe). http://www.ec-gis.org/inspire/reports/dt/inspire_drafting_teams.pdf

catch, biomass). Indicators of change, also called indicators of direction, represented by relative rates of increase or decrease, by pluses and minuses (+ and −) or by arrows, reflect the dynamics of the system and show whether and how fast the fishery system is moving in the right direction, eventually defined by a reference level or direction.

4. *The nature of the representation*. Indicators can be quantitative or qualitative. Quantitative indicators are observed or calculated numbers and can be used as absolute or relative values. Qualitative indicators are useful for aspects of the system that are not easily quantified or when hard data is lacking. For example, the description of social or institutional variables may rely on qualitative opinion obtained from experts or discussion groups, using a limited number of options such as nil, weak, average, important or very important, implying a value judgement. Indicators can also be simple (consisting of a single element) or composite (consisting of many elements that have been aggregated).
5. *The perspective*. Indicators could be retrospective or predictive, describing past or future states. Retrospective indicators (such as those generated by a cohort analysis) provide information on past states and can be used to estimate, in retrospect, the 'pristine' situation. Predictive indicators may provide expectations when selecting management options. They emerge from scenario analysis and involve statistical forecasting or more complex modelling.
6. *The level of aggregation and integration*. The potentially long lists of candidate indicators needed, for instance, in a systemic approach to fisheries lead to a need to condense the information losing as little meaning as possible, for example:

   (a) aggregating available indicators within coherent dimensions of the system (e.g. resource, environment, economic, social) using appropriate weighting factors and rescaling. The ESD component tree and its weighting factors described in Section 12.3 is indeed designed to facilitate aggregation, for instance, at the level of total impact on the ecosystem. Life cycle analysis (LCA) (Kautsky 1997; Papatryphon et al., 2004) is also increasingly used for this purpose. Technical issues when aggregating variables include (i) the disappearance of the variations in single indicators by being compounded with those of the aggregate, complicating interpretation; (ii) the heterogeneity of the variables that are aggregated (e.g. monetary and physical variables) for which a common 'currency' might not be available; (iii) the validity of the explicit or implicit assumptions behind the aggregation decisions; (iv) the decision about weighting factors which, in most cases, is more political than scientific and better left to highly participative processes involving all concerned.
   (b) elaborating synthetic indicators. It is often assumed, for instance, that the MEY corresponds to the best aggregated return to society in the long term. Within that paradigm, only one dimension would need to be covered (economics) and one indicator (economic yield). Data needed would refer to catches, dockside prices and operating costs. The Human Development Index (HDI) introduced by the United Nations Development Programme (UNDP) in 1990 is another example integrating information on *per capita* GDP, adult literacy and life expectancy, to give an indication of living standards. Ecological economics is emerging as a transdiscipline, combining conventional economic concerns with natural resources valuation, bridging short- and long-term incentives and providing the necessary linkages between environmental and economic indicators. The System of Integrated Environmental and Economics Accounting (SEEA) has been developed for this purpose (UNEC *et al*., 2003).

Indicators may also be simply co-represented. Plate 5 conveys a synthetic message while not losing any of the detailed information. Koeller (2007) gives examples of application of this and more complex types of fuzzy logic representation for fishery ecosystems.

12.4.3 The quality of indicators

The realism of the representation of any fishery system with a set of indicators depends, *inter alia*, on the details retained and hence on the number of indicators used (comprehensiveness). It will also depend on the frequency of updating compared to the rate of change in nature (currency). Operational indicators (used for short-term management) need more frequent updating than strategic ones (used for policy setting and longer-term management decisions). It is not less important to realise also that the effectiveness of the system as a planning and management performance tool will require simultaneous consideration of indicators of state and indicators of change, and of operational and strategic indicators.

For reasonably realistic representations of the fishery system, the number of relevant indicators could loom large. Resources being limited, parsimonious selection will be necessary and quality will be an important criterion. Based on the guidelines elaborated by FAO (1999) and other literature, quality indicators will be expected to be[11]:

- relevant, referring to priority issues and objectives at the desired scale;
- consensual (i.e. developed with and accepted by stakeholders);
- current (i.e. updated as often as required by variability and change);
- timely, available when needed for decision;
- representative, reflecting accurately changes in the criteria;
- responsive, responding rapidly to stimuli[12];
- accurate and based on verifiable science;
- tested through experience or simulations;
- precise, with a low uncertainty (high signal/noise ratio);
- robust, forgiving in case of reasonable levels of error;
- stable, maintaining the same relation with the criteria over time;
- affordable, based on data available or easy to obtain;
- practical, functional (i.e. easy to compile and use; adapted to needs);
- cost effective relative to the value of the fishery;
- optimised, (i.e. making maximum use of the information available);
- flexible, able to handle different levels of complexity and scales;
- easy to integrate and aggregate with other indicators;
- communicable, easy to understand by all stakeholders;
- commented (i.e. accompanied by expert analyses and commentaries);
- institutional, integral part of decision-making processes;

[11] Depending on the use of the indicator, one or several of the properties listed may be more important than others.

[12] The response time of the system to environmental stimuli (e.g. climate variability or change, pollution) or human-induced ones (e.g. management measures, market oscillations) is important. Bio-ecological and social response times are probably very different, complicating the understanding of causality. The amount of inertia but also the capacity for unexpected and fast reactions should not be underestimated.

- formal, with a strong legal foundation (e.g. part of a convention);
- documented (i.e. accompanied by a 'pedigree' stating the origin of the data, methodology, legal foundation).

This list is probably not complete, but it is in line with the Principles of Sustainable Development Performance Measurements established by the Bellagio Conference (Bellagio, Italy, 1996) (Garcia and Staples, 2000).

12.4.4 Scaling indicators and value judgements

In order to be jointly represented on a single system, or aggregated, quantitative indicators need to be standardised on the same scale. The appropriate time and space scales depend on the scope, resolution and purpose of the system. Scaling is often done by dividing the indicator value by a reference value, for example, obtaining values ranging from 0 to 1 (Plate 6). In addition, in order to be effectively used for decision and communication, indicators need to be explicit in terms of the interpretation (value judgement) to be made, as well as about the action expected, for each level of the indicator range. For example:

- 0.00–0.19 = bad/unacceptable: calling for immediate and drastic action, preferably agreed beforehand, for example a moratorium.
- 0.20–0.39 = poor: calling for corrective action to be taken soonest: for example, implement the contingency plan.
- 0.40–0.69 = Average: suboptimal. Calling for attention, for example, in case of bad environmental conditions: Check the contingency plan.
- 0.70–0.89 = good: optimal. Apply optimal harvest rules.
- 0.90–1.00 = excellent: relax any constraint, for example, aim at higher harvest values in the agreeable range.

The value judgements might be underlined by the usual 'traffic light' colours. When qualitative indicators (e.g. poor, good, excellent) are used, the scale of the indicator and the value judgement are intrinsically combined.

12.4.5 Testing and evaluation of indicators

Evaluations of the system of indicators are needed in relation to three issues: (1) the feasibility of building and maintaining the system; (2) the ability of the selected indicators to fulfil their role and (3) the capacity of the management framework to integrate the system in the governance process. An ex-ante evaluation, using complex modelling and/or intense consultation, would improve the probability of success from the onset. Pilot testing in the field, on a smaller scale, is recommended even though scaling up the system to cover larger realities is always problematic. Once adopted and routinely used, the system of indicators should be submitted to external evaluation every few years. The process of ex-post evaluation can be more or less formal and may lead to application for a label (e.g. ISO 9000, 14000 or labelling from an eco-labelling scheme such as the Marine Stewardship Council). The evaluation should cover all the steps mentioned earlier and assess the degree of acceptance by

stakeholders and the public. The procedures and criteria for testing the system of indicators are described in much more detail in the FAO Guidelines (FAO, 1999).

12.4.6 Success factors for systems of indicators

Systems of indicators are costly to put in place and to maintain. It is therefore important to ensure from the onset that they meet the criteria for success. In a decision-support perspective, a successful indicator (and *a fortiori* a system of indicators) is one that is effectively used for making decisions, which evolves and is recurrently re-assessed. The risks exist for an indicator to end up in the 'cemetery' of indicators where born-dead candidates and 'white elephants' lie. There is also a risk of a highly regarded indicator becoming 'totemised' or enshrined to the point that it cannot evolve further as the situation would require.

Experience has shown that the development process can only be successfully implemented and durable if it is recognised by the stakeholders as a fair representation of the system within which they operate and on the basis of which, therefore, decisions can be made (system legitimacy). This requires consensus, scientific and procedural rigour and reliable data.

1. *Consensus*. This is needed to ensure that the system reflects a common understanding and vision. As a consequence, systems of indicators should rather be co-developed by stakeholders (managers, fishworkers, scientists and other users when relevant) in order to reach a strong consensus regarding the overriding policy principles, the central issues, the important components of the system and their interrelations, the agreed objectives and constraints, the criteria, references and indicators. This implies establishing the institutions needed for negotiation, conflict-resolution, mediation and communication.
2. *Scientific and procedural rigour*. Scientific rigour is important not only because the LOSC and FAO Code of Conduct requires that decisions use the best scientific information available but also because rigorous analytical approaches will be a guarantee of objectivity in front of vested interests. Indicators will therefore be elaborated using tested methodology and best information available, including relevant traditional knowledge. Scientific rigour does not eliminate the risk of errors though. As a consequence, reference values and control rules will need to take uncertainty into account and be precautionary. Particularly, but not only, in data-limited situations, the use of a system of indicators should be looking for correct directions more than accurate predictions and rely on adaptive processes to improve the system performance.
3. *Durable sources of reliable data*. While indicators may be developed with *ad hoc* information for an isolated exercise, maintaining a system of indicators as an institution improving with time through adaptive processes and better data, it is essential to have access to durable (budgeted) sources of reliable data. A parsimonious use of indicators will be imposed by limited budgets.[13] Cooperation between ministries and with the industry and fishworkers will allow convenient pooling of data sources at shared costs. Reliability is particularly crucial for a decision support system and should be improved through active participation of stakeholders to the system.

[13]It has also been suggested that a formal SDRS should not contain more than three to seven indicators (Boulanger, 2007; Rey-Valette *et al*., 2007) and that the communication strategy could emphasise the limited official set while making the more detailed sets available to interested users (e.g. on Internet).

12.4.7 Systems of representation

In order to be used and communicated, indicators need to be presented in a meaningful manner and the whole range of graphical representations is potentially available. Although some proposals were made to graphically represent changes and uncertainty (Garcia, 1997), most representations have remained static. Static and deterministic abstractions such as statistical pies and bar charts are easier to produce. In the same category of representations, multivariate graphs such as kite or star diagrams give a synoptic view of the system across dimensions. The sustainability barometer of Prescott-Allen (1996) (Plate 2) is an interesting qualitative representation using value judgements and colours to qualify sustainability in reference to both human and environmental well-being. The precautionary plot (Plate 3) used by ICES provides a convenient way to represent the current state of a stock as well as its trajectory. The same system of representation with the same reference values was used by Garcia and De Leiva (2005) to summarise the situation and trend of the major North Atlantic resources on one single graph. Kite diagrams (also referred to as amoeba diagrams) using the same colour coding have been used (Garcia, 1994, 1996; Pitcher, 1999) to compare fisheries (Plate 7) or to illustrate historical trajectories. Vectors have also been used to portray the outcome of a RAPFISH analysis (Pitcher, 1999; Pitcher and Preikshot, 2001; Figure 12.4).

Mapping of indicators allows for a more strategic analysis when space is a relevant dimension (e.g. in ecosystems), and GIS tools can be very useful in producing overlays. Time sequences of maps can powerfully convey some of the time dynamics in the system.

12.5 Main issues and challenges

Developing and running a system of indicators as an integral part of a management system leads to meeting and having to resolve a number of issues. We will only look at some of them in the following sections.

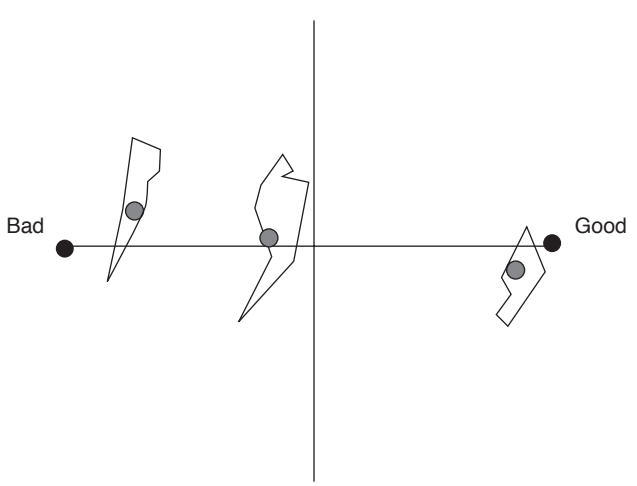


Figure 12.4 RAPFISH plot. Relative position of three Canadian fisheries kites on the ethical axis ranging from bad to good. Each polygon is constituted by the position of nine ethical attributes. The grey dots show the result of the aggregation into one single value (Pitcher, 1999).

12.5.1 The need for standards

Standards adopted at national or international level can ensure quality and facilitate comparisons between areas or fisheries. The standard may be established by a law.[14] At regional level, references points such as $F_{0.1}$ or $F_{2/3\ MSY}$ have been abundantly used in the past, reaching a status of quasi standards, for example in ICES, NAFO and NEAFC. The scope for standardisation is limited, however, by the highly specific nature of the different fishery systems and communities. Standards for social indicators pose particular problems in that respect, directly related to the non-continuous and hierarchical nature of social organisation and to the impact of cultural factors. The HDI of UNDP is an exception, however, which allows an effective and comparative measurement of human capital characteristics. The same is true for the UNDP governance indicators (2002) largely based on qualitative expert evaluation. Many existing international indices or surveys offer references concerning socio-political indicators (Lemel, 1997; Rey-Valette and Cunningham, 2003), but they do not allow any detailed analysis of results by area or by sector and cannot be used to address fisher community characteristics.

12.5.2 Simplification and realism

Systems of indicators are often proposed as elements of decision-making as replacements for complex models, which are difficult to specify and parameterise and allegedly harder to understand by stakeholders. One of the central challenges, however, is to capture the high complexity and dynamics of the real system through a rather static system of representation with few variables. The consequences of the tension between the complexity and simplification, and related loss of information, have been addressed by Garcia and Charles (2007). Hilborn (2002) has argued against using model-based indicators and reference values because of the loss of transparency for the stakeholders. In practice, it is advisable to combine the use of complex models (possibly developed with stakeholders) with a large suite of indicators (Rochet *et al.*, 2007) and use them within adaptive participatory processes. Koeller (2007) reminds us that, in any case, the more complex representations needed for EAF cannot be assumed to have the predictive capacity expected of the simple control rules used for single stocks.

12.5.3 Participation

As hinted earlier, the process of development of a system of indicators should be participative to ensure relevance and legitimacy, drawing on a large range of stakeholders (see Chapters 3 and 11 for important developments on this issue). The process requires (i) a formal need on the part of the authority (e.g. represented by the fisheries department, a decentralised office or a community in the case of devolution (ii) an administration to support the data management and the assessment process with its participatory groups; (iii) a feasibility study (ex-ante evaluation); (iv) a definition of respective roles of stakeholders in the development and implementation processes and (v) an agreed process with core resources, including a testing phase and an ex-post external evaluation.

[14]For example, the use of MSY is established by the LOSC. A standard definition of overfishing as a reference and the mandatory course of action to be taken when overfishing is detected are introduced in US fishery law.

12.5.4 Institutionalisation of indicators

Indicators can obviously be used in fisheries management on an occasional basis (e.g. in a crisis-solving environment). However, when formally adopted by policy makers and implemented by managers, the indicator system must be placed under the responsibility of a formally mandated institution. Ideally, the formalities should be completed before developing the system and should help mobilise resources. The system requires formal support (e.g. in the form of a requirement in national fishery law), a budget, the constitution of an audience, vigilant consumers of the indicators' products, including obviously the fisheries administration itself, but also, necessarily, the main stakeholders. The indicator framework should become an integral part of the fishery information and statistics system of the management authority. Capacity building is usually needed (see later).

Like all human institutions, indicators may follow cycles of formulation, development, success and demise (Boulanger, 2006). During the period of intensive routine use, the indicator gets better known. The price of that fame might be overuse and trivialisation. The context evolves and if the indicator does not adapt to needs (e.g. because it has been 'totemised'), the indicator may face a crisis during which it is reviewed and possibly reformulated. Failing to satisfy its clients, the indicator would fall into disuse or be formally abandoned and replaced.

12.5.5 Capacity building

The process of adoption, construction and maintenance of an operational system of indicators is a significant burden that needs to be integrated into the whole management planning process. Capacity building (including in research) will be essential, both in developed and developing countries. It may involve increasing the resources of the statistical division and strengthening the connection with scientists doing the assessments. Training of staff in advanced statistics, computer modelling, information technology (for Internet publication) and communication (as the interface with the media and the public) may be needed. It will also require improvement of databases and the inter-connection of sources of knowledge. This may sound scary, but needs can be tailored to means available through priority ranking and focus as well as through close partnership with stakeholders, whose capacity to participate will also need to be enhanced, together with indicator-specific awareness raising and education about indicators and sustainability.

12.5.6 Information gaps and uncertainty

Available data systems have usually not been established to assess sustainability. In addition, the availability of long-term data varies with the bigger gaps in the social and environmental dimensions of the system. While proxies may be used in some cases, there is a risk of focusing mostly on dimensions for which data are available (the street light syndrome). Indicators' systems have often been compared to pilot[15] dashboards. In a fishery system, where visibility is poor, variability is high, instruments numerous and confusing, and many inexperienced pilots are attempting to drive together while learning by trial and error, imprecise or inaccurate indicators and erroneous reference values will be dangerous indeed. Important

[15]The problem with the dashboard metaphor and the issue in general are discussed in Levrel (2007).

phenomena might remain undetected – detections may lead to false alarms. A harmless artefact might be taken as a danger and costly but useless or counter-active action taken (Type 1 error). On the contrary, a harmful phenomenon might not be detected in time leading to high costs (Type 2 error). System development and maintenance should follow a precautionary approach.

12.5.7 Inter-sectoral systems of indicators

Fisheries operate in a multi-sectoral environment with strong interactions within watersheds or in the coastal zone. A recurrent problem is that the various sectoral policies, even when based on the same principles of sustainable development, are rarely coordinated, and never integrated, creating more conflict than synergy. As a consequence, integrated management and ecosystem-based management have been prescribed for decades with limited success. The FAO Code of Conduct addresses the integration of fisheries in the coastal zones in Article 10 and the issue is particularly relevant for small-scale fishing communities, the livelihood of which rests on multiple activities beyond fisheries. Despite significant political activity and scientific involvement at regional and international level, progress has been limited.

The development of integrated sets of indicators for the coastal areas might help, following at inter-sectoral level the process outlined in Section 12.3.3, at a significantly higher level of challenge. The initiative may come from the government ministries in charge of the environment and finance, the two major drivers of fisheries.

The implementation of integrated management approaches has generated abundant research on the development of coastal and marine indicators, based on input from the construction of more general sustainable development indicators. For example, the European DEDUCE programme for sustainable development of European coasts (www.deduce.eu) led to a list of 27 variables and 45 key indicators built within a common methodological framework structured around seven main stakes: control of development; protection of biological and cultural diversity; support to coastal economy; management of beaches; reducing exclusion and promotion of social cohesion; sustainable use of natural resources and protection against risk related to climate change (see Annex 2). The methodological framework aims at the evaluation of coastal and marine zone management, constitutes a research coordination framework, improves access to information and transparency, and supports diffusion and sharing of information according to international standards of referencing and interoperability.

12.5.8 EAF and indicators

An immediate consequence of the adoption of the EAF is the need for more complex mental, mathematical or graphical representations, including more comprehensive systems of indicators. As an extension of the conventional approach, the EAF requires an extension of the conventional fishery system representation to explicitly include more compartments (e.g. habitats, environment, biodiversity, people), more interactions (predator/prey; climate/resources, between sectors). New indicators are needed regarding emerging or reinforcing environmental issues such as bycatch, discards, ecosystem composition (trophic structure), habitat,

vulnerable habitats and endangered species, and the impact of other activities including climate change. Biodiversity indicators are *a priori* required at the species, community, ecosystem and genetic level, but the formal use of long lists of indicators proposed by academia for operational decision-making and control is not always clear. The necessity to integrate ecosystem and biodiversity indicators within the sectoral indicators framework was stressed in the FAO Guidelines on indicators for sustainable development of marine capture fisheries (FAO, 1999), on the PAF (FAO, 1996c) and on the EAF (FAO, 2003). Resources being generally limited, however, efforts are being made to develop reliable but parsimonious approaches to decision-support systems for EAF, including systems of indicators (Daan, 2004).

A central implication of the broadened representation required by EAF is the complication of the functions of indicators systems, particularly those of audit and control (Trenkel *et al.*, 2007). It has been shown that no single synthetic or aggregated indicator can provide a reasonable picture of an ecosystem (Fulton, *et al.,* 2003). The solution is rather in developing a suite of indicators for the key attributes and processes of the ecosystem (including the human sub-system) using different kinds of data, qualitative and quantitative, provided by science and stakeholders. The challenge is, as usual, in the tension between comprehensiveness of the system of indicators and its cost. Based on simulations, however, Fulton and colleagues suggest that the most effective indicators of ecosystem performance are those aggregated at the community level, between the stock and the ecosystem levels. These indicators appear sufficiently robust, with reduced short-term variability, and respond fast enough for an effective use in operational management. So far, however, it has been difficult to identify reference levels for any ecosystem indicator. Finally, assuming that a useful integration of space and time trends is achieved, the main issue will remain that of testing adaptive management frameworks and ecosystem-level decision rules in the field.

The Index of Biological Integrity (IBI) has been widely used in the United States as a tool for water management. It combines indicators on fish assemblages in rivers and lakes, related to species richness and composition, trophic chain composition, fish abundance and condition. It is used to classify the condition of water bodies on a scale going from excellent to very poor (Karr and Chu, 2000).

Among the very large shopping list of candidate indicators for EAF, the one reflecting the average TL in catches (Pauly and Palomares, 2005) is the only ecosystem indicator that has received global attention and is globally applicable, using FAO catch statistics time series covering more than 50 years. These indicators, for which, to our knowledge, no general reference value has been proposed, have attracted the attention of the environmentalist community and a formal status with the Convention on Biological Diversity. It has also met with significant resistance from the fishery science community because (a) it describes changes in the catch and not the ecosystem and (b) its changes may reflect fishing impacts on the ecosystem, changes in fishing strategies or natural climatic oscillations, complicating the interpretation of its behaviour (Essington, *et al.,* 2006). This indicator should therefore be interpreted as part of a suite of indicators regarding the fishery and the environment which might help understanding its meaning.

Several indicators are used to characterise the status of coral reef ecosystems, including percentage of live coral, abundance and diversity of coral and reef species, fishery catch, presence of other stressors. Wilkinson (1999) and Ablan *et al.*, (2004) have also established indicators as a means to assess the state of coral reefs and effectiveness of marine protected areas (MPAs) in these ecosystems. The level of fishing is indicated by (i) the catch of indicator species of high versus low market value; (ii) the fish size in catches; (iii) the presence and size of haloes, habitats areas cleared from any vegetation by herbivorous fish and invertebrates,

signalling the depletion of piscivorous predators and (iv) the types of algal settling on corals, with filamentous algae indicating the depletion of even the herbivorous fish prey species. Combined with decision rules, these indicators, as well as other indicators of pollution and genetic connectivity between reefs, were used to define levels of risk for the reefs.

Under EAF, at least as prescribed in FAO, human well-being indicators are also needed regarding, for example, poverty, food security, social justice and democratic institutions. The scarcity of the related information is a major issue.

The management of fisheries as a component of Integrated Coastal Area Management (ICAM) is progressively gaining attention. FAO Guidelines have been published (FAO, 1996b) albeit with little echo and application as of today. It can be considered, however, as a special case of EAF in which fisheries are managed within a policy and operational cross-sectoral framework (see, for example, Linton and Warner, 2003).

The viability approach to fisheries (Cury *et al*., 2005) is also an integrated approach to decision-making that fits well into the EAF, but which is still of limited application because of the computing capacity needed and the limited amount of components the approach can presently deal with (see Cury *et al*., 2005; Eisenack *et al*., 2005, for examples). The approach recognises: (a) the systemic nature of fisheries; (b) the fact that stakeholder groups tend to agree more easily on undesirable states of the system (limit reference value) than on long-term objectives (target reference value); (c) the necessarily fuzzy nature of both limits and targets and (d) the poor predictability of exploited ecosystems. In contrast with management aiming at dubiously precise targets, the viability approach proposes to aim at a family of trajectories that maintain the key indicators of the fishery within the 'viability envelope' represented by a set of limits references corresponding to undesirable states of the fishery or sector.

12.5.9 Tensions and trade-offs

Tensions emerge in the development of indicators systems that imply trade-offs and call for strategic solutions (Levrel, 2007). The tensions are between:

1. *The possible levels of implementation of the system*. Fisheries' realities are different at the local, national or regional levels; when addressing the short or the long term; for individuals or for communities; for scientists, managers, fishers or citizens. Indicators useful at local or fishery level for everyday fishing activities appear irrelevant and unrealistic if applied at national or higher level, and vice versa. The solution is to develop a nested system of indicators with a few generic ones at the top and a larger number of more specific ones at the bottom. The ESD component tree is useful in this respect as, in theory, it can span many levels and its components can be aggregated at any level.
2. *The scientific and political dimensions of indicators*. From a political angle, indicators need to be simple and understandable by the ordinary citizen. For the manager, they must be understandable by the sector. For the scientist, the indicator must be an element of evidence (including sometimes in court) accurately reflecting the facts and the available understanding. There is a tension, however, between the requirements of scientific rigour, political relevance and communication simplicity. The solution is to have a battery of indicators of scientific standard and a smaller suite of indicators, derived from the scientific set, meeting political requirements.

3. *The objective and subjective nature of the indicators*. Whether they reflect a convention or a reality, indicators can only be incomplete and partial approximations (as our representation of Nature will always be). Co-constructed by the stakeholders they are quantitative and qualitative hybrids, combining facts and value judgements, and for that reason are both necessary and criticised.

These tensions result from the 'gravitational forces' exerted on the indicator interface that bridges science, policy and society. As imperfect as they may be, indicators allow different communities of knowledge, with different interests, cultures and capabilities to communicate, including through argumentation, progressively developing a new language, for a common vision of the sector.

12.6 Synthesis

The systems of indicators prescribed by UNCED and the CSD as a means to monitor sustainability and guide decision-making have been used in fisheries for more than 50 years in the form of analytical (yield-per-recruit) or synthetic (surplus production) models. During the last decade, and following the UNCED and CSD prescriptions, additional and complementary efforts have been made, particularly in relation to the precautionary and ecosystem approaches to fisheries. While their use is still far from being generalised or perfect, it has spread in the developed world and some parts of the developing one. Through these efforts, indicators and reference values have been used to describe the evolution of the fishery system, communication with the public and stakeholders, control of fishing operations and conceptual representation of the fishery system.

This development is not without problems and numerous issues have been raised. It is important to accept the fact that an indicator reference system is a means to be integrated in the fishery management process, providing information to it, but also drawing information from it. It cannot be an end in itself and its adequacy, with regard to the questions to be resolved by management, must be constantly questioned and tested. Constructing and maintaining a system of indicators should be seen as an integral part of the fishery management system with its data collection, monitoring, assessment and implementation components. The success of indicator systems rests in their conception, development and implementation in an active partnership with stakeholders.

The co-development of systems of indicators reveals the existence of numerous 'visions' and understandings of the fisheries' world. As a result, tensions emerge; 'gravitational forces' generated by the forced proximity of different stakeholder visions within the indicator interface that bridges science, policy and society. Co-developed indicators are a key instrument for communication between different communities of knowledge and for effective co-management based on a common vision.

Sources and recommended reading

Ablan, M.C.A., McManus, J. and Viswanathan, K. 2004. Indicators for management of coral reefs and their application to marine protected areas. *Naga, WorldFish Center Quarterly*, 27(1–2): 31–39.

Arias, E.G. and Fischer, G. 2000. Boundary objects: Their role in articulating the task at hand and making information relevant to it. *International ICSP Symposium on Interactive and Collaborative Computing, December 2000*. ICSC, Australia, Intelligent Systems and Applications. 1–8. Online http://www.cs.colorado.edu/~gerhard/papers/icsc2000.pdf

Bodiguel, C., Rey-Valette, H. and Cunningham, S. 2006. *Utility and uses of socio-economic indicators on the environmental impact of fishing activities case study of the French Mediterranean trawler fleet*. Project deliverable 14a, INDECO, EU project, No.513 – 754, 46p.

Bossel, H. 1999. Indicators for sustainable development: Theory, method, application. A report of the Balaton Group. IISD, Winnipeg, Canada. 124p.

Boulanger, P.M. 2006. La décision politique: Calcul rationnel ou processus discursif: Quels rôles pour les indicateurs? *Communication au Colloque International Usages des Indicateurs de Développement Durable,* 3–4 avril 2006. Cirad, Montpellier.

Boulanger, P.M. 2007. Political uses of social indicators: Overview and application to sustainable development indicators. *International Journal of Sustainable Development,* 10: 1–2.

Butterworth, D.S. and Punt, A.E. 2003. The role of harvest control laws, risk and uncertainty and the precautionary approach in ecosystem-based management. In: *Responsible Fisheries and the Marine Ecosystem*. Sinclair, M. and Valdimarsson, G. (eds). pp. 311–319. CAB International, Wallingford, U.K., FAO, Rome, Italy.

Butterworth, D.S., Cochrane, K.L. and De Oliveira, J.A.A. 1997. Management procedures: a better way to manage fisheries? The South African experience. In: *Global Trends: Fisheries Management*. Pickitch, E.K., Huppert, D.D. and Sissenwine, M.P. (eds). pp. 83–90. American Fisheries Society Symposium, 20, Bethesda, Maryland, U.S.A.

Caddy, J. and Mahon, R. 1995. Reference Points for Fisheries Management. FAO Fisheries Technical Paper No. 347. Rome, FAO. 83p.

Charles, A.T. 1995. *Sustainability Indicators: An Annotated Bibliography, with Emphasis on Fishery Systems, Coastal Zones and Watersheds*. Strategy for International Fisheries Research (SIFR), Ottawa, Canada.

Chesson, J. and Clayton, H. 1998. *A Framework for Assessing Fisheries with Respect to Ecologically Sustainable Development*. Bureau of Rural Sciences, Canberra, Australia.

Cury, P.M., Mullon, C. and Garcia, S.M. 2005. Viability theory for an ecosystem approach to fisheries. *ICES Journal of Marine Science*, 62: 577–584.

Daan, N., Christensen, V. and Cury, P. (eds). 2004. Quantitative ecosystem indicators for fisheries management. *ICES Journal of Marine Science*, 62(3): 316–614.

Duda, A. 2002. *Monitoring and Evaluation Indicators for GEF International Waters Projects*. 11p. GEF Corporate Monitoring and Evaluation Team, Washington, U.S.A.

Eisenack, K., Scheffran, J. and Kropp, J.P. 2005. Viability analysis of management framework for fisheries. *Environment Modelling and Assessment* (doi: 10.1007/s10666-005-9018-2).

Essington, T.E., Beaudreau, A.H. and Wiedenmann, J. 2006. Fishing through marine food webs. *Proceedings of the National Academy of Science of the United States of America (PNAS)*, 103(9): 3171–3175.

FAO. 1996a. Precautionary approach to fisheries. Part 2. Scientific papers. Prepared for the Technical Consultation on the Precautionary Approach to Capture Fisheries, Lysekil, Sweden, 6–13 June 1995. FAO Fisheries Technical Paper No. 350.2. Rome, FAO. 210p.

FAO. 1996b. Integration of fisheries into coastal areas management. FAO Technical Guidelines for Responsible Fisheries No. 3. Rome, FAO. 17p.

FAO. 1996c. Precautionary approach to capture fisheries and species introductions. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome, FAO. 54p. The guidelines are also available at http://www.fao.org/docrep/003/w3592e/w3592e00.pdf

FAO. 1999. Indicators for sustainable development of marine capture fisheries. FAO Technical Guidelines for Responsible Fisheries No. 8. Rome, FAO. 68p. The guidelines are available at ftp://ftp.fao.org/docrep/fao/004/x3307e/x3307e00.pdf

FAO. 2003. Fisheries management. 2. The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome, FAO. 112p. The guidelines are available at ftp://ftp.fao.org/docrep/fao/003/W3593e/W3593e00.pdf

FAO. 2007. The sate of world fisheries and aquaculture. Rome, FAO. 162p. (+ CD-Rom).

Fletcher, R., Chesson, J., Fisher, M., Sainsbury, K., Hundloe, T., Smith. T. and Whitworth, B. 2002. *National ESD Reporting Framework for Australian Fisheries: The 'How to' Guide for Wild Capture Fisheries*. 120p. Fisheries Research and Development Corporation, Canberra, Australia. FRDC Project 2000/145.

Fulton, E.A., Smith, A.D.M. and Punt, A.E. 2005. Which ecological indicators can robustly detect effects on fishing? *ICES Journal of Marine Science*, 62: 540–551.

Garcia, S.M. 1994. The precautionary principle: Its implications in capture fisheries management. *Ocean and Coastal Management*, 22: 99–125.

Garcia, S.M. 1995. Stock-recruitment relationships and the precautionary approach to management of tropical shrimp fisheries. *Marine and Freshwater Research*, 47: 43–58.

Garcia, S.M. 1996. The precautionary approach to fisheries and its implications for fishery research, technology, and management: An updated review. FAO Fisheries Technical Paper No. 350.2. Rome, FAO. pp. 1–75.

Garcia, S.M. 1997. Indicators for sustainable development of fisheries. Proceedings of the Workshop on Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development, 25–26 January 1996. FAO, Rome. FAO. *Land and Water Bulletin*, 5: 131–162.

Garcia, S.M. and De Leiva Moreno, I. 2005. Evolution of the state of fish stocks in the Northeast Atlantic within a precautionary framework, 1970–2003: A synoptic evaluation. *ICES Journal of Marine Science*, 62(8): 1603–1608.

Garcia, S.M. and Charles, A.T. 2007. Fishery Systems and linkages: From Clockwork to softwatches. *ICES Journal of Marine Science,* 64 (4): 580–587.

Garcia, S.M. and Staples, D. 2000. Sustainability reference systems and indicators for responsible marine capture fisheries: A review of concepts and elements for a set of guidelines. In: Sustainability indicators in marine capture fisheries. Special Issue. *Marine Fisheries Research*, 51: 385–426.

Gates, J.M. 1989. Les modèles bio-économiques. In: *l'Homme et les Ressources Halieutiques, essai sur l'usage d'une ressources commune renouvelable*. Troadec J.P. (Sci. ed.). pp. 463–495. IFREMER, Paris.

Hilborn, R. 2002. The dark side of reference points. *Bulleting of Marine Science*, 70(2): 403–408.

Karr, J.R. and Chu, E.W. 2000. Sustaining living rivers. *Hydrobiologia*, 422/423: 1–14.

Kautsky, N., Berg, H., Folke, C., Larsson, J. and Troell M. 1997. Ecological footprint concept for assessment of resource use and development limitations in shrimp and tilapia aquaculture. *Aquaculture Research*, 28: 753–766.

Koeller, P. 2008. Ecosystem-based psychology, or, how I learned to stop worrying and love the data. *Fisheries Research*, 90: 1–5.

Lemel, Y. 1997. Le repérage des positions sociales dans les travaux comparatifs internationaux. In: *Les Indicateurs Sociopolitiques Aujourd'hui*. Dupoirier, E. and Parodi, J.L. (eds). pp. 69–95. L'Harmattan, Paris.

Levrel, H. 2007. *Quels Indicateurs Pour la Gestion de la Biodiversité*? 96p. Institut Français de la Biodiversité, Paris.

Linton, D.M. and Warner, G.F. 2003. Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. *Oceans and Coastal Management*, 46(3–4): 261–276.

Maguire, J J., Sissenwine, M., Csirke, J. Grainger, R. and Garcia, S.M. 2006. The state of world highly migratory, straddling and other high seas fishery resources and associated species. FAO Fisheries Technical Paper No. 495. Rome, FAO. 84p.

Marine and Freshwater Research. 2000. Special issue: Sustainability indicators in marine capture fisheries. CSIRO Publications, Collingwood, Australia. *Marine and Freshwater Research*, 51(5): 381–541 (Special issue).

Mohn, R. and Chouinard, G. 2007. Harvest control rules for stocks displaying dynamic production regimes. *ICES Journal of Marine Science*, 64(4): 693–697.

Moldan, B., Billharz, S. and Matravers, R. (eds). 1997. *Sustainability Indicators: A Report on the Project on Indicators of Sustainable Development*. 58p. Scientific Committee on Problems of the Environment (SCOPE), U. K.

OCDE. 2003. *Coût de Gestion des Pêcheries*. 184p. OECD ED, Paris.

Papatryphon, E., Petit, J., Kaushik, S.J. and van Der Werf, H.M.G. 2004. Environmental impact assessment of salmonid feeds using life cycle assessment (LCA). *Ambio*, 33(6): 316–323.

Pauly, D. and Palomares, M.L. 2005. Fishing down marine food web: it is far more pervasive than we thought. *Bulletin of Marine Science*, 76(2): 197–211.

Pitcher, T. and Preikshot, D. 2001. RAPFISH: A rapid appraisal technical to evaluate the sustainability status of fisheries. *Fisheries Research*, 49: 255–270.

Pitcher, T.J. 1999. *RAPFISH, a rapid appraisal technique for fisheries and its application to the code of conduct for responsible fisheries*. FAO Fisheries Circular No. 947. FAO, Rome, Italy. 47p.

Prescott-Allen, R. 1996. *Barometer of Sustainability. What It's Used for and How to Use it?* 25p. The World Conservation Union (IUCN), Gland, Switzerland.

Prescott-Allen, R. 2001. *The Well-being of Nations. A Country-by-country Index of Quality of Life and the Environment*. 342p. Island Press, Covello, Canada.

Rey-Valette, H. and Cunningham, S. 2003. Evaluation of the social impact of fishery management measures. *Communication presented to the European Seminar on: The introduction of right-based management in fisheries*. Brussels, 3–4 April. 25p.

Rey-Valette, H., Bodiguel, C. Cunningham, S., Degnbol, P., Hegland, T.J. and Sverdrup-Jensen, S. 2005. Review of the usage of socio-economic indicators on the environmental impact of fishing activities. INDECO – Development of indicators of environmental performance of the common fisheries policy. Project No 51375. 48p.

Rey-Valette, H., Laloë, F., Le Fur, J. and Rousse, I.S. 2006. Usages des indicateurs de développement durable. Entre offre et demande d'indicateurs. *Communication au colloque international GECOREV Gestion concertée des ressources naturelles et de l'environnement. – du local au global: pour un dialogue entre chercheurs, société civile et décideurs. Université Saint Quentin en Yvelines*. 26–28 juin. 15p.

Rey-Valette, H., Laloë, F. and Le Fur, J. 2007. Introduction to the key issue concerning the use of sustainable development indicators. *International Journal of Sustainable Development* 10(1–2): 122–138.

Rochet, M.J., Trenkel, V.M., Forest, A., Lorance, P. and Mesnil, B. 2007. *How Could Indicators Be Used in an Ecosystem Approach to Fisheries Management*. 15p. ICES CM 2007/ R: 05, Copenhagen, Denmark.

Rosenberg, A. 1999. How can managers use precautionary management advice? In: *Proceedings of the Fifth National NMFS Stock Assessment Workshop: Providing Scientific Advice to Implement the Precautionary Approach Under the Magnuson/Stevens Fishery Conservation and Management Act*. U.S. Department. of Commerce. July . Restrepo, V.R. (ed.). 102p. NOAA Technical Memorandum NMFS/F/SPO-40, Silver Spring, Maryland, U.S.A.

Rosenberg, A.A. and Restrepo, V.R. 1996. Precautionary management reference points and management strategies. FAO Fisheries Technical Paper No. 350/2. Rome, FAO. pp. 129–140.

Trenkel, V.M., Rochet, M.J. and Mesnil, B. 2007. From model-based prescriptive advice to indicator-based interactive advice. *ICES Journal of Marine Science*, 64(4): 768–778.

UNEC, IMF, OECD and World Bank. 2003. *Integrated and environmental economic accounting. Final draft circulated prior to official editing*. United Nations European Commission (UNEC); International Monetary Fund (IMF); Organization for Economic Cooperation and Development (OECD); World Bank. Studies in Methods Series F. Handbook on national accounting, 61, Rev. 1 (ST/ESA/STAT/SER.F/61/Rev. 1.)

United Nations. 1993. Reference points for fisheries management: Their potential application to straddling and highly migratory resources. *A Report Presented to the United Nations Conference on straddling fish stocks and highly migratory fish stocks*. New York, 12–30 July. A/CONF/164/INF/9. 35p.

Wilkinson, C.R. 1999. Global and local threats to coral reefs functioning and existence: Review and predictions. *Marine and Freshwater Research*, 50(8): 867–878.

Zenetos, A., Steftaris, N. and Larsen, L.-H. 2002. An indicator-based approach to assessing the environmental performance of European marine fisheries and aquaculture. *Paper presented at Joint Workshop EEA-EC DG Fisheries-DG Environment Tools for measuring (Integrated) fisheries policy aiming at sustainable ecosystem*, Brussels, Belgium, 28–29 October 2002. EEA Technical Report. 87p.

Web resources

International Institute for Sustainable Development (IISD, http://www.iisd.org). See, for instance, Bossel, H. 1999. Indicators for sustainable development. Theory, methods and applications. A report of the Balaton Group. IISD. http://iisd1.iisd.ca/pdf/balatonreport.pdf

Agenda 21, Chapter 40 http://www.un.org/esa/sustdev/documents/agenda21/index.htm

Le Gallic, B. 2002. Fisheries Sustainability Indicators: The OECD experience: Paper presented at the Joint workshop EEA-EC DG Fisheries-DG Environment 'Tools for measuring (integrated) fisheries policy aiming at sustainable ecosystem', October 28–29, Brussels (Belgium). http://www.oecd.org/dataoecd/43/63/2507611.pdf

ANNEX 1

Example of linkages between operational objectives and indicators and data needs (extracted from FAO 2003, Annex 4)

Objective	Example indicator	Data requirements
Control/reduce fishing pressure		
Reduce fishing effort	Fishing effort of different fleets	Vessels, time fished and gear type per fleet
Reduce fleet capacity	Fleet capacity	Vessels registered and gear type per fleet
Rebuild fishery resources (target species)		
Increase/maintain spawning stock biomass of key retained species above a predefined limit	Spawning stock biomass of key retained species (or suitable proxy such as standardised cpue)	Biomass estimates or indicators for major retained species Length and/or age composition of major retained species
Decrease/maintain the level of fishing mortality for key retained species below a predefined limit	Level of fishing mortality for key retained species	Estimates of biomass and catch for key retained species, or other estimates of fishing mortality (F). Trends in fishing effort

(*continued*)

ANNEX 1 (*continued*)

Objective	Example indicator	Data requirements
Other ecological concerns		
Reduce discards to the extent practical	Total amount of discards	Total catches of bycatch species (or species groups/indicator species), per fleet per year
Increase amount of habitat protected by MPAs to predefined level	Amount of habitat protected by MPAs	Area under MPAs by habitats
Economic		
Increase the contribution of fishing to the national economy	Net economic return for fishery	Revenue from fishing per fleet per year. Costs per fishing unit per year
Increase exports	Export value	Destination of landings from each fleet
Social		
Ensure seafood quality meets food safety requirements	Number of food compliance reports	Food safety compliance reports
Increase/maintain employment in the harvesting and processing sector by fleet	Employment in the harvesting sector by fleet	Total number of fishers employed in each fleet. Total number of people employed in fishery-associated activities (e.g. processing)
Maintain or improve lifestyle value	Lifestyle value	Social surveys

ANNEX 2

Indicators and 45 measurements for sustainable development in coastal zones (Source: DEDUCE project: http://www.deduce.eu/results.html)

Goals	Indicators	Measurements
To control further development of the undeveloped coast as appropriate.	1 – Demand for property on the coast 2 – Area of built-up land 3 – Rate of development of undeveloped land 4 – Demand for road travel on the coast 5 – Pressure for coastal and marine recreation 6 – Land taken up by intensive agriculture	1-1 – Size, density and proportion of coastal population 1-2 – Value of residential property 2-1 – % of built-up land by distance from the coastline 3-1 – Area converted from non-developed to developed 4-1 – Volume of traffic on coastal motorways/major roads 5-1 – Nb of berths and moorings for recreational boating 6-1 – Proportion of agricultural land farmed intensively
To protect, enhance and celebrate natural and cultural diversity	7 – Amount of semi-natural habitat 8 – Area of land/sea with statutory protection 9 – Effective management of designated sites 10 – Change in significance of coastal/marine habitats and species	7-1 – Area of semi-natural habitat 8-1 – Area protected for conservation, landscape, heritage 9-1 – Rate of loss of, or damage to, protected areas 10-1 – Status and trend of specified habitats and species 10-2 – Number of species per habitat type 10-3 – Number of Red List coastal area species
To promote and support a dynamic and sustainable coastal economy	11 – Loss of cultural distinctiveness 12 – Patterns of sectoral employment 13 – Volume of port traffic 14 – Intensity of tourism 15 – Sustainable tourism	11-1 – Number and value of sales of local products 12-1 – Full/part time/seasonal employment per sector 12-2 – Value added per sector 13-1 – Nb of incoming and outgoing passengers/port 13-2 – Total volume of goods handled/port 13-3 – Proportion of goods carried by short sea routes 14-1 – Nb of overnight stays in tourist accommodation 14-2 – Occupancy rate of bed places 15-1 – Nb tourist accommodation units with EU Eco-label 15-2 – Ratio of overnight stays to number of residents
To ensure that beaches are clean and that coastal waters are unpolluted	16 – Quality of bathing water 17 – Amount of coastal, estuarine, marine litter 18 – Nutients in coastal waters 19 – Amount of oil pollution	16-1 – % bathing waters compliant with the guide values 17-1 – Volume of litter collected/length of shoreline 18-1 – Riverine/direct inputs of N and P in inshore waters 19-1 – Volume of accidental oil spills 19-2 – Nb observed oil slicks from aerial surveillance

To reduce social exclusion and promote social cohesion in coastal communities	20 – Degree of social cohesion 21 – Relative household prosperity 22 – Second and holiday homes	20-1 – Indices of social exclusion by area 21-1 – Average household income 21-2 – % Population with a higher education qualification 22-1 – Ratio of first to second and holiday homes
To use natural resources wisely	23 – Fish stocks and fish landings 24 – Water consumption	23-1 – State of the main fish stocks by species/sea area 23-2 – Recruitment and spawning stock biomass/species 23-3 – Landings and fish mortality/species 23-4 – Value of landings/port and species 24-1 – Number of days of reduced water supply
To recognise the threat to coastal zones posed by climate change and to ensure appropriate and ecologically responsible coastal protection	25 – Sea level rise and extreme weather conditions 26 – Coastal erosion and accretion 27 – Natural, human and economic assets at risk	25-1 – Number of 'stormy days' 25-2 – Rise in sea level relative to land 26-1 – Length of protected and defended coastline 26-2 – Length of dynamic coastline 26-3 – Area and volume of sand nourishment 27-1 – Number of people living within an 'at risk' zone 27-2 – Area of protected sites within an 'at risk' zone 27-3 – Value of economic assets within an 'at risk' zone

Chapter 13

The Use of Scientific Information

Kevern L. Cochrane

13.1 Why and when are data and information needed in fisheries management?

13.1.1 Costs and benefits of fishing – what are we managing for and what do we need to look out for?

The preceding chapters have clearly demonstrated the dynamic and complex nature of the social–ecological system that makes up a fishery. With all of these complexities and uncertainties put together, the fisheries manager is operating in a difficult and often confusing environment that makes his or her task much more difficult. Drawing an analogy with a pharmaceutical company trying to develop a new drug, the best medication (management measure) to cure an illness (the operational objective) will be determined by undertaking an intensive series of laboratory tests. The results will inform the company as to whether any of the drugs they have been developing will provide a cure and should be commercially produced. Unfortunately, controlled tests of this nature are not possible in fisheries management but livelihoods and incomes still depend on wise decisions, and wise decisions are only possible if the managers have adequate knowledge of the ecosystem and fishery to allow them to understand the current situation and to forecast how the resource and fishery will change in response to management measures. This chapter examines what needs to be considered by the manager in planning and implementing an effective set of management measures, the information needed to guide those decisions and how this information should be used in making the decisions.

The fisheries manager must be working within the framework of the relevant fisheries policy and goals (Steps 1 and 2, Table 13.1). Policy and goals are a part of the strategic planning of the fishery and are usually put in place and modified infrequently, typically being reviewed only every five years or longer (see also Chapter 16). They set the framework for the fishery and should be established with careful consideration of the best available knowledge of the resources and fishery. On a day-to-day basis, the manager is likely to be more involved with the shorter-term, tactical decisions of fisheries management, translating the goals into operational objectives and ensuring that the management measures being used are the best means of achieving those objectives. These are primary tasks of fisheries management. The great challenge is to choose and implement the best management measures to achieve the objectives, despite the fact that there will always be gaps and uncertainties in the knowledge available.

Table 13.1 The steps normally required in determining the appropriate management measures to achieve specified operational objectives.

Step	Scope	Role of scientific information
1. Determine fisheries policy (usually presented in the relevant Fisheries Act).	Applies to whole fisheries sector.	Guided by broad information on types of fisheries, nature of resources and ecological context, social and economic characteristics and importance.
2. Set goals.	Applies to specific fishery (e.g. as defined by target resources).	• Draws on historical performance, including yields, economic performance and social contribution. • Considers existing problems and opportunities. • Constrained by scientifically estimated biological and ecological limits. • May be assisted by formal decision-making techniques.
3. Determine operational objectives and set reference points.	Applies to specific fishery. Social and economic objectives may also differ according to sub-sector in fishery (e.g. large-scale commercial, small-scale commercial, subsistence.).	• Analyses and models used to test, refine and quantify objectives. • Conflicts between different objectives resolved. • Target and/or limit reference points defined. • Requires iterative consultation between decision-makers, stakeholders and scientists. • May be assisted by formal decision-making techniques.
4. Determine set of management measures.	Composed of management measures and decision rules to adjust measures as a function of new information. Some measures may be sub-sector specific (e.g. gear restrictions and fishing areas) while others (e.g. closed seasons and areas) may apply to fishery as a whole.	• Uses analyses, models and stakeholder knowledge to test performance of management measures against operational objectives. • Determines suite of management measures best able to achieve operational objectives. • Considers realities of fishing operations in sub-sectors. • Considers compliance and enforcement. • Requires iterative consultation between decision-makers, stakeholders and scientists.

13.1.2 Identifying conflicting objectives: the need for explicit and transparent consideration of trade-offs

Another factor that makes fisheries management so difficult is the inevitable existence of conflicting objectives (Section 3.5). The most fundamental conflict is between maximising present returns from a fishery and ensuring sustainability. The need to resolve this basic conflict underlies much of the conventional stock assessment used in fisheries management since the middle of the 20th century.

On top of this basic conflict there are usually many others related to the suite of ecological, social, economic and political goals that are found in most fisheries. Box 13.1 lists nine broad objectives that have been identified for a demersal fishery in Angola. The objectives cover conservation, resource sustainability and restoration, poverty alleviation, economic performance and equity. It would be impossible to give priority to any one of these without some negative impacts on others, and the political task of fisheries management is to come up with a set of management measures to achieve an agreed, optimal balance of objectives which is also in accordance with the internationally agreed target of sustainable use of resources and ecosystems. This requires first that all the objectives of the full set of stakeholders are recognised and recorded. Conflicts between objectives must then be identified and, through a combination of use of the best available scientific and stakeholder knowledge and transparent negotiation, the conflicts reconciled into a set of operational objectives that can realistically be obtained from the fishery.

13.1.3 Characteristics of an effective decision-making process

Enormous advances have been made in scientific assessment of stocks, fisheries and ecosystems in recent decades, fuelled especially by easy access to powerful computing capacity. In contrast, formal approaches to decision-making in fisheries have progressed much less. There is greater

Box 13.1

The broad objectives identified for the demersal finfish fishery in Angola (as reported in Cochrane et al., 2007).

- Restore biomass of commercially important demersal species to optimal levels of productivity
- Maintain demersal community structure in terms of size structure and species composition
- Minimize impacts of bottom trawl fishery on threatened, protected or vulnerable species (sea turtles, sharks, marine mammals and others)
- Minimize impacts of bottom trawling on bottom substrate
- Contribute to poverty alleviation through the increase of opportunities of employment in the fisheries extractive sector and in the fish processing industry in the coastal provinces
- Promote the development of the industrial productive fisheries sector
- Promote reliable supply of fish products to the population at accessible prices
- Promote equity in the distribution of employment and income among the regions of the country and in the coastal provinces
- Maximize long-term economic benefits from the fishery

awareness now of the need to involve stakeholders in management (e.g. Chapters 3 and 11) but, with or without formal stakeholder involvement, the approach to making decisions still usually comes down to simple argument and persuasion about immediate management measures (e.g. the total allowable catch ,TAC, for the coming fishing season). The greatest weaknesses of such informal approaches are that they fail to evaluate long-term consequences of management measures and are heavily influenced by personalities and therefore prone to bias arising from, for example, self-interest, short-term objectives and hidden agendas. Succumbing to any of these may compromise achievement of the agreed long-term goals.

Some formal methods for decision-making have been developed to assist in reaching the best decisions (e.g. Belton and Stewart, 2002). However, these approaches have not yet proven very popular in fisheries and do not seem to have been widely adopted for routine application. One explanation for this may be that they are seen by some as reducing the opportunities for them to fully exercise their skills in getting their own way!

When using formal statistical methods, operating in the traditional manner of discussion and debate or a combination of the two, what is most important is that all the legitimate stakeholders are represented in decision-making, are able to express their opinions and preferences, are listened to and their needs and desires taken seriously. It is also essential for these groups to be provided with relevant, objective and easily understood information by the fisheries scientists from relevant disciplines.

13.1.4 What information is needed to help ensure the best decisions are made?

In many fisheries agencies, insufficient attention is given to the collection of data and information, and management of their fisheries is therefore flawed from the outset. Other agencies go to considerable trouble and expense to collect information but then do not process, store or analyse the data properly, or at all. Collection of fisheries data is not an end in itself: data stored in log books or on data collection sheets collecting dust in a cupboard represent a wasted resource. For responsible fisheries management, the required data must be collected and used to obtain information to assist in managing the fishery effectively. The data requirements are determined by the issues and operational objectives that the manager needs to consider and are summarised in Table 13.2.

The following simple questions point to the types of data commonly needed:

- Are current catches in the fishery sustainable and making good use of the resource?
- Are current fishing practices avoiding any damaging and irreversible impact on non-target species in the ecosystem?
- Are the current fishing activities having minimum practical impact on the physical habitat?
- Are other non-fishing activities in the fishing grounds and in the supporting ecosystem being adequately managed to avoid damage and irreversible impact on the ecosystem, including the critical habitats?
- Is the fishery being conducted in an economically responsible and efficient manner consistent with the economic goals and priorities of the country or local area?
- Are those dependent on the fishery for income and livelihoods receiving appropriate, beneficial returns from their fishery-related activities?
- Are the major stakeholders satisfied with the current management approach and with the net benefits they are obtaining from the fishery: is the fishery free from substantial conflicts?

Table 13.2 Some basic data requirements for fisheries managers and decision-makers.[a]

Objective(s)	Data requirements
Biological	Stock structure Total landings by major species or stock units per fleet per year Total effort by fleet per year Length and/or age composition of landings, by fleet, for major species Discards of species per fleet per year Length and/or age composition of discards per species of particular interest per fleet per year Areas fished by each fleet Life history parameters Abundance trends
Ecological	Total catches of bycatch species (including discarded species), or selected indicator species, per fleet per year Length and/or age composition of catches of bycatch species or selected indicator species Impact of fishing gear and activities on the physical habitat Impact on critical habitats brought about by non-fishery activities Impacts of non-fishery activities on other components or properties of the ecosystem
Economic	Average income per fishing unit per year for all fleets Costs per fishing unit per year Profitability of each fleet (in the absence of detailed economic data this could be based on interviews or similar information) Destination of landings from each fleet, and a measure of the dependence on the fishery of other sectors of the community (e.g. processors, wholesalers.)
Social	Total number of fishers employed within each fleet Total number of people employed in fishing or shore-based activities per fleet, by gender and age group where appropriate Dependence of fishers and shore-based workers for their livelihoods for each fleet

[a] Additional information on these can be found in the Technical Guidelines (FAO, 1997)

If the answer to any of these questions is 'No', then the manager needs to consider how the current management measures should be adjusted to correct the situation without unacceptable negative impacts on the issues raised by the other questions. If the manager is unable to answer any of these questions with a reasonable degree of confidence, then he or she is insufficiently informed to be able to fulfil the mandate of the job properly and needs to give urgent attention to improving the systems and processes for collection and analysis of data and the provision of scientific advice.

13.1.5 Where do I get the information and how can I use it?

Recognising both the importance and difficulties of using good knowledge, the FAO Code of Conduct (Paragraph 6.4) requires that 'Conservation and management decisions for fisheries should be based on the best scientific evidence available, also taking into account traditional

knowledge of the resources and their habitat, as well as relevant environmental, economic and social factors.' This requirement involves four steps:

1. Identifying the data that are required to monitor whether the management measures are achieving all the operational objectives and what corrections are needed if they are not.
2. The collection of the data and information on the fisheries identified in step 1.
3. Analysis of these data and information, including consideration of the uncertainties in them, so that they may be used to address the decisions to be made by the fisheries managers.
4. The use of the analysed data and information in making the decisions.

Data collection and monitoring is a vast topic in its own right and has been the subject of many publications (e.g. FAO, 1999) and is also discussed in some detail in the Technical Guidelines to the FAO Code of Conduct: Fisheries Management (FAO, 1997). The subject of Step 3, covering statistical analysis, stock assessment and social and economic analyses, has been discussed even more thoroughly in the literature (e.g. Hilborn and Walters, 1992; Seijo, Defeo and Salas, 1998; Walters and Martell, 2004 and Hoggarth *et al*., 2006). Therefore this chapter does not go into the details of those processes but focuses on Step 4: how the results and conclusions from the analyses can and should be used to inform decision-makers.

Formal science is not the only source of information, and there is an increasing awareness of the value of the knowledge and insights of the users of the resource, including traditional knowledge. The FAO Code of Conduct recognises this in Paragraph 6.4 and in Paragraph 12.12 where it says that 'States should investigate and document traditional fisheries knowledge and technologies, in particular those applied to small-scale fisheries, in order to assess their application to sustainable fisheries conservation, management and development.' This is discussed later in this chapter and in Chapters 3 and 11.

13.2 Types of knowledge and the role of the scientist

13.2.1 Formal scientific knowledge

The discussion in the previous section has highlighted the role of the scientist, which here is taken to include the full spectrum of fisheries scientists including biologist, economist, sociologist, gear technologist and others, as a provider of scientific information to the decision-makers. This author prefers to refer to this type of information as 'formal scientific knowledge', thereby leaving the way open for the 'informal scientific knowledge' which would typically be that obtained from validated stakeholder knowledge, as discussed in Section 13.2.3.

The scientific method has been slowly developed and refined for as long as humans have been struggling to understand the world in which we find ourselves. The origins go back several millennia but were heavily influenced by two European philosophers of the 16th and 17th centuries, Francis Bacon of England and Rene Descartes of France. Both were concerned about the dominance of dogmas, prejudices and mistruths in the beliefs and practices of their worlds: human attitudes still very prevalent today, even if in different forms. They developed processes for understanding that were intended to be free from bias and prejudice and to reveal the true explanation or answer, rather than the answer one wanted to believe. This process, which set the foundations of the modern scientific method, should include careful, accurate observation, rigorously controlled experimentation where possible, orderly but open-minded examination of the results of the observations and experiments to identify the most likely explanation

or answer, and then continual review and testing of the answer or explanation against future observations or experiments to see whether it is correct or, at least, the best available answer.

Their methods had some weaknesses and limitations, and the scientific method continues to be challenged, refined and developed today. The contemporary view, drawing heavily on a 20th-century philosopher, Karl Popper, is that we can never know anything with absolute certainty but can only either disprove a theory or explanation or gain more confidence in it as it is found to hold 'true' in more and more tests. Scientific knowledge is therefore by no means perfect and the perfect, unbiased scientist is yet to be born. Errors do occur, more frequently than we would like. Nevertheless, the method, when properly applied, is still the most reliable way to observe, interpret and understand what we see and what is happening around us. Fishery managers and agencies must ensure that they are informed by the best possible science whenever they have to make an important decision. They must also accept that it is often not possible to identify a single most-likely explanation, and there may be a number of possible answers. For example, it may not be possible to determine with confidence whether a stock is heavily over-exploited, moderately over-exploited or just fully exploited. In such cases, all of the more likely explanations must be considered and management measures identified that will work under all of them. This is discussed further in Section 13.3.2.

13.2.2 Advocacy versus science

When the philosopher Francis Bacon was trying to develop a rigorous method for understanding the natural world, he was reacting to biases and prejudices that prevent people from seeing the true situation or explanation for an event or events. He referred to them as 'idols' and identified a number of idols including culture, language and individual prejudices arising from the unique background and situation of each individual. He also identified biases that can occur in the application of the scientific method such as the representativeness of the data used and the design of an experiment or sampling programme.

People are as susceptible to error, bias and prejudice today as they were in Bacon's time and as a result there is both good and bad science. Science can also be misused, either intentionally or unintentionally. Advocacy is an attempt, through words or arguments, to provide support for a particular cause or position, and science has been, and is frequently, used as a vehicle for advocacy. Of course, advocates of a cause may use the results from very good and relevant science in an open and unbiased way to help them to convince others and to achieve their goal. The danger arises when advocates selectively use science, for example choosing and publicising only those results that suit their cause.

Advocacy comes from different sources, with each stakeholder group frequently more concerned about ensuring that their voice is heard and taken seriously than they are about the accuracy and completeness of their arguments. Some environmental and conservationist groups, fishing interests and lobbyists of other natural resource users are all likely to use science to justify their claims and now routinely use science and scientists to help them in their causes. This is consistent with the use of the best information available and is therefore to be encouraged, but problems arise when biased science, commonly in the form of selective use of results, is used to further the cause of any particular advocacy group. Use of biased science in decision-making will lead to poor decisions. Scientists within government agencies are also susceptible to biases, conscious or unconscious, and in some cases this has also led to major problems in fisheries management decisions and actions.

In the end, whatever the source, poor science and misuse of science will lead to poor decisions that ultimately will generate new and perhaps greater problems. It is therefore in the long-term interests of all stakeholders to ensure that only validated and unbiased scientific information is taken seriously in fisheries management. Separating poor or biased scientific information from good, balanced information is not easy. Whether qualitative and based on limited information, or based on sophisticated quantitative analyses, it is usually fairly easy to distort and direct the outcomes towards a desired set of results and conclusions, or at least to overemphasise some of the outcomes over others. The best means of ensuring high quality of scientific information is to

- have all important scientific studies and results peer-reviewed by independent third parties;
- ensure full and transparent participation of all stakeholders in the provision and application of scientific results; and
- create a culture of transparency, participation and mutual respect so that all stakeholders will believe they are part of a fair and honest process, even if their own objectives cannot always be fully met.

13.2.3 Traditional and local knowledge

Scientists are not the only ones with insight into and understanding of a fishery and the social–ecological system of which it is a part. As discussed in Section 3.6, on the one hand, science has its limits and, on the other, the different stakeholders have knowledge that is essential for effective management. This knowledge can include traditional ecological knowledge, handed down through generations, or more recent, practical 'local knowledge'. Including such knowledge in planning and decision-making has many advantages: it provides a broader knowledge base that can supplement and improve the formal scientific knowledge; it increases the confidence the stakeholders will have in the knowledge base and thereby in the resulting decisions; and it contributes to greater participation and partnership in fisheries management.

Just as scientific information can be flawed, managers must also be aware that stakeholder knowledge has its own pitfalls that can undermine its accuracy in some cases. Stakeholder knowledge can be influenced by underlying beliefs that may not be applicable to the problem or phenomenon being observed or biased by selective observation and interpretation (how many fisheries scientists and managers have not heard the statement from fishers of all scales 'there are so many fish out there you can walk on them', which on investigation is found to be a local concentration in an otherwise reduced population?). The underlying valid (or empirical) knowledge within the broader traditional or local knowledge must be separated from the 'belief' component in a careful and socially sensitive way. After this process, the validated empirical knowledge can be considered to be equivalent to scientific knowledge, albeit 'informal' scientific knowledge. The benefits of doing this outweigh the costs and the 'co-production of knowledge' (see Section 3.6) should be seen as the best, if not only, means of providing the best available information for management.

13.3 Uncertainty and the precautionary approach

Throughout this book, the problems of uncertainty, or lack of knowledge, in fisheries management are emphasised. Trying to estimate the abundance of fish and their productivity

is difficult enough, and the estimates we obtain of these values are always just that, estimates, with considerable uncertainty associated with them. When we try to forecast or predict what the abundance of fish will be next year, we introduce more uncertainty, and when we try to forecast how the stock, fish community, fishers or ecosystem will respond to management measures, we introduce even more (Section 12.2).

13.3.1 Uncertainty and risk

There are many sources of uncertainty in fisheries stock assessment and management which can be summarised as[1]:

- process uncertainty, or random and therefore unpredictable variability, in the biological, ecological and human processes themselves, such as in recruitment to a stock;
- observation uncertainty, from our inevitably imperfect attempts to measure factors such as total catch, biomass or effort in a fishery;
- estimation uncertainty in our final estimates of quantities, such as the status of the stock or the economic returns from the fishery and which arises from the combination of process and observation uncertainties and also because our models are usually simplifications of the reality;
- implementation uncertainty arising from the implementation of management measures, including how effective they will be and how well the fishers will comply with them; and
- institutional uncertainty, which refers to the uncertainty as to how well participants in the process can communicate with each other, to what extent people are willing to compromise, how decisions will be made and how good they will be.

Where there is sufficient information, we can estimate values for some of these uncertainties and use these values in stock and bioeconomic assessments and decision-making. For example, by measuring recruitment to a stock over a number of years, an estimate can be obtained not only of the average recruitment but also of the typical variability from year to year, which could be expressed by measures such as the standard deviation about the mean, the 95% confidence intervals or simply the range of observed recruitments. Probabilistic representations of the stock–recruitment relationship could then be used in stock projections to represent likely stock responses to management measures. With this sort of knowledge, management measures can be selected so that they would still be effective under the range of possible outcomes.

In some cases, good numerical estimates of uncertainty may not be available, but scientists should then provide a carefully considered statement of the reliability of each piece of information. For example, they could indicate whether their estimate of total landings is good, fair or only an approximation. Implementation uncertainty and institutional uncertainty are generally much more difficult to estimate than the other types of uncertainty listed earlier. In most cases the best information that may be available for these types is, for example, only that there is a high or a low probability of serious violation of regulations (see Section 14.5) or that there is a high, medium or low level of confidence that the management measures selected

[1] From Francis, R.I.C.C. and Shotton, R. 1997. 'Risk' in fisheries management: A review. *Canadian Journal of Fisheries and Aquatic Sciences*. 54: 1699–1715.

will achieve the desired result. Even estimates such as these will assist the decision-makers in interpreting the information and making the best decisions.

13.3.2 Risk management

Risk management is still in its infancy in fisheries management, and there are no commonly applied formal ways of doing it. In essence, risk management requires the decision-makers to make the best decision they can based on the information they have, but then also to consider the likelihood of that decision being wrong and how important it will be if it does go wrong. This can also be done through quantitative assessments and modelling but, where that is not possible, simpler approaches can still be useful.

Risk is the product of two components:

risk = (the likelihood of the feared outcome occurring)
× (the consequences of that outcome if it does occur)

Even semi-quantitative scores (e.g. on a scale of 0 to 4 for increasing likelihood [from 'not going to happen' to 'definitely will happen'] and a similar scale for consequence [from unimportant to catastrophic]) can help managers and decision-makers to consider the risks of choosing a particular management measure or measures, or taking no action at all. If a particular measure is estimated to give a high risk of something undesirable happening, managers should consider modifying the action or taking an alternative one. For example, increasing the mesh size of gill nets to decrease the capture of juvenile fish may increase the risk of turtles becoming entangled in the nets. Before deciding on the new regulation, scientists should try to estimate the likelihood of an increase in turtle entanglements and also the consequences for turtle conservation if there was in fact such an increase. For further details on simple approaches to risk assessment, the reader is referred to the publication by Fletcher *et al*. (2002) listed in the references at the end of the chapter.

When managers decide on management measures, they must take into account the risks and select measures that will be effective not only if circumstances fall within the expected range but also if things turn out to be very different from the initial expectations. This requires implementing actions that are robust (strong, sturdy or effective) to the range of possible circumstances, where the 'circumstances' could include, for example, the abundance of the fish resources, the behaviour of the fisher and the performance of the fishing gear. Testing the robustness of management measures requires considering how a measure will perform under conditions or states of nature different to those considered in the basic assessments or how it will perform if some of the information used in those basic assessments is incorrect. Models, whether they are simple conceptual models or more sophisticated numerical ones, can be very useful for robustness testing as long as they represent the best available information on the system or problem being considered. Robustness testing can assist in identifying possible undesirable outcomes from a management measure or set of measures before they occur, thereby allowing alternatives to be considered to try to avoid undesirable outcomes before a measure is implemented. Being robust to uncertainty could mean being more cautious than the basic assessments suggested in, for example, setting total allowable effort. Alternatively, it could involve putting in place adequate feedback mechanisms to allow prompt detection of potential problems and ensuring that effort can rapidly be scaled down if necessary, without creating unnecessary social and economic disarray.

13.3.3 The precautionary approach

Consideration of uncertainty and risk leads directly to consideration of the precautionary approach. Application of the precautionary approach in fisheries is included in the FAO Code of Conduct. It can be summarised as 'the application of prudent foresight' and requires

- consideration of the needs of future generations and avoidance of changes that are not potentially reversible;
- prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly;
- that any necessary corrective measures are initiated without delay and that they should achieve their purpose promptly;
- that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource;
- that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource (production), and that increases in capacity should be further contained when resource productivity is highly uncertain.

It is also suggested in the FAO Technical Guidelines on the precautionary approach (FAO 1996, Paragraph 7d) that, in applying the precautionary approach, 'the standard of proof to be used in decisions regarding authorization of fishing activities should be commensurate with the potential risk to the resource, while also taking into account the expected benefits of the activities.'

In practice, application of the precautionary approach means that the less that is known about a system (i.e. the higher the uncertainty), the more caution is required and the more conservative managers and decision-makers should be in relation to fishing effort and mortality

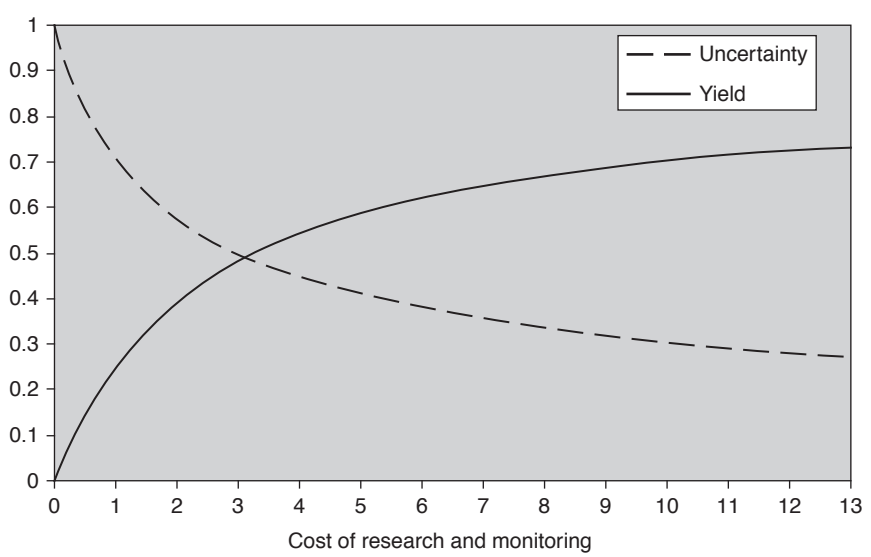


Figure 13.1 Investment and effort in research and monitoring: the general relationship between decreasing uncertainty (increasing knowledge) and the potential benefits possible without threatening sustainability. The yield is given as a fraction of the possible maximum long-term average yield if there was perfect knowledge about the social–ecological system.

or other impacts of fishing. If there was perfect knowledge it would be possible to know, for example, the exact amount of fish of any given size that could be caught, and the optimal spatial distribution of that catch, in order to meet the objectives for the fishery in a fully sustainable manner. The less one knows, the smaller and smaller the fraction of that hypothetical maximum catch that can be taken without a high risk of over-exploiting the stock or damaging the ecosystem. Therefore, in terms of direct benefits, more knowledge can allow higher levels of catch, up to some maximum beyond which the stock will be harmed. That maximum could only be known exactly if there was perfect knowledge. However, obtaining more knowledge usually costs money and human resources, and those costs rise more and more steeply as the more basic information is obtained and research and monitoring is invested in the more detailed and difficult questions and unknowns (Figure 13.1).

The optimal balance between investment in research, monitoring and management to decrease uncertainty and risk and increase long-term average catches will vary from case to case depending on the national or local priorities, management capacity and value (social or economic) of the fishery. A key task of the manager is to ensure that the degree of precaution used is in balance with the existing state of knowledge about the social–ecological system.

13.4 What tools can be used to generate information to advise management?

Despite incomplete knowledge, by monitoring trends in populations and communities and observing their responses to fishing and to environmental factors, we can gain invaluable information on how they are likely to respond in the future, including to changes in management measures. In the same way, we can forecast the likely impacts of management actions on humans and perhaps also the likely response of humans to those actions. In general, the closer the forecast situation is to circumstances that have been experienced before, the more reliable it is likely to be. Put another way, be cautious with long-term forecasts and forecasts that go far beyond previously experienced conditions.

The scientific staff of the management agency are responsible for trying to obtain the best knowledge with the capacity and data that they have available in order to

- provide the information required by the decision-makers;
- be sufficiently accurate to minimise the chances of making incorrect decisions and
- reduce the uncertainty remaining in the answers to a low enough level for the decision-makers to be reasonably confident that their selected measures will work.

They must also ensure that the decision-makers are aware of uncertainties and potential errors in the estimates and forecasts.

13.4.1 The role of models

A model is any simplified representation of the real system that is being considered. Models come in many different forms but, for fisheries management, they are generally quantitative or qualitative descriptions of the best available understanding of the particular system.

Models serve a variety of functions that include improving the conceptual understanding of a system; providing information and advice for strategic planning and providing information and advice for tactical planning and decision-making (see Chapter 1 for a discussion of strategic and tactical management).

Whether strategic or tactical, fisheries management involves making decisions; decisions that must choose from a set of possible options. Good choices are only possible if there is some means of predicting the outcome and, in fisheries, that usually means predicting what will happen in the future if a particular decision, such as implementation of a particular management measure, is made. Single-species models were developed to help predict how a fish stock or community would respond over time to a given management measure or measures and how this would affect the objectives for the fishery, for example the status of the stock and the yield to the fishery. These need to be supplemented by models addressing the broader aspects of ecosystem approach to fisheries (EAF). Models are essential tools to help the manager understand how the system functions and therefore how it is likely to respond to any changes, particularly changes that are brought about by management actions.

13.4.2 Single-species methods

Single-species methods of stock assessment consider only the population or stock of a single species or species group and generally make assumptions about how the dynamics of the population (recruitment, growth and mortality) are affected by its own abundance or biomass and the impacts of fishing. Environmental effects are often included as random influences, overlooking the effects on the stock of specific changes in the environment and the abundance of other populations such as predators and prey. Single-species methods are still successfully used despite these blatantly incorrect assumptions because (i) there is an underlying population effect which is important to understand in managing fisheries; (ii) the interactions between the environment and the stock of interest are frequently so complex and poorly understood that it is impossible to build models that reflect any verifiable understanding of this reality and (iii) the environment is usually out of the control of the manager. The underlying population effect is sufficiently important that in most cases where good single-species assessments are undertaken using reliable data, they do provide invaluable information for the management of that stock. They are still generally used for making tactical management decisions.

Single-species methods have been intensively studied and applied for decades, and many different approaches now exist for different circumstances and different fish types (Table 13.3). Different methods have different data requirements, make different assumptions and enable different questions and scenarios to be addressed.

An important modern application of single-species methods is in predicting the performance of different management measures in order to select the one or ones that are most likely to achieve the desired objectives. In this process, known as management strategy evaluation (MSE) or management procedure evaluation (MPE), the entire cycle of data collection, stock assessment, decision-making and implementation is simulated, providing managers and decision-makers with estimates of how different options, for example different TACs or alternative gear selectivity options, are likely to perform in practice. While commonly used in sophisticated, data-rich fisheries, the process can also be applied using ecosystem models in strategic decision-making and also with simple qualitative models if those represent the best available knowledge of the system. Use of MSE or MPE is strongly recommended as the

Table 13.3 Main categories of single-species stock assessment methods and their characteristics.

Method	Main information required	Comments
A. Production models	– Annual catch – Annual index of abundance for example CPUE or biomass estimate	– Do not consider age structure of catch or population – Estimate parameters and variables such as MSY, effort at MSY, mean unexploited stock size and biomass time series – Very widely applied in, for example tuna commissions, south east Atlantic – Equilibrium methods should not be used for fitting models – Good estimates require good data contrast in effort and biomass
B. Size and age-based models		
B1. Yield and biomass-per-recruit	– Somatic growth rate – Natural mortality rate – Age/size at recruitment to fishery – Selectivity of gear for different age/size classes – Mean size at sexual maturity	– The Beverton and Holt per-recruit models assume knife-edge selectivity and constant fishing mortality and natural mortality for all ages. Methods that include a stock–recruit relationship and allow for consideration of uncertainty are available
B2. Statistical catch-at-age analysis (SCA), VPA and cohort analysis	– Number of fish caught per age class	– Provide estimates of historical exploitation rates by age and estimates of trends in recruitment to fishery. Can provide estimates of current stock size but those can be misleading so caution needed in interpreting results – Require independent estimates of 'boundary' values of numbers at age at the start or end of the time series – Assumptions on M are an important source of error in these methods
C. Stock recruit models	– Separate estimates of stock and recruitment over a number of years	– Recruitment will almost certainly drop if the stock size is reduced sufficiently and managers must take this into account – Stock size is only one determinant of recruitment, and recruitment will vary substantially around the mean stock–recruit relationship, that is uncertainty in forecast recruitment will be high even when a good relationship has been determined

standard that should be applied whenever establishing or revising the management measures in a fishery (see Hoggarth *et al*., 2006 under Sources and recommended reading at the end of the chapter).

13.4.3 Multi-species and ecosystem methods

Single stocks and populations are usually affected by other species and fisheries in the ecosystem through direct and indirect interactions. Direct biological interactions occur when a species is a predator, prey or competitor of another, in which case any change in abundance and distribution of either predator, prey or competitor will affect the dynamics of the other. These effects are not included in single-species models. Indirect biological interactions also occur, for example, when two species are indirectly linked through a common prey or predator.

Direct interactions with fisheries occur when one species is affected by the fishing activity directed at another species, for example if it is caught as bycatch (see Chapter 7). In general, direct fishery interactions are easier to quantify and consider in fisheries management than biological interactions which are more complex and dynamic. Multi-species per-recruit models are particularly useful for consideration of technical interactions and not necessarily especially demanding of data and expertise. More complex spatial models may be important if spatial closures are being considered as a management measure.

It is now recognised that the interactions between a fishery and the wider ecosystem must also be taken into account in fisheries management and therefore that focusing only on the impact of a fishery on the target species is insufficient. Models can play a valuable role in considering these wider interactions, but the amount of uncertainty is generally much higher in more complex models. As a result, complex multi-species and ecosystem models are rarely used for tactical decision-making in fisheries but are increasingly being used to help in strategic decision-making. For example, single-species models may indicate that an increase in mesh size of some fishing gear will lead to improved long-term yields of a target species. The same change could then be tested in a multi-species or ecosystem model to see what effects, both direct and indirect, it would have on other ecosystem components and whether it could lead to any undesirable consequences.

The better developed and more commonly applied multi-species and ecosystem models are shown in Table 13.4. Of these, multi-species virtual population analysis will be too demanding of data for application in most fisheries and multi-species surplus production approaches are likely to be equally impractical. Aggregated production models, multi-species per-recruit models and dynamic trophic level models have all been applied and found to provide information of relevance and use to fisheries management objectives and strategies.

13.4.4 Considering the benefits to society

Berkes, in Chapter 3, lists 22 potential objectives for fisheries management including to provide employment, increase fishers' incomes, reduce conflicts within and between different stakeholders, protect sports fisheries, improve the quality of fish, maintain low consumer prices, increase women's participation, improve foreign relations and increase foreign exchange. In Chapter 4, Eide discusses some economic and political objectives which, in

Table 13.4 Main categories of multi-species and ecosystem-based assessment methods and their characteristics.

Method	Main information required	Comments
A. Multi-species extensions of single-species methods		
A1. Multi-species surplus production models	Same as for single-species + indices of abundance +, preferably, abundances of all species with important interactions with the 'dependent' species	In theory, enable consideration of biological interactions, but of little practical value because – if only indices of abundance are available for the species included, then enormous statistical problems will be encountered in estimating the parameters and – as for single-species, good data contrast is required for good estimates
A2. Aggregated production models	– Annual catch aggregated into appropriate species groups – Annual index of abundance, for example CPUE or biomass estimate for same aggregated groups	– Has proven informative in some cases where tried – Provides a feasible source of information for ecosystems with high species diversity – Caution required as the selected reference point for the aggregation could lead to depletion of some vulnerable species while producing sustainable yield for the aggregation as a whole
A3. Multi-species per-recruit models	– As for single-species per-recruit analyses. – The relative catchability of each species for a unit of fishing effort – The relative recruitments of the different species	– Can be used for more than one fishery at a time as well as more than one species – Considers technical interactions, not biological interactions – Involves the same assumptions and limitations as single-species per-recruit methods – A useful tool for assisting in setting reference points in multi-species fisheries
A4. Multi-species stock recruit models	– As for single-species method – Abundance estimates of other predators and competitors on the species of interest.	– Extends single-species stock recruit models to consider the effect of other species on a given species
B. Multi-species VPA	– As for single-species method – Estimates of the number at age of individuals of the species of interest consumed by all other species	– Has the potential to provide very useful information taking into account some biological interactions – Very data intensive and therefore probably not applicable in most circumstances
C. Food web and trophic level models	– Estimates of biomass of all major species or species groups – Production per unit biomass for each group – Consumption per unit biomass per group – Average diet composition per species group	– The requirements listed here are for a simple food web type model, and models incorporating, for example, physical factors require more information – In equilibrium form, they are useful for gaining insight into trophic relationships and direct and indirect interactions – In dynamic form (e.g. Ecopath with Ecosim), they can be used to explore multi-species implications of harvest policies – Invariably include substantial uncertainty which must be rigorously explored, reported and considered

addition to some of those listed by Berkes, can include maximising the sustainable profit from the fishery, a desire by the government to obtain resource rent, or fisheries development.

As with stock assessment tools, there have been many different models developed to consider economic performance. One commonly applied bioeconomic model is the Gordon–Schaefer model (see also Chapter 4) which incorporates the Schaefer surplus production model. It can be used, for example, to estimate maximum economic yield (Chapter 12) and other economic indicators and reference points (Figure 13.2).

Age-structured bioeconomic models and models including spatial distribution of the resource and fleets have also been developed, allowing the investigation of management strategies that exploit different size or age classes of the resources and in which spatial patterns are significant. Good examples of such models can be found in, for example, Seijo *et al.* (1998) listed at the end of this chapter.

In the same way that bioeconomic models can be developed from the standard stock assessment models, so they could be adapted to include social factors. For example, it may be useful to consider effort in the Gordon–Schaeffer model in terms of number of fishers, giving a measure of employment as well as revenue. Similarly, if there is a relationship between yield from the fishery and the number of fishing and shore-based jobs, these models can be used to investigate how different management strategies will affect employment. Some ecosystem models such as Ecopath with Ecosim[2] can include basic social and economic characteristics of the different fleets fishing on an ecosystem and can therefore be used to investigate the biological, ecological, economic and social impacts of different harvesting strategies within the ecosystem as a whole. This facility has the potential to provide useful strategic information to supplement that obtained from the single-species models, which typically contain more detailed information on that specific resource.

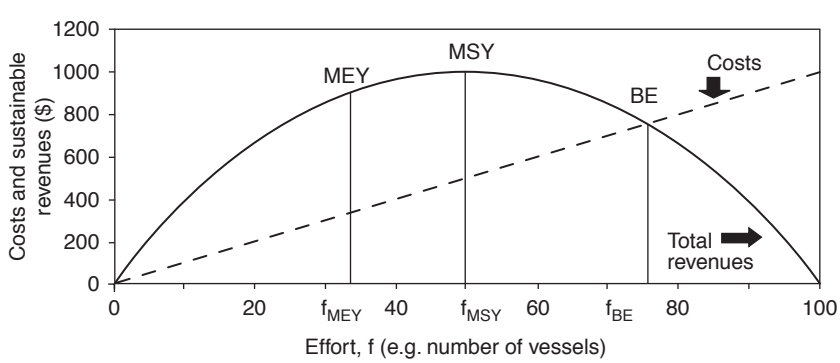


Figure 13.2 Gordon–Schaefer bioeconomic model of costs and sustainable revenues for a fishery as a function of fishing effort. MEY = maximum economic yield, MSY = maximum sustainable yield, BE = the bioeconomic equilibrium (see Chapter 4). The suffix f indicates the effort at each of those reference points.

[2] For further details on Ecosim, see Walters, C.W., Christensen, V. and Pauly, D. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. *Reviews in Fish Biology and Fisheries*. 7:139–172 or http://www.ecopath.org/

13.5 Scientific advice for management

13.5.1 The direct impacts of fishing on target resources

A primary consideration in selecting a set of management measures is their impact on the status of the stocks being targeted. In cases where time series of catch and effort information are available, it may be possible to analyse trends in the catch-per-unit-effort (CPUE), which with careful interpretation may provide an indication of trends in resource abundance. Such trends can indicate when adjustments in the management measures are required, for example, to prevent ongoing declines. Catch and effort data may also permit more sophisticated analyses, such as the application of biomass dynamic models and, with additional information on the length or age structure of the catch, virtual population analysis (VPA). More sophisticated analyses allow more sophisticated biological reference points to be determined (Chapter 12) enabling the management agency to aim for, for example, obtaining the maximum average sustainable catch (with appropriate precaution), instead of simply aiming to avoid ongoing declines. Figure 13.3 shows the estimated biomass obtained from fitting a biomass dynamic model to catch and effort information from the sardinella fishery in Angola. From this information, the manager could see that the sardinella stock had been recovering from a period of over-exploitation since the catches had declined. The estimated reference points (not provided here) showed that there was scope at that time for increasing the annual catches from their recent levels. Catch and effort data from a fishery are generally the cheapest and easiest information to obtain, and collecting (and using!) good estimates of annual catches and effort should be a fundamental task of the scientific branch of the management agency.

Yield- and biomass-per-recruit calculations can also be used to provide information on useful reference points to guide management decisions. Per-recruit methods require estimates

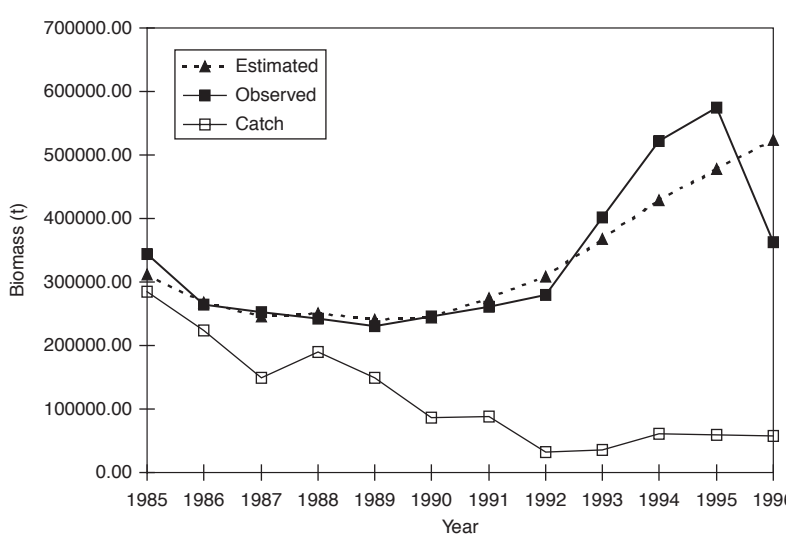


Figure 13.3 A biomass dynamic model fitted to catch and effort data for the fishery for sardinella in Angola. The chart shows the catch, the observed biomass (indicated by CPUE data) compared to the biomass estimated from a biomass dynamic model.

of the growth rate of the species being assessed, their natural mortality rate (which can be approximated from the knowledge of other characteristics) and the selectivity of the fishing gear for different size groups or, at least, the size at which the species become vulnerable to capture (Table 13.3). While this information may appear more difficult to acquire than simple time series of catch and effort, good time series of the length frequencies of the catches can be used to estimate them.

Consideration of the yield- and biomass-per-recruit curves for a particular species and gear type (Figure 13.4) enables the manager to determine what level of fishing mortality will achieve a good yield-per-recruit while at the same time maintaining a high enough spawner biomass-per-recruit to sustain recruitment. In addition to estimates of appropriate reference points, knowledge would also be needed of the current level of fishing mortality in relation to the target fishing mortality. With the same data, an initial estimate of fishing mortality may be obtained through undertaking a catch curve analysis on good estimates or samples of the population length frequency (see e.g. Hilborn and Walters, 1992). However, these estimates require assumptions of equilibrium which are rarely correct. More accurate and precise estimates can be obtained through the use of time series (usually a minimum 3–5 years of data) of at least good catch and effort information. Tagging studies can also provide valuable information on biomass and fishing mortality rates.

The potential yield from a stock is dependent on the average size and age of the fish taken by the fishery and there is generally an optimum average size, below which there is considerable risk of over-exploiting the stock and above which potential yield from the resource is lost. The size selectivity of the gear used in the fishery is therefore important in managing the fishery (see Chapter 7). Per-recruit analyses can provide useful information on how changes

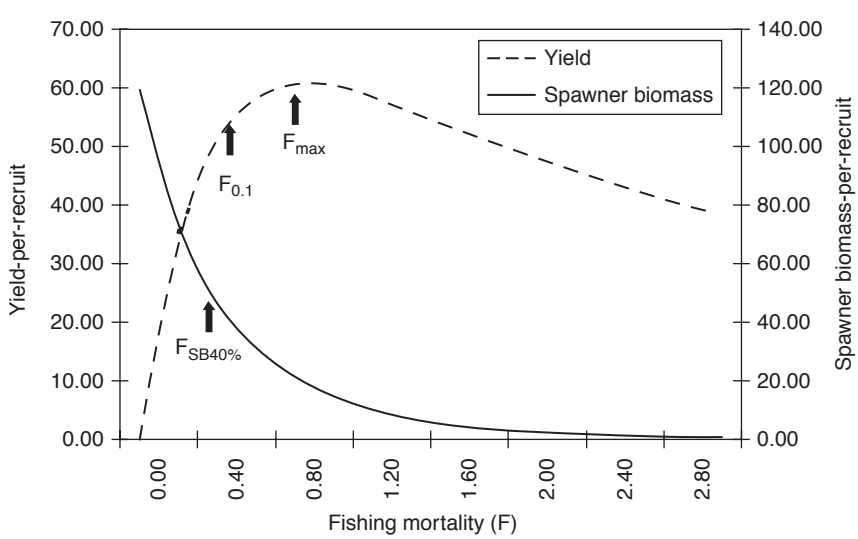


Figure 13.4 Yield- and spawner biomass-per-recruit plots for a hypothetical snapper stock showing common reference points for fishing mortality. F_{max} is the fishing mortality at which yield-per-recruit is at a maximum, $F_{0.1}$ is a pragmatic reference point that is more conservative than F_{max} and $F_{SB40\%}$ is the estimated fishing mortality that would reduce the biomass of spawners to 40% of that biomass in the absence of fishing. F_{max} is rarely used as a reference point because it typically reduces the biomass to too low a level.

in selectivity of the gear can influence the potential yield from the resource and the probable survival per-recruit, helping in the selection of appropriate gear. Figure 13.5 shows the biomass-per-recruit for a finish caught as bycatch in an offshore trawl fleet targeting mainly shrimp and in a nylon gill net targeting fish. Per-recruit analyses on the two species indicated that a fishing effort suitable for sustainable utilisation of shrimp would result in severe overexploitation of the snapper and other fish species. Using such approaches, it is possible to consider the trade-offs required, for example, in foregoing yield in the shrimp fishery in order to ensure the sustainable use of the snapper resource.

All stock-assessment approaches require making certain assumptions about the data and the dynamics of the resource. Two common and important assumptions are that CPUE is proportional to the abundance or biomass of the resource, and that natural mortality rate, M, is constant for all ages of fish and in all years. The assumptions behind any stock assessment should be considered when using information and when making decisions. For example, many applications of per-recruit analyses and most analyses based on length or age frequency analyses assume that recruitment will remain constant. In practice, one of the greatest sources of uncertainty in resource dynamics, and hence in fisheries management, is the very high variability from year to year in recruitment of young animals to a stock, which can easily vary by an order of magnitude or more from one year to the next (Figure 13.6). When providing advice on the effect of management measures, scientists should also consider the impact of variability of recruitment on their results and on the attainment of the operational objectives.

Useful information on the status of the stocks can also be obtained by examining their size structure to determine whether there have been any major changes over time. However, size structure alone is not enough to assess stock trends. A significant decrease in the average length of fish in the catch may indicate growth overfishing, suggesting that the larger

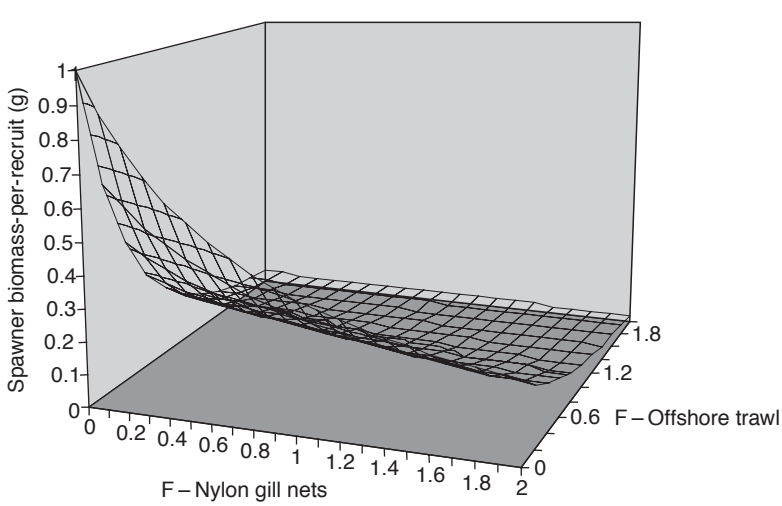


Figure 13.5 Spawner biomass-per-recruit of a snapper species under different fishing mortalities (F) for two different gear types. The nylon gill nets catch the snapper at a much larger size than the shrimp-directed offshore trawl gear. (Adapted from FAO. 1999. Meeting report of the second CFRAMP/FAO/DANIDA stock assessment workshop on the shrimp and groundfish fishery on the Brazil-Guianas shelf. Georgetown, Guyana, 18–29 May 1998. Rome, FAO. 41pp.)

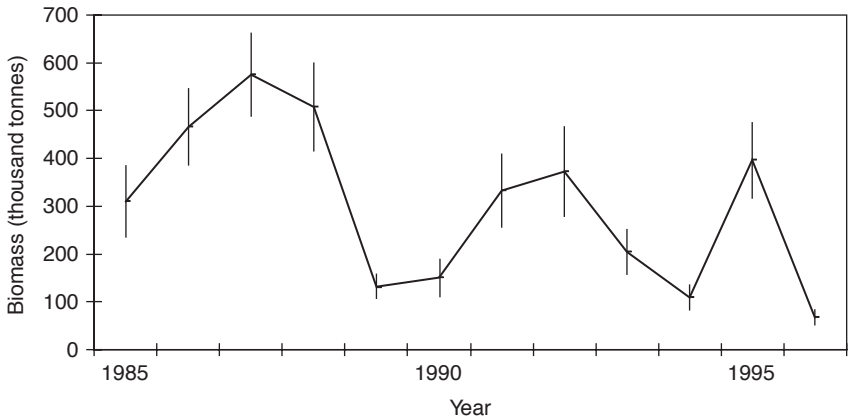


Figure 13.6 Time series of recruitment biomass estimates in the South African anchovy stock demonstrating high variability in this short-lived species. The vertical lines show one standard deviation of the estimated mean on either side of the estimate, giving an indication of the uncertainty in the estimates. The 95% confidence limits of the estimate would be approximately double the length of each vertical line. Data from Marine and Coastal Management, South Africa.

individuals are being removed at a rate too high for sustainable utilisation. Conversely, the decrease in size in the catch may be the result of good recruitment in recent years. The two different scenarios would require very different responses from management, and it is important to determine the likely cause of the change. Similarly, an increase in the average size may indicate poor recruitment in recent years resulting in older and larger animals becoming relatively more abundant in the catch but perhaps being exploited at higher fishing mortality rates, or a decrease in effective fishing mortality rate leading to more fish surviving through to attain larger sizes. Again, the underlying cause of the change should be investigated and the appropriate management response considered.

Some methods for considering uncertainty in single-species methods include

- Sensitivity analyses, for data and assumptions, in which the impact of a change in a parameter or assumption on the output from a model is explored.
- Monte Carlo analyses, in which, instead of undertaking an analysis once with fixed values of all parameters and variables, the analysis is run a large number of times, each time selecting a different value of each parameter from pre-specified distributions. These analyses will generate a large number of estimates of the unknown parameters and variables, giving an indication of the range and distribution of possible values for each.
- Bayesian approaches and Monte Carlo methods are alternatives to maximum likelihood approaches. One major advantage of these methods is that they can make use, in a formal statistical manner, of other sources of information in addition to the data available for the stock under consideration, including stakeholder information. For example, Bayesian approaches could use estimates of key parameters from other stocks or expert opinion on possible parameter values in fitting a model to fisheries data to help 'inform' the estimation procedure of likely values of these parameters in a particular case. They therefore have potential value in fisheries where there are only limited data available from the fishery itself.

13.5.2 Direct and indirect impacts of fishing on the wider ecosystem

With the adoption of the ecosystem approach, it is necessary to consider the impacts of fisheries on other components and human users of the ecosystem and the impacts that other sectors may have on the target species and fishery. For example, the destruction of mangroves for fuel or coastal zone development could reduce critical habitat for the target species of a fishery, reducing long-term productivity and yield. Within EAF, fishery managers need to be aware of important interactions within the wider social–ecological system.

Assessing the direct impacts of fishing

Where bycatch is considered to be a problem, for example where it is having excessive impacts on species of conservation concern, the methods that can be used are effectively the same as those for target species. Monitoring catch and effort, supplemented by fisheries independent information where possible including stakeholder knowledge, and using this information to monitor trends and estimate status of the species of concern should provide the information to enable managers to take appropriate action.

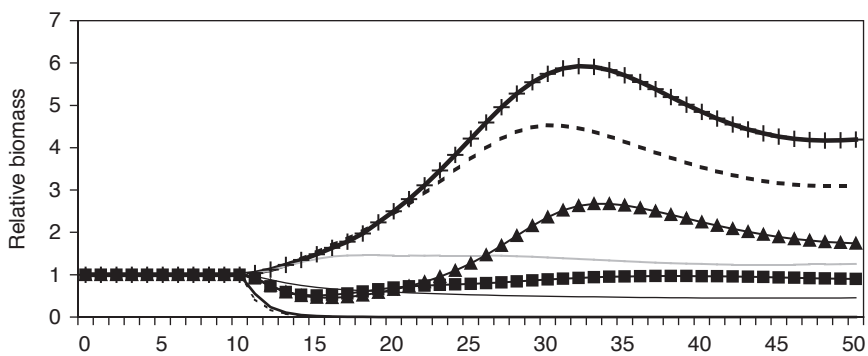
Where a fishery is taking target species of another fishery as bycatch, the catches and effort of both fisheries must be considered as a part of a dual- (or multi-) fleet fishery. In this case, managers may face a conflict between two fisheries and, if restrictive action is required, they will need to decide how to allocate the restrictions (e.g. effort reduction, changes to gear or fishing practices) between the two fleets. Decisions of this sort should take into account national and local goals and priorities for the fishing sector, biological and ecological impacts of the two fisheries and the social and economic characteristics of each of the two fisheries.

The nature and consequences of direct impacts of fishing gear on habitats, especially habitats in deeper water, are often costly and difficult to estimate. In addition, the dependence of different species on the habitat being affected will often not be known. Nevertheless, persistent and widespread damage to critical habitats can have major implications for fish communities and ecosystems feeding back into fisheries in the form of reduced productivity or changes in the species composition of the fish community being targeted (see the example from the northwestern Australian Shelf in Section 8.4.5). Where there is a reasonable likelihood that a fishery could be having a significant impact on critical habitat, managers need to take action on the basis of a mixture of locally available knowledge, common sense, application of the precautionary approach and drawing on knowledge from other comparable fisheries where the problem has been better studied.

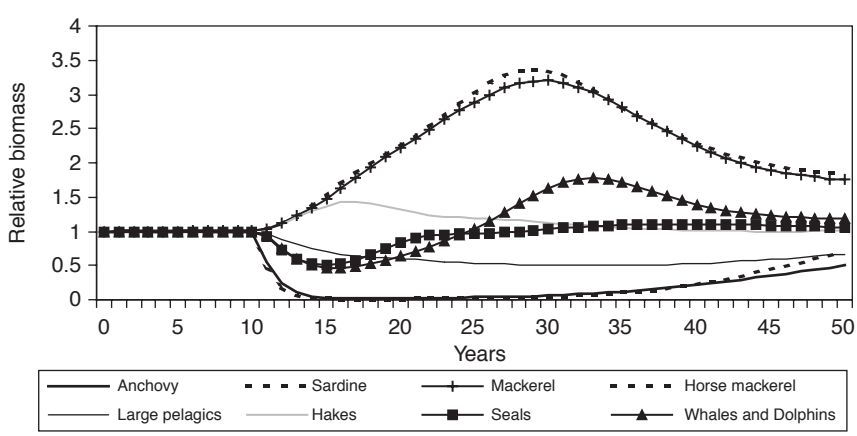
Assessing the indirect impacts of fishing

Table 13.2 shows that including ecological considerations in fisheries management adds to the demands on the data collection and analysis requirements of the responsible agency, increasing the number of species which need to be monitored as well as requiring information on ecosystem interactions and the state of the different habitats occurring in the ecosystem. The manager needs to have this wider perspective to ensure optimal and sustainable use of the system. Minimising damage from the fishery will require reference points to be developed for those ecosystem components identified as being of particular importance or particularly useful as indicators of some ecosystem property (see Chapter 12).

Our knowledge of ecosystem dynamics is notoriously incomplete, but suitable models representing our best understanding can still be informative. Figure 13.7 shows the results of a simulation from an Ecopath with Ecosim model of the southern Benguela ecosystem under two different management strategies, in both cases a simple modification of fishing mortality on sardine, anchovy and roundherring which are the main species caught in the commercial fishery for small pelagic fish. The simulation estimated that in addition to the target species, a large number of other species, for example chub mackerel and large pelagics, would also be affected by the changes in fishing mortality. The assumption of constant recruitment made in these projections is unrealistic (see Figure 13.6), but the results still provide useful insight into the nature and direction of potential ecosystem impacts of the management measures.



(a) Permanent increase



(b) Pulsed increase

Figure 13.7 Simulated effects of increased fishing effort in the small pelagic fishery on selected taxonomic groups in the southern Benguela ecosystem. (a) Results from a fourfold increase in fishing mortality on small pelagics from year 10 onwards and (b) from a fourfold increase in F from years 10 to 15 only. Relative biomass is the biomass as a proportion of the biomass at the start of the simulation. (Figure modified from Shannon, L.J., Cury, P.M. and Jarre, A. 2000. Modelling effects of fishing in the southern Benguela ecosystem. *ICES Journal of Marine Science*, 57: 720–722. With permission from Oxford University Press.)

Knowledge of ecosystem dynamics is still very limited and most predictions of ecosystem behaviour therefore include a lot of uncertainty; but good models, including conceptual models if these are all that are available, and careful interpretation of results can still provide very useful information on the potential ecosystem implications of different management strategies.

Assessing the impacts of external factors on the fishery

All fisheries are likely to be impacted, both directly and indirectly, by a large number of factors external to the direct interactions between a fishery and the target resource. These can be 'natural' factors (i.e. not caused by human) or human impacts and they may be from within or outside the ecosystem (Figure 13.8).

The important impacts of external factors on the fishery need to be taken into account or, again, management measures may turn out to have unexpected and undesirable consequences. For example, converting the nearest fishing grounds into a no-take area may mean that the local community has to travel further to fish, which could mean that they cannot compete with other suppliers on the local or international markets. Similarly, failing to recognise that the primary reason for an ongoing decline in resource abundance is not excess

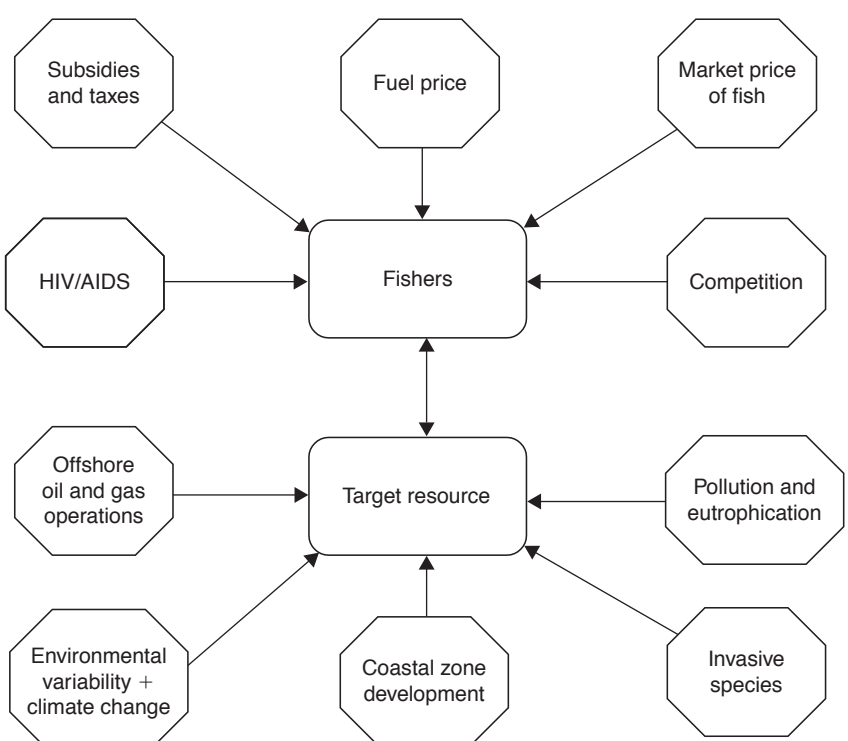


Figure 13.8 Some examples of external factors that could have an impact on a fishery targeting a particular resource.

fishing mortality but actually pollution or destruction of critical coastal habitat could mean that fishers are unnecessarily forced to reduce their effort, with resulting loss of income, without successfully addressing the problem.

There are many possible external impacts and there are no 'one-size-fits-all' approaches to assessing the impacts and identifying management solutions. The first step is to ensure that all significant external impacts on the resources, fishery and ecosystem are identified. In some cases measuring and analysing trends, for example in fishing effort, fish catches and rising levels of pollution, may allow the scientists to determine the underlying cause for trends in abundance and productivity. In other cases the fishers may be able to report and demonstrate the impact of an external factor on their livelihoods or on a management measure being considered. Alternatively, comparisons may be made with a similar impact that has been well studied in another fishery. Once the external impacts have been identified and assessed, the best available validated information should be used for decision-making and action.

13.5.3 Societal goals and impacts

Fisheries exist to provide social or economic benefits to society, and it is a task of the manager to ensure that these benefits are obtained in an appropriate and sustainable manner consistent with the fisheries goals. Management measures nearly always involve the fisher and hence affect him or her directly. They may also influence the abundance, the availability and the size structure of the stocks impacted by the fishery and may therefore affect the fisher and other users indirectly. Consequently, operational objectives reflecting the economic and social goals need to be developed and alternative sets of management measures evaluated against these objectives. The results of the social and economic analyses should be presented to the decision-makers together with the available biological and ecological information.

In nearly all cases, the quantity of most interest to the fisher is the magnitude and nature of the catch they can expect in the near future, as this is translated directly into income for them. Scientists should therefore attempt to estimate how changes in management measures are likely to affect future catches by fishers. Probably, fishers will also be interested in likely changes from year to year in catches, and species and size composition of the catches in the future as well as, where relevant, in distribution of the fish. These estimates of future catch characteristics can be translated into probable gross income for fishers: important information for them and, therefore, also for the managers.

Gross income is not the only economic variable that affects fishers' livelihoods. The costs associated with their fishing activities are as important to them as their income. Different management strategies may affect both fixed and variable costs and hence the total cost and profitability of fishing. The fishers themselves will be essential sources of this sort of information and should be key participants in the assessment process. However, as with all information, it is important to verify the information obtained from the fishers. In some cases their perceptions may be erroneous, while in others, they may see it as being to their advantage to provide incorrect information. Their information should therefore be validated and may also need to be supplemented from alternative sources where incomplete or uncertain (Section 3.6).

The estimated combined net present value of the shrimp trawling fleets of Trinidad and Tobago and Venezuela, both fishing on the same resource, is shown in Figure 13.9a. The results indicated that there was too much capacity in these two fisheries in relation to maximising the long-term returns and that effort should be reduced in both national fleets. However,

there may also be social objectives that need to be considered, for example maintaining employment and earnings per fisher and shore worker, in which case any decision on effort reduction should strive for a desirable balance between the social and economic goals. Open access to the fishery (see Chapters 3 and 4) would not be a long-term solution, and the analysis estimated that if access were not limited, the gross earnings per unit of effort would decrease with time as more and more fishers entered the fishery (Figure 13.9b). Information such as this, with consideration of important uncertainties, is important for management in attempting to achieve the desired operational objectives.

Different strategies may also have other social implications. For example, in many artisanal fisheries, women and children are involved in processing or selling the landings, and changes in management strategies that influence the landings by such fleets may have wider social consequences than just the direct impacts on the fishers themselves. Management measures may also have the effect of increasing or decreasing conflicts between different users, and managers should 'regulate fishing in such a way as to avoid the risk of conflict among fishers using different vessels, gear and fishing methods' (FAO Code of Conduct, Paragraph 7.6.5). Target and limit reference points should be established for social criteria to enable their consideration in selecting management strategies. It may not be always possible to obtain quantitative estimates of the performance of strategies against some of these criteria

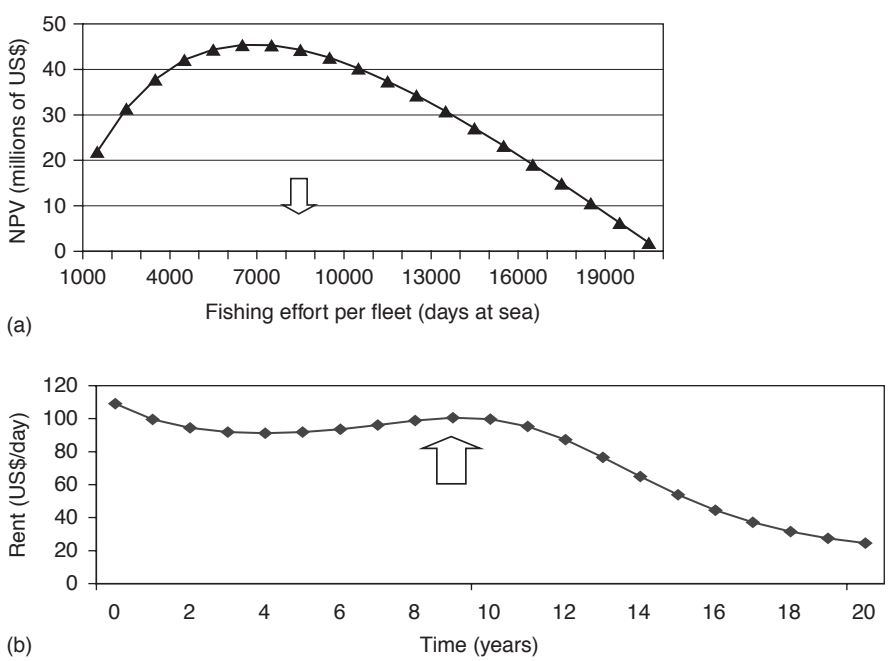


Figure 13.9 (a) Net present value (NPV – the estimated long-term value) of the shrimp landings for the combined trawling fleets of Trinidad and Tobago and Venezuela for different levels of effort. (b) The estimated rental obtained per unit of effort in the Trinidad groundfish fishery under open access conditions. In both cases the arrow indicates the current status in those two fisheries. (Figures taken from Ferreira, L. and Soomai, S. (2000). Management Report: Trinidad and Tobago. In: Report of the 4th Workshop on Assessment and Management of the Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf. Cumana, September 2000. FAO, Rome (in press).)

but the best available qualitative estimate could still provide valuable information. The users themselves are an essential source of such information.

13.6 Using the knowledge in decision-making

When a change in management measures is being considered in order to address a problem or bring about an improvement, there are obviously many different combinations of management measures that could be examined. Deciding on which to consider and comparing their likely performance should be a consultative process between the decision-makers, stakeholders and scientists undertaking the analyses. Only certain changes to the existing measures may be feasible or desirable, and these should clearly be considered first. There is little point, for example, in considering TAC as a management measure in a fishery where it is impossible to monitor the catches or landings of all the fishers (see Chapter 9) or considering implementation

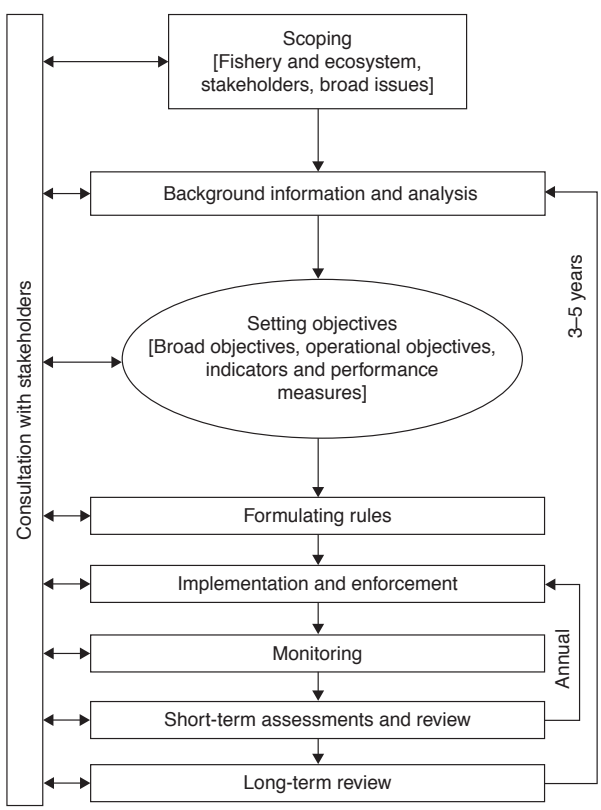


Figure 13.10 Process for developing and implementing a management plan. Evaluation and review should occur on a variety of time scales, for example as shown here, a tactical review of the management measures every year and a comprehensive strategic review every 3-5 years. From the FAO Technical Guidelines on EAF (FAO, 2003): the numbers shown at each step in the Figure refer to the relevant sections explaining the step in those Guidelines.

of a gear regulation that would be impossible for the fishers to implement. As discussed in Section 13.1.2, it is also important for all those involved in fisheries management to have agreed upon the objectives that are being pursued in the fishery. The implications of different management measures for each of the objectives can then be considered and taken into account in decision-making.

Once the general approach and constraints have been agreed upon, the consequences of implementing different management measures should be evaluated making use of the best available information. This information should include consideration of uncertainties and consideration of robustness to those uncertainties. Usually the scientists will take the lead in this but, as discussed in Section 13.2.3, they should be working with the stakeholders in 'co-production of knowledge'. Working iteratively, different management measures, or sets of management measures, can be evaluated and considered leading ultimately to a set of measures which comes closest to achieving the desired objectives (Figure 13.10).

13.7 Presenting information to decision-makers

Decision-makers in fisheries have to consider several different objectives in deciding on optimal management strategies. Because of potential conflicts in these objectives, there will never be a solution that simultaneously maximises all the potential benefits and minimises all the potential risks. The decisions made will therefore invariably mean deciding on suitable trade-offs between these conflicting requirements and tend to be of a political nature. If they are to be good decisions, they need to be informed by the best available scientific information and that information should be presented clearly and in an easily understandable manner.

One of the more useful ways in which information can be presented to facilitate comparison and decision-making is in a decision table (e.g. Table 13.5). A well-structured and complete decision table will not only summarise and present key results from the analyses, but can also serve to remind the decision-makers of their operational objectives and how different management strategies perform against each of them. Commonly a decision table will reflect different possible 'states of nature' such as high, medium or low recruitment or different rates of growth. Including information such as this allows for consideration of the robustness of management measures across those states.

The hypothetical results in Table 13.5 would present decision-makers with some difficult decisions. The measures in place at the time (Management Measures 1) are estimated to be having a substantial impact on the target stock, reducing it to an estimated 36% of its mean unexploited level, with a possibility that the stock is as low as 18%. Measures 2, which could be, for example, a reduction in effort or a change in gear selectivity, would have substantial benefits for the target stock and the most heavily affected bycatch stock but would reduce the average earnings of the fishers and require a reduction of 15% in the number of fishers in the fishery. Measures 3 would result in a slight increase in the number of fishers and a substantial rise in their average annual earnings in the short term but with a much greater impact on the resource with a real possibility of reductions in recruitment (not taken into account in these 'simulations') and downward spiral in biomass and yield. Based on these results, there would be no easy options for the decision-makers in this fishery. Taking the uncertainty into account (in this case that includes the possibility that the stock is as low as 18% of its pristine level), Measures 2 are clearly the best ones and possibly essential for ensuring the sustainability

Table 13.5 Hypothetical decision table for presentation to decision-makers, enabling comparison of different strategies against some operational objectives. 95% confidence limits are shown in parentheses. In this example, estimates are averaged across the different 'states of nature'.

Performance indicator	Management measures 1 (existing)	Management measures 2	Management measures 3
Mean annual biomass of stock as a percentage of unexploited level	36 (18–54)	53 (26–79)	28 (14–42)
Mean annual biomass (percentage of unexploited) of bycatch species most heavily impacted by fishery.	49 (22–66)	63 (28–98)	19 (7–31)
Economic indicators			
Mean annual catch ('000t)	20 (16–24)	17 (12–22)	23 (17–29)
Mean annual income per fisher ('000 US$).	18 (14–22)	15 (11–19)	20(15–25)
Inter-annual variability in mean annual income per fisher (% of mean income)	12	9	14
Change in the number of fishers in the fishery compared to the existing level (%)	0	−15	+1

of the resource and bycatch species and therefore of the fishery. However, the social and economic impacts of Measures 2 may be considered highly undesirable. Under such circumstances, the decision-makers may choose to go back to the scientists and ask them to attempt to identify alternative measures that provide a compromise between Measures 1 and 2, providing adequate protection to the resource but with less severe social and economic implications. This may or may not be possible, but could be investigated before a final decision was made.

Results of the type shown in Table 13.5 would require a fairly advanced, stochastic model based on comprehensive, and probably costly, data and information. This will often not be available in smaller, less valuable fisheries. A decision table is no less useful when the information is semi-quantitative or even qualitative. For example, Table 13.6 is taken from another southern African fishery, this time from Angola, and shows the estimated positive and negative consequences (benefits and costs) of the use of marine protected areas (MPAs) as a management measure to reduce undesirable bycatch and other negative impacts of gear on the ecosystem. This was one of a series of tables produced in that study to examine alternative management measures and identify the measure, or set of measures, which would best meet the objectives for that fishery.

Graphic output, such as that shown in Figures 13.2–13.8 and the range of different approaches in Chapter 12, is also helpful to the decision-makers. The fisheries scientists should work with the decision-makers in order to find out what sort of information is most useful and how best to present it. However, this should not be seen as meaning that the scientists should only provide the information requested of them. If they have results or information that they consider important for the decision-makers to consider, it is their responsibility to ensure that this information is provided. Overall, the process should be equivalent to

Table 13.6 The estimated positive and negative impacts (benefits and costs) of the use of MPAs to address problems related to bycatch and other gear issues in management of the artisanal fishery in Angola, which catches some over-exploited stocks. Comparison with similar tables for other possible measures to address these issues enables the manager to determine the best management measure across all the objectives for the fishery. The scales range from 0 (no benefit or cost) to a maximum benefit or cost of 4.[a]

		Short term		Long term	
Broad objectives	Comments	Cost	Benefit	Cost	Benefit
Maintain biomass of commercially important coastal fish species at optimal levels of productivity.	If properly designed and managed, may help protect critical habitats, promoting stock recovery.	0	1	0	2
Minimise impact of fishery on juvenile or undersized fish.	If properly designed and managed, may help protect critical habitats where juveniles tend to concentrate.	0	1	0	2
Minimise impacts of fishery on threatened, protected or vulnerable species (turtles, cetaceans, seabirds).	If properly designed and managed, may help protect critical habitats for these species, and areas where species of conservation concern concentrate or are particularly vulnerable.	0	1	0	2
Minimise impact of fishery on coastal communities and ecosystems.	If properly designed and managed, may help protect critical habitats and ecosystems, especially mangrove areas.	0	1	0	2
Maintain or increase the supply of good-quality fish to the population.	Indirect positive effect via stock recovery. May have negative effect, especially in the short term, if their location and system does not take the needs of coastal provinces into account.	1	1	0	2
Contribute to poverty alleviation through the increase of opportunities of employment in the fisheries-extractive sector and in small-scale fish processing in the coastal provinces.	Indirect positive effect via stock recovery. May have negative effect, especially in the short term, if their location and system does not take the needs of coastal provinces into account.	2	2	1	2
Increase equity in the distribution of employment and income among the regions of the country and in the coastal provinces.	May have an indirect positive effect via stock recovery. May have negative effect, especially in the short term, if their location and system does not take the needs of coastal provinces into account.	1	2	1	2
Maximise the contribution of the fishery to the national economy, and especially of the coastal provinces.	May help stock recovery. Will have noticeable economic costs, especially related to enforcement.	2	1	1	2
	Total cost–benefit	6	10	3	16
	Average cost–benefit	0.8	1.3	0.4	2.0
	Benefit to cost ratio	1.7		5.3	

[a] Source: Adapted from Cochrane *et al.* (2007)

that reflected in Figure 13.10, which emphasises the consultation and feedback between the decision-makers and the providers of information necessary for ensuring the correct information is provided and is presented in a way that ensures it is used well.

13.8 Adaptive management

Anyone involved in fisheries and fisheries management will know that the only forecast that can be made about the future with any confidence is that we cannot be sure about what will happen. Marine social–ecological systems are dynamic and variable, and our knowledge of them is still very imperfect. Two fundamental approaches provide the means to help managers and stakeholders keep on track and ensure that, except in the case of major unexpected events or catastrophes, the agreed objectives are achieved. The first is the precautionary approach (see Section 13.3) and the second is the use of adaptive management or feedback control.

While the term adaptive management may sound intimidating, it is simply the implementation in fisheries management of an approach that we all employ almost instinctively in many aspects of our lives. In driving a car, one does not aim in the general direction of one's destination, turn up the music, close eyes and relax. On the contrary, driving, even along a straight road, requires constant evaluation of the direction of the road ahead compared to the direction the car is heading and continual adjustments of the steering wheel to stay in the correct lane and go in the right direction. Adaptive management in fisheries uses the same principle.

Implementation of adaptive management requires that (i) the manager is fully aware of the agreed operational objectives for the fishery; (ii) the key features of the system related to those objectives are being monitored with sufficient accuracy and precision to enable the manager to determine whether or not they are being met (Chapter 12) and (iii) the management system and process allow for the frequent review and modification of the management measures when necessary. In practice, this will require that, for example, every year the data are analysed and stakeholders consulted to generate the required indicators; the indicators are compared to the agreed reference points or reference directions; excessive deviations from the reference points are identified and appropriate modifications to the management measures are identified and implemented. In addition, every 3–5 years, a major strategic review of the fishery should be undertaken, the objectives reviewed to ensure that they are still desired and feasible (and revised where necessary), and the management measures modified as necessary in order to achieve the updated set of objectives, also taking into account any changes in the system (Figure 13.10).

Lessons learned from the monitoring and analysis of indicators will frequently enable scientists and stakeholders to gain more insight into the dynamics of the system, which in turn can feed back into improved management. In this way, adaptive management also allows for continual updating of knowledge and understanding of the system.

In adaptive management, the learning need not only be passive and the manager, with full knowledge and consent of the stakeholders, could allow active exploration of the system to learn more about how it will respond to different actions. For example, still applying a precautionary approach, fishing mortality could be increased above the target level for a season to see whether the stock does decline as expected (ensuring that the decline is not to dangerous levels) and then eased the following year to see whether it recovers as expected. In this way, it should be possible to improve the best estimate of stock productivity. Similar cautious exploration of other properties of the fishery as a whole can be pursued through adaptive management.

Such active adaptive management can be particularly effective in cases where different approaches can be used for different physical areas, for example where a fishery is exploiting relatively sedentary organisms such as molluscs or resident fish species. Comparison of the results for the different areas will then help to indicate the best approaches to use.

13.9 Synthesis and outlook

If there is a single key message to be extracted from this chapter, it is that, in order to be effective, fisheries management must be driven by the objectives for the fishery. It is therefore imperative that those objectives are identified, conflicts between them recognised and resolved with the stakeholders, and that the manager knows and understands the agreed set of objectives. The task of the fisheries manager is then to ensure that the management processes and measures are the most suitable to achieve the objectives, given the nature of the social–ecological system and the capacity of the management agency and stakeholders. This will require transparent, participatory decisions based on the best available scientific and stakeholder knowledge, backed up by effective monitoring, control and surveillance (Chapter 14). The manager and decision-makers must also realise that no set of scientific results or other forms of information are ever completely accurate or precise and there is always uncertainty in any analysis. With considered application of the precautionary approach, management must take into account this uncertainty, and management measures must be robust to it, so that there is a minimum risk of unexpected events leading to failure to achieve the expected objectives. In addition, social–ecological systems are continually changing and the changes must be monitored and measures modified in an ongoing process of adaptive management.

The future issues and developments in the use of scientific information for fisheries management need to be considered in the context of two extreme cases, even though the majority of fisheries around the world fall somewhere between those extremes. The extremes are, first, 'clean' commercial fisheries that target only one or very few species and have relatively high commercial value, and, second, the opposite: fisheries that catch many different species and that generate relatively low financial returns.

In the case of the first, the relatively high value means that there is generally money available to support high capacity management, potentially including fisheries independent and dependent monitoring of biological, ecological, social and economic features and indicators. In these fisheries, improvement and future solutions to reducing scientific uncertainty, ensuring effective stakeholder participation, decision-making and monitoring control and surveillance are likely to be sophisticated and 'high-tech'. Management procedures (Section 12.4.1) are likely to become the standard as they provide a valuable framework for incorporation of the best available knowledge and information, formal consideration of uncertainty and good stakeholder participation. Advances in computing power will also mean that Bayesian methods of assessment are increasingly used to generate scientific advice across biological, ecological, economic and social factors.

In such fisheries, a range of scientific models will be used to examine tactical and strategic decision-making for an ecosystem approach. Single-species models will still be used for the target species and, where necessary, for important bycatch species but they will be supported by other models that include the most important ecosystem interactions for the questions being asked. With such intense and sophisticated information, used within an effective and well-implemented adaptive management approach, serious failures could become very rare.

The outlook for effective management of multi-species, low value fisheries is far more uncertain and it is in this field that the greatest scientific challenges arise. In the view of this author, the future direction of scientific assessment and provision of advice is far from clear and, while a number of broad directions are being explored and promoted at present, none of them promise the levels of scientific accuracy and precision attainable in single-species fisheries. As a result, considerably greater precaution is, and will continue to be, required for sustainable use, which means that potential benefits will have to be forsaken to reduce the risks of undesirable impacts to acceptable levels. As many of the cases of this type of fishery can be found in developing countries, potential benefits will be lost where those dependent on fisheries have the greatest basic need of them. However, without the necessary precaution, there will be high risks of over-exploitation and depletion leading to even greater hardship in the future.

The problems to be addressed in these cases include the following:

- Identifying simple indicators that can be measured and monitored with low management capacity but nevertheless provide reliable measures of the state of resources and the ecosystem.
- There are frequently many widely dispersed landing sites in such fisheries but landings and effort need to be effectively monitored and aggregated for the stocks and ecosystem as a whole.
- Multi-species catches include species of differing vulnerability as a result of differing productivities and catchabilities. Identification of fishing gear and practices as well as management measures that allow for selective exploitation at rates proportional to productivity should be a priority.
- Identifying and applying management measures that are more robust to uncertainties in knowledge.

The solutions to these problems will be only partly scientific. Stakeholder participation in monitoring, enforcement and provision of valid information to supplement limited capacity of management agencies must be a key ingredient in any progress towards effective management in these fisheries. At the scientific level, further exploration of suitable indicators of the status and trends of resources and important ecosystem properties is important to determine which are reliable and cost effective. Indicators could be in the form of trends in selected indicator species (e.g. particularly vulnerable species or predators that 'integrate' changes across a variety of prey species), changes in the length composition and structure of exploited fish communities and changes in indirect measures such as extent and quality of habitat. Equally important will be how to use these indicators within an adaptive management framework that allows rapid response to significant changes while minimising the risk of fruitless and wasteful adaptive responses to false alarms. Management procedures will also provide the framework for such systems, but in these multi-species fisheries, the rules will be based on and triggered by information that is more qualitative and more dependent on stakeholder information than in the former case.

Sources and recommended reading

Belton, V. and Stewart, T.J. 2002. *Multiple Criteria Decision Analysis: An Integrated Approach*. Kluwer Academic Publishers, Dordrecht.

Caddy, J.F. and Mahon, R. 1995. Reference points for fisheries management. FAO Fisheries Technical Paper No. 382. Rome, FAO. 83p.

Charles, A.T. 2001. *Sustainable Fishery Systems*. Blackwell Science, Oxford, United Kingdom.

Cochrane, K.L., Augustyn, C.J., Bianchi, G., de Barros, P., Fairweather, T., Iitembu, J., Japp, D., Kanandjembo, A., Kilongo, K., Moroff, N., Nel, D., Roux, J.-P., Shannon, L.J., van Zyl, B. and Vaz Velho, F. 2007. *Results and conclusions of the project 'Ecosystem approaches for fisheries management in the Benguela Current Large Marine Ecosystem'*. FAO Fisheries Circular No. 1026. Rome, FAO. 167p.

FAO. 1996. *Precautionary Approach to Capture Fisheries and Species Introductions*. FAO Technical Guidelines for Responsible Fisheries. No. 2. Rome, FAO. 54p.

FAO. 1997. *Fisheries Management*. FAO Technical Guidelines for Responsible Fisheries. No. 4. Rome, FAO. 68p.

FAO. 1999. Guidelines for the routine collection of capture fishery data. FAO Fisheries Technical Paper No. 382. Rome, FAO. 113p.

FAO. 2003. The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome, FAO. 112p.

FAO. 2005. *Putting into Practice the Ecosystem Approach to Fisheries*. FAO, Rome. 76p.

Fletcher, W.J., Chesson, J., Fisher, M., Sainsbury, K.J., Hundloe, T., Smith, A.D.M. and Whitworth, B. 2002. National ESD Reporting Framework for Australian Fisheries: The 'How To' Guide for Wild Capture Fisheries. FRDC Project 2000/145, Canberra, Australia.

Fletcher, W.J., Chesson, J., Sainsbury, K.J., Hundloe, T. and Fisher, M. 2003. National ESD Reporting Framework for Australian Fisheries: The ESD Assessment Manual for Wild Capture Fisheries. FRDC Project 2002/086, Canberra, Australia.

Gayanilo, F.C. Jr., Sparre, P. and Pauly, D. 2005. *FAO-ICLARM Stock Assessment Tools II (FiSAT II)*. Revised version. User's guide. FAO Computerized Information Series (Fisheries) No. 8, Revised version. Rome, FAO. 168p.

Hilborn, R. and Walters, C.J. 1992. *Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty*. Chapman and Hall, New York. 570p.

Hoggarth, D.D., Abeyasekera, S., Arthur, R.I., Beddington, J.R., Burn, R.W., Halls, A.S., Kirkwood, G.P., McAllister, M., Medley, P., Mees, C.C., Parkes, G.B., Pilling, G.M., Wakeford, R.C. and Welcomme, R.L. 2006. Stock assessment for fishery management – A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP). FAO Fisheries Technical Paper No. 487. Rome, FAO. 261p.

Plagányi, É.E. 2007. Models for an ecosystem approach to fisheries. FAO Fisheries Technical Paper No. 477. Rome, FAO. 108p.

Punt, A.E. and Hilborn, R. 1996. BIODYN. Biomass dynamic models. User's manual. FAO Computerized Information Series. Rome, FAO.

Seijo, J.C., Defeo, O. and Salas, S. 1998. Fisheries bioeconomics. Theory, modelling and management. FAO Fisheries Technical Paper No. 368. Rome, FAO. 108p.

Walters, C.J. and Martell, S.J.D. 2004. *Fisheries Ecology and Management*. Princeton University Press, Princeton. 399p.ww

Part V

Implementation

Chapter 14

Fishery Monitoring, Control and Surveillance

Per Erik Bergh and Sandy Davies

14.1 Introduction

14.1.1 Illegal unreported and unregulated fishing

Fishing that falls into the categories of illegal, unreported or unregulated is variably estimated to have a value of between $9 and $23 billion per year. Illegal unreported and unregulated (IUU) fishing covers a complex range of unlawful actions and entities (Box 14.1) and is without doubt a growing global concern for fishery managers, producers, traders, consumers and the fishers themselves. Economic gain is the main force behind IUU fishing, at a time when the demand for fish is increasing, while the constraints on legal fishing are also increasing. Together, these form a strong motivation for IUU fishing with many opportunities for gains.

Box 14.1 Definition of IUU Fishing from the International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU)

Illegal fishing refers to activities conducted by national or foreign vessels in waters under the jurisdiction of a state, without the permission of that state, or in contravention of its laws and regulations; or conducted by vessels flying the flag of states that are parties to a relevant regional fisheries management organization but operate in contravention of the conservation and management measures adopted by that organization and by which the states are bound, or relevant provisions of the applicable international law; or in violation of national laws or international obligations, including those undertaken by cooperating states to a relevant regional fisheries management organization.

Unreported fishing refers to fishing activities which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization.

Unregulated fishing refers to fishing activities in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a state not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and

management measures of that organization; or in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with state responsibilities for the conservation of living marine resources under international law.

(http://www.fao.org/DOCREP/003/y1224E/Y1224E00.htm).

Box 14.2

The 1993 FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, known as the compliance agreement facilitates international and regional cooperation. This covers vessel listing and information sharing with clear responsibilities given to the flag state to exercise the required controls to ensure that fishing vessels do not engage in illegal activities. It places an obligation on the flag state to take 'such measures as may be necessary to ensure that fishing vessels entitled to fly its flag do not engage in any activity that undermines the effectiveness of international conservation and management measures'.

The Agreement entered into force on 24 April 2003 upon the receipt by the Director-General of FAO of the twenty-fifth instrument of acceptance. The purpose of the agreement is to restrict the issue of re-flagging of fishing vessels into flags of convenience to avoid compliance with agreed conservation and management measures.

(http://www.fao.org/fishery/topic/14766).

A number of global responses have taken place to quantify and help combat IUU fishing including the UN Convention on the Law of the Sea, the FAO Code of Conduct for Responsible Fisheries, the FAO UN Fish Stocks Agreement, the FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (Box 14.2) and the International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU) (Box 14.3; Chapter 5).

Due to its inherent complexity across all stages of the exploitation and utilization of fish, no one response alone is adequate to overcome IUU fishing. However, robust and flexible national monitoring, control and surveillance (MCS) systems linked to strong regional and international cooperation on MCS are essential elements towards stopping IUU fishing.

14.1.2 Monitoring, control and surveillance

In brief it could be said that MCS is all about ensuring compliance with fishery management measures. The core objective is to contribute towards good fishery management through ensuring that the required information is available to set the appropriate controls, and that

Box 14.3

The International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU) is a voluntary instrument listing various measures that countries and regional fishery management organizations may wish to adopt in order to eliminate IUU fishing. Although voluntary in nature, the IPOA-IUU sources many of its provisions from binding international fisheries instruments so it provides a good source of guidance to an MCS manager in finding MCS solutions that are compliant with international legal frameworks and best practise. Countries are also encouraged to develop a National Plan of Action (NPOA-IUU) that will be closely linked or integrated into the MCS strategy and plan.

(http://www.fao.org/fishery/ipoa-iuu).

Box 14.4 Definition of MCS

Monitoring refers to the collection, measurement and analysis of fishing activity including, but not limited to, catch, species composition, fishing effort, bycatch, discards and area of operations. This information is primary data that fisheries managers use to arrive at management decisions. If this information is unavailable, inaccurate or incomplete, managers will be handicapped in developing and implementing management measures.

Control involves the specification of the terms and conditions under which resources can be harvested. These specifications are normally contained in national fisheries legislation and other arrangements that might be nationally, sub-regionally or regionally agreed. The legislation provides the basis for which fisheries management arrangements, via MCS, are implemented.

Surveillance involves the regulation and supervision of fishing activity to ensure that national legislation and terms, conditions of access and management measures are observed. This activity is critical to ensure that resources are not over-exploited, poaching is minimized and management arrangements are implemented (FAO, 1981).

these are monitored and complied with (Box 14.4). Controls have been discussed in detail in Chapters 7 and 8 (technical measures) and Chapter 9 (input and output controls) all of which are considered as part of the 'control' element of MCS.

In order to meet the objective of compliance with fishery management measures and thus stopping IUU fishing, there is a wide combination of options available to the MCS manager. These include a range of components of hardware in varying degrees of sophistication, various capacity in human resources, a range of approaches to implementation ranging from military-type enforcement to community-driven compliance programmes and finally to more choices of how to manage the MCS system and organization. This chapter gives an overview of the most common options available and an insight into some advantages and disadvantages associated with them.

14.1.3 A historical perspective to MCS

The need for formal MCS systems is a relatively new concept that links very strongly to the United Nations Convention on the Law of the Sea and the establishment of the exclusive economic zones (EEZs) and their related legislative systems. Prior to this, as the majority of fishing activities within the 'managed' territorial seas could be viewed from the shore, MCS requirements were often simplified to a code of behaviour that existed within an informal management system.

The MCS systems that were developed for the new EEZs were essentially the implementing or policing arm of fishery management. Their role was to ensure that control measures were adequately implemented and that fishing took place within the legal framework set up to manage the fishery. This is still a core function of MCS systems, but due to a more integrated approach to fishery management, encouraged through many international instruments but specifically the FAO Code of Conduct, a far wider and more linked role for MCS has emerged.

MCS strategies now focus more strongly on integration within fishery management plans (see Chapter 16); promotion of compliance by fishers through user participation (see Chapter 11); and provision of information for regional fishery management organizations and the monitoring of international obligations and agreements. Thus the modern MCS organization works closely with other sections of the fishery management organization, the fishing community, industry and regional or international bodies guiding or managing shared fisheries resources.

14.1.4 The role of MCS in fishery management

Potentially, illegal fishing or illegal fishing activities could compromise the implementation of management plans and can, in extreme cases, undermine the rational exploitation of the resource. Ensuring that management plans are properly implemented and that non-compliance is kept to an acceptable level is therefore a priority. This involves interlinked and compatible systems that provide feedback and checks into the management strategy. The MCS organization, as a key implementer of fishery management plans, provides information into the fishery management process to guide the development of management measures and priorities for fishery strategies and plans. For example, the use of total allowable catches (TACs) as a means to control catch levels implies that all landings must be monitored and catch by species recorded, adequate steps are required to prevent discarding at sea and the unregistered transhipment of catches. It must therefore be asked: can the MCS organization do this or can they be developed to do so? It is answers to the questions in the Box 14.5 that the MCS manager must seek in order to develop the practical MCS response to annual planning and also the longer-term strategic planning.

14.2 The MCS solution

There is no unique MCS solution for all fishery situations, nor are there inherently right or wrong approaches to the implementation of MCS systems. MCS systems are usually developed or evolve for either specific fisheries or a group of interacting fisheries taking into account the ecological and fisher or fleet dynamics and interactions. MCS systems will also be shaped by a variety of factors that include aspects important to all three elements of MCS.

Box 14.5 Questions for MCS managers

The following questions give examples of the type of questions that the MCS managers should be asking:

1. Have you *been consulted* when fisheries management plans were developed? Input from the MCS operational element is vital to ensure choice of realistic management measures.
2. What are the *practical requirements* needed to implement the management measures, this could be considered from the monitoring, surveillance, compliance and enforcement points of view, and are these available?
3. What is the *estimated cost of implementing* these management measures from both a financial and resource perspective and, from a financial perspective, who should cover these costs, government, industry or both?
4. Have any *evaluations of the success or failure* of previously set management measures been made, and if so, do the results provide any practical guidance to the new proposals?
5. What are the factors that will *encourage compliance* rather than demanding enforcement and what are the requirements to develop these – are they feasible?
6. Have any *risk assessments* been undertaken on the impact of non-compliance of proposed management measures on the status and viability of the fishery?
7. How are you going to present and justify the requirements to implement the legislative framework including management measures to the political and senior management of your organization (your case has to be *clearly argued*, properly budgeted and explicable in relation to the consequences of not implementing the different components of your plan)?
8. Have you included any *monitoring and evaluation routines* into your annual plan to ensure a better knowledge of the compliance within each fishery? Better knowledge about fisheries compliance will ease future planning and prioritizing.

The following section provides an overview of some of the key factors that may influence the design of an MCS system.

14.2.1 Type of fishery

Different fishery types require different responses; for an *industrial fishery* the emphasis is more commonly on enforcement than on voluntary compliance, and involves a range of more traditional components such as vessel registers, observer programmes, Vessel Monitoring System (VMS) and patrol vessels and aircrafts. The monitoring requirements are generally simpler than in artisanal fisheries as vessel logbooks can be implemented, VMS and observers can be placed on larger vessels and the landing of fish can be directed through certain ports that facilitate monitoring of landing. Whereas in an *artisanal or small-scale fishery*, the combination of large numbers of fishers and landing places, mixed gears and migrant fishers often makes MCS a complex task. Two approaches are commonly adopted for artisanal

fisheries; these are a community-based approach to participatory management (Chapters 3 and 11) and the use of government data collectors, combined with annual frame surveys and where possible some enforcement personnel.

The type of gear in use in the fishery is important: generally passive gears are easier to monitor and control than active gears that require more mobility, equipment and complex detection systems. When an effective MCS system is in place, potential poachers are far more likely to use active gears than to risk the possibility of being caught when returning to collect passive gears. For example, in the Norwegian salmon fishery, the fishery officers lie in wait for returning fishers that have left unlabelled or mislabelled nets in the water, when offenders are identified they receive significant fines and the nets are confiscated.

Multi- or single-species fisheries will also have different demands on the MCS system. Single-species fisheries will often have more sophisticated control measures, but as the fishers or vessels are more similar this makes monitoring simpler. Multi-species fisheries may have less complex controls but a large variety of fishing methods and vessels that require considerable effort to monitor adequately.

If foreign fleets or migrant fishers are involved in the fishery a good MCS system is vital. This system must place an emphasis on deterrence and enforcement while ensuring adequate monitoring of catches. In general, foreign or migrant fishers and vessels are less inclined to comply with the regulatory regime of the fishery than national fishers or fleets that have a longer-term interest and involvement in the fishery.

A multi-user fishery is when more than one type of fisher is targeting a fishery, for example artisanal, industrial or recreational. In this case the MCS effort may need to be prioritized by targeting the user that potentially offers the biggest threat to the fishery, and also developing different but complimentary approaches for the different sectors.

14.2.2 Type of management measure

Input controls control the effort put into fishing (refer to Chapter 9 for more details). This can include controls related to the number and size of vessels (capacity control) or the time spent fishing (usage control). Broadly speaking, effort control is the simpler control type to enforce. Vessels and fishers need to be monitored for compliance to effort controls, but in general fishers will be more willing to provide catch and effort data as there is no obvious benefit from giving falsified information.

Closed areas and seasons (Chapter 8) are also a means for controlling effort as well as restricting bycatch, size or spawning conditions by means of limiting the area available for fishing. This type of zoning lends itself well to self-policing through community involvement. Generally, closed areas are easier to enforce than gear or catch restrictions or 'no take' areas, as no vessels are allowed in the area, and this can be monitored more easily than having to check gear or ensure if fishing is actually taking place.

Output controls limit what is caught through limits of TAC, bag size or limiting bycatch (refer to Chapter 9 for a fuller description). Output controls require more intensive MCS systems to ensure that the controls are fully enforced. To obtain accurate figures on catches by species, complete monitoring at landing sites is required or detailed inspections at sea or observer programmes as methods to validate logbook, landing or production information. If a high level of infringement is anticipated, a strong deterrent to fishers will be needed combined with an evaluation of the levels of non-compliance.

14.2.3 The legal framework

The national legal arrangements within a country set the framework for the operational activities of the MCS system (see Chapter 5). The legal framework will establish: who can fish, where they can fish, what they can fish with, how much they can catch and where it can be landed. Important elements of the framework also include: how to correctly conduct fisheries investigations and arrests; how to prepare for and conduct successful prosecutions; and how to ensure coherence of penalty across different violations of the legislative regime. It is important that those developing and those operating an MCS system understand the legal arrangements and the mechanisms to change them.

The leading legislation in each country is the Constitution, followed by Acts (or similar instruments). There will normally be an Act relating to Fisheries and one that determines the Maritime Zones. These are both of importance to any MCS strategy or plan. The Act relating to fisheries will provide details on definitions, management regimes (including the designation of power to the appropriate government authorities and local governments or communities to determine and implement fishery and MCS policy), powers of MCS officers (inspectors, observers, etc.) and details on the offences that can be made under the Act (see Chapter 5). There will most commonly be some form of regulations or system for providing lower-level supporting legislation to the fisheries, this may include licences and other legally binding documents where the rules and regulations of the individual fisheries are set out. It is important to design an MCS strategy that will work effectively within this legal framework.

14.2.4 Human resources

People are at the core of any MCS organization or operation: no technology, strategy or plan will be able to replace the demand for skilled and reliable personnel. A realistic evaluation of the personnel available in relation to: the MCS needs; the financial resources; the time available; and the feasibility for long- and short-term training are an important step in planning for MCS activities. The following points could be considered in such an evaluation:

- Knowledge levels: what are the minimum knowledge levels required for the different personnel tasks or professions?
- Recruitment and retention procedures: what are the criteria used for recruitment and will these be suitable for the MCS needs?
- Probability of corruption: what is the potential for corruption among MCS personnel and are anti-corruption initiatives and mechanisms implemented into the system?
- Training capability and capacity: what level of training can the organization provide for personnel and what external training will be required, how long will it take?
- Political, social and policy requirements: is your organization aiming for a labour-intensive system or is efficiency more important?

MCS personnel with adequate knowledge and skills are one of the main keys to success in MCS operations. Basic knowledge will be needed immediately to get the organization going (international technical support may be one option to initiate a professional and functioning operation if this knowledge is not available locally). However, in order to assure the long-term sustainability of the organization, it is prudent to develop and put into place, as early as

possible, a training plan for all levels of staff which runs throughout their career structure. In planning the organization's human resource strategy it is worth considering:

- If a well-trained, better-paid and smaller workforce would result in higher productivity, greater transparency and a more effective organization than a less competent larger workforce.
- That training should ideally be officially acknowledged, for example through incentives such as permanent employment, higher rank, bonuses or higher salary. This is important for motivation, sustainability and recruitment in the organization.
- That practice has shown that the most effective way to train for lower-level jobs is through vocational training preferably based on adult learning principles. These training programmes (for observers, data collectors, inspectors, clerks and VMS operators) can often be taught by more senior personnel in the organization and developed for specific local situations.
- That for in-house training courses it is also important that quality criteria are implemented for instructors.

14.2.5 Financial requirements

Cost-effectiveness is a primary consideration for all MCS systems and a comparison between the costs and benefits from different MCS options is required in order to develop the most suitable system for each situation. The MCS strategy should provide guidelines on the financial resources available and generally, if the cost of the MCS system exceeds this alternative, less costly options should be explored.

Evidently, the benefits to a country of a fishery cannot be measured by the income to government from levies, fees and taxes alone. However, many countries, especially those in the developing world tend to have to keep their fishery management costs within this limit. Examples include: in the 1990s, the United States spent approximately US$80 million on the surveillance of foreign fishing operations while collecting only US$41.5 million annually from the same fishing fleet (Kuperan *et al*., 1998). While, in contrast, in the small coastal state of Costa Rica, the cost of a modest enforcement programme for the tuna fishery was calculated to be about 50% of the expected revenue from this fishery. The choice as to which MCS system is developed will be highly influenced by the level of finances available to develop and maintain it.

Special provision is given to developing countries in the FAO Code of Conduct, Paragraph 5.5.2 where assistance is requested in areas including financial and technical assistance, technology transfer, training and scientific cooperation. Funding for fisheries management in many developing countries relies, to some extent, on donor assistance. There are some pitfalls related to this type of support; examples include the donation of expensive hardware to countries that do not have the capacity to operate and maintain these generous gifts. In such cases, greater benefit would have resulted from a more moderate MCS system with consideration of long-term costs and sustainability. Where an MCS strategy or plan is in place, any development assistance should be implemented in line with this, where no strategy or plan exists the development assistance should assist in the development of a plan.

14.2.6 MCS dimensions

Fisheries are managed by managing the fishers not the fish, that is to say that MCS relates to the fishers and fishing-related activities and not to the fish stock *per se* (see Section 3.1). This

includes routine fishery operations in four key dimensions: before fishing, during fishing, during landing of the fish and post landings. These dimensions along the value chain should be considered in order to obtain the optimal level of monitoring and surveillance at the least cost. For example, in the European Union, cross-checking is made through logbooks, catch and effort reports, VMS, patrol vessels and planes during fishing, landing declarations at point of landing and sales notes at post landings.

14.2.7 Targeted MCS

The use of targeted MCS is an important strategic consideration that can impact on the cost-effectiveness and the efficiency of the organization. When an individual fishery covers a large physical area or the total number of fisheries managed by one authority covers a large area, the available MCS resources may become stretched. Random checks as part of a sampling strategy may be sufficient for monitoring, but the surveillance effort would benefit from targeting known or suspected offenders, that is it must be intelligence driven. This targeting of routine offenders rather than the occasional or opportunistic offender is important to increase detections and to serve as a visible deterrent to potential offenders.

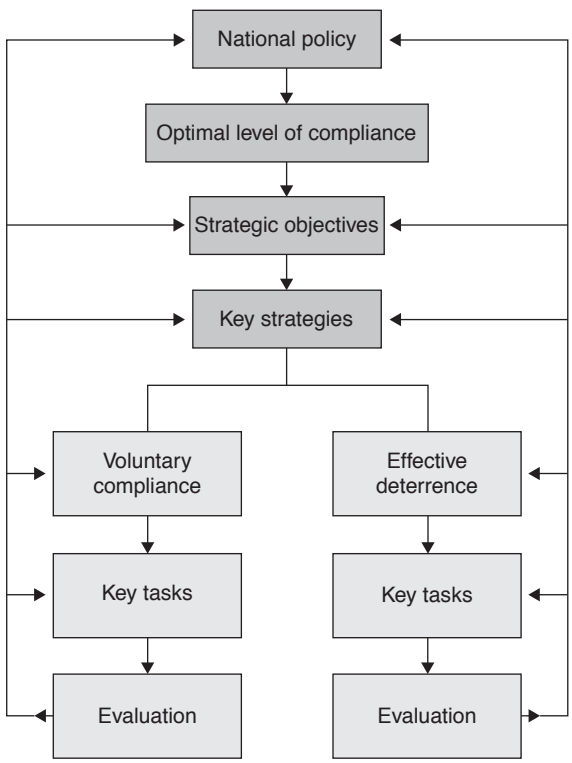
Intelligence-driven enforcement is also known as adaptive enforcement. The information often comes from the fishing community itself as part of a cooperative or participatory management approach. Encouraging reporting can be a difficult task: fishers will often feel loyal to their colleagues, especially as one day their safety may depend on them. To encourage fishers to report, the following suggestions may help: a code of ethics for fishers; education to the fishers about their role in the management system; easy reporting methods (e.g. Western Australia's 24-hour telephone line or the Internet reporting system for the Southern Ocean toothfish); a reward for the information; clear administrative systems and legislation; and, perhaps most importantly, the nurturing of good relationships between the inspection officers and the fishers.

14.2.8 Compliance or enforcement

Many fishers operate in an environment rigorously controlled by the authority, yet an environment that is isolated and without witnesses or law enforcement units present. Fishers are easily and frequently tempted to violate the regulations designed, as they often see it, specifically to restrict their effectiveness. So what can the fishery manager do? The answer lies in balancing the enforcement and compliance aspects of the MCS system, to encourage an environment where maximum compliance from fishers occurs and to use enforcement in areas where this is not successful or requires support. Box 14.6 demonstrates the Australian fisheries national compliance strategy and how they have balanced the roles of voluntary compliance and effective deterrence to achieve the optimal level of compliance as that '*which holds the level of non-compliance at an acceptable level, which can be maintained at a reasonable cost for enforcement services while not compromising the integrity and sustainability of the resource*'.

Fisher compliance, called voluntary compliance, has a role to play in all MCS strategies and it is considered to be one of the positive outputs of adopting a participatory approach, which is the essence behind Paragraph 7.1.2 of the FAO Code of Conduct. However, voluntary compliance is more of a process than an end point; it tends to take longer to nurture

Box 14.6 Australian Fisheries National Compliance Strategy 2005–2010[1] Compliance Schematic



Strategy 1: Maximizing voluntary compliance

- Key Task 1.1: Demonstrate the benefits of fishery management measures by providing adequate information and education
- Key Task 1.2: Engage key stakeholders in compliance planning and development of the legislative framework
- Key Task 1.3: Implement complementary compliance programmes across all jurisdictions
- Key Task 1.4: Demonstrate the capacity to rapidly adapt compliance programmes in response to changing circumstances
- Key Task 1.5: Allocate compliance funding sufficient to achieve optimum compliance
- Key Task 1.6: Continually monitor and report on effectiveness
- Key Task 1.7: Ensure that fisheries laws are administered and enforced fairly, reasonably and cost-effectively

Strategy 2: Creating effective deterrence

- Key Task 2.1: Deliver the optimal mix of compliance functions appropriate for each fishery
- Key Task 2.2: Utilize risk management principles in compliance planning
- Key Task 2.3: Match legislative deterrents to severity and frequency of resource crime, including forfeiture of proceeds from illegal activity
- Key Task 2.4: Actively engage law enforcement partners in pursuing fisheries criminals through complementary legislation, systems and practices
- Key Task 2.5: Implement cost-effective strategies for maximizing detection of offences
- Key Task 2.6: Utilize the media appropriately to communicate compliance outcomes
- Key Task 2.7: Continually monitor and report on effectiveness
- Key Task 2.8: Maintain the effectiveness and integrity of compliance staff through advanced training, processes and accountable decision-making

Source: http://www.afma.gov.au/management/compliance/docs/compliance_strategy_2005.pdf

and for results to become apparent. This may not be fast enough if violations are critical to the sustainability of the stock, in which case, the best option may be immediate enforcement action with a longer-term view to increasing voluntary compliance.

People are more inclined to obey rules that they feel are legitimate, rightful, justifiable and reasonable (see Section 11.1). If a perception of fairness exists in the legislation it will be more effective. Creating this sense of legitimacy towards the management strategy or any particular control will depend on factors, such as

- the content of the regulation itself – how does it compare with the view of the fishers?
- do the regulations target fishers equitably?
- are other partners (fishmongers, processors, recreational sector etc) carrying a fair burden?
- were the fishers involved in the formulation of the controls and regulations?
- is the implementation of the management regime transparent?
- do the fishers feel an ownership towards the management?
- is there a good dialogue between the authorities and fishers?

Legitimacy does not just apply to the legislation itself, but also to the perception of the fishery management authority. If the public perception of the authority's governance, technical skills, work ethics and approach to the public is low, this may reduce the overall compliance by fishers as it reduces their respect for the management authority.

Deterrence is another way to increase voluntary compliance and it mainly relates to the severity and certainty of sanctions. Illegal activities must be unprofitable, and more importantly it is vital that fishers cannot get caught for a violation and still gain from the crime. If voluntary compliance is an objective, then crime must not pay (FAO Code of Conduct, Paragraph 7.7.2); if the deterrence is high enough, then compliance is encouraged. In Western Australia the rock lobster fishery is a high-value fishery where industrial fishers are given

'black marks' for serious offences. If three black marks are given in a 10-year period then their license is cancelled. This high penalty system has ensured high compliance.

Community management is a term that generally refers to the involvement of small-scale or artisanal fishers in the fishery through the community structure, while participatory management refers to all types of fisheries and includes community management. Community management has a special place to play in MCS and for many countries it is the most feasible option to encourage compliance especially in situations where fishers are financially or socially marginalized. This may prove to be a difficult situation for a fishery manager, who appreciates the needs of fishers but is also responsible for managing the long-term sustainability of the fishery. Often, only community intervention will be able to influence fishers in such situations (Chapter 11 discusses this subject further). Many success stories in community management have been reported from the Philippines. In a country of 7000 islands and a coastline of 17,460 kilometres, sustainable management of coastal resources is vital. The principle of community management has been institutionalized in laws at the national, provincial and municipal levels.

14.2.9 Balancing trade-offs

There will inevitably be trade-offs between different combinations of solutions such as the choices between covert or overt surveillance, education of interest groups or traditional enforcement, total monitoring or sampling. For example, a regular presence by MCS platforms such as patrol vessels will act as a deterrent to discourage potential violators from carrying out illegal operations, but equally, it may be important that an initial inspection performed in an area arrives as a surprise to the crew of the fishing vessels. These two strategies are obviously inconsistent and it is therefore important to find a balance that suits the objectives of the specific situation or operation.

Aiming for 100% compliance may be less cost-effective than achieving 80% compliance, with the 20% non-compliant element being factored into the management plan. The point of interest is that when developing a strategy for monitoring or surveillance, a balanced and realistic approach must be considered, with the aim for level of compliance being a strategic decision.

14.3 Core components

This section considers the most common components of an MCS system with a focus on physical components and hardware. Information is included on the objectives of each component and its ability to monitor implementation of different control measures (Table 14.1). There are inherent advantages and disadvantages in each component (Table 14.2) and these need to be matched and compared to the individual situation.

14.3.1 Before fishing

Control of fishing vessels or small crafts and fishers before fishing trips, at the time of the issue of a licence, through annual frame surveys or through spot checks is a useful and low-cost MCS operation that can facilitate the following:

- the checking of gear and effort control mechanisms (e.g. horsepower and vessel capacity) to ensure that regulations or licence conditions are complied with;

Table 14.1 Comparison of the effectiveness of different MCS components to implement control measures.

Dimension	Component	Effectiveness of element for management controls			Detection of unlicensed vessels/fishers	Ability to arrest	Cost
		Input	Output	Technical			
Before fishing	Clearance/issue of documentation	Medium	None	None	No	Yes	Low
	Vessel clearance	Medium	None	Low	No	Yes	Low
While fishing	Logbooks	Medium	Medium	Low	No	No	Low
	Patrol vessels	Medium	Medium	Medium	Medium	Yes	High
	Patrol planes	None	None	High	High	No	Medium
	Helicopters	None	None	High	High	Yes	High
	Observers	High	High	Medium	Low	No	Low/medium
	VMS	Medium	None	High	No	No	Low/medium
	Satellite imagery	None	None	Medium	Medium	No	Low/medium
	Beach patrols	High	High	High	High	Yes	Low
	Navy or coastguard	Low	Low	Low	High	Yes	High
During landing	Catch monitoring	None	High	None	No	Yes	Low
	Transhipment monitoring	None	High	None	No	Yes	Low
Post landing	Market and sales monitoring	None	Medium	None	No	Yes	Low
	Export monitoring	None	Medium	None	No	Yes	Low
	Roadblocks and transport monitoring	None	Low	None	No	Yes	Low

- the securing of illegal gear detected so that it is not possible to use it while fishing;
- the gathering of information for fishery statistics;
- the determination of any catch remaining onboard from previous fishing trips;
- a positive interface between fishers and the MCS organization and personnel;
- feedback from the fishers for planning or fisher intelligence; and
- an opportunity to distribute legal and administrative information.

Fishery inspections can also link to safety inspections (FAO Code of Conduct, Paragraph 8.4.1). Fishing at sea is one of the most dangerous occupations in the world and it is important for fisheries management authorities to play a supportive role in reducing this risk in cooperation with the maritime authority.

14.3.2 While fishing

Fisheries MCS operations carried out at sea can have an impact as a deterrent or for enforcement of all control measures. It is the only method that allows infringements in relation

Table 14.2 Advantages and disadvantages of different components of MCS.

Component	Advantages	Disadvantages
Clearance/issue of documentation	Ensures valid documentation among the fishers and provides opportunity for briefing of captains.	Can only be performed on vessels calling at national ports with an MCS presence.
Vessel clearance	Good source for information about the fishery. Controls in relation to (e.g. engine size, fishing gear) can be conducted.	Fishing gear and other equipment may be hidden.
Logbooks	Can be used onboard any fishing vessel in any language. Keeps historical track on catches and positions. Cheap.	Poor literacy rate by fishers may be an obstacle in certain fisheries. Quality of data will depend on fishers' motivation.
Patrol vessels	Provides at-sea verification of fishing gear, discards, dumping, logbooks and catches. Most important to control offshore operations and foreign fleets. The only platform that can effectively conduct an arrest offshore. High deterrence factor.	High-cost and limited area surveillance capability. Low rate of detection of infringements.
Patrol planes	Can provide high coverage for identification of illegal incursion of unlicensed vessels and effectively patrol borders and closed areas.	No ability to arrest or to inspect catch or gear.
Helicopters	Can cover relatively large area, can deploy inspectors on vessels and arrest.	High cost and limited distance covered compared to patrol plane.
Observers	Can monitor all operations onboard a specific vessel and verify catches, discard, dumping, gear and validation of required documents.	Medium cost. Only viable on larger vessels. The integrity of observers may be a relevant question in terms of the quality of data provided.
VMS	Provides up to real time monitoring for licensed or fitted vessels and can reduce interception times for enforcement craft. Low to medium capital and running costs.	No coverage of vessels not fitted with the required equipment. Require integration with other platforms or sensors to be utilized effectively. Technical maintenance and IT support can be limited in some countries.
Satellite imagery	Full coverage of area scanned.	Expensive for regular scans. No positive identification of targets unless verified by other sensors.
Beach patrols	Efficient tool within recreational and near-shore fisheries. Contact with fishers.	Visibility of inspectors, access to remote areas can be difficult.
Navy and coastguard	If available can be free to fisheries organization, if they are in the field they can monitor border violations.	Limited capability – only border violations as limited fishery knowledge.
Catch and transhipment monitoring	Can monitor landed catch and quotas. Has power to arrest in port. Low capital and running costs.	No possibility of monitoring vessels that do not call at port. No possibility of monitoring dumping, gear violations or offshore transhipments. Information is only of fish landed not those discarded and no geo-referenced data.
Market and sales monitoring	Good information source in terms of landed species and market demands.	Difficult to trace the origin of the fish.
Export monitoring	Good information source on volume of landed fish in high value fisheries.	Only part of the landed catch may be exported.
Roadblocks and transport monitoring	Good tool against sale and transport of illegally caught fish.	Roadblocks are easily detected and can be avoided.

to logbooks, gear types and catch to be detected on the site of the crime (while fishing). Important information is also collected at sea that can be time, date and position referenced, which is particularly important to output and technical controls.

Logbooks

Logbook data such as catch, effort, location, environmental parameters, and gear information are completed by fishers during fishing activities. Logbooks are usually fishery-specific as different information is required for different fishing methods. When completed properly they provide valuable information for scientific assessment and catch monitoring. Control routines or cross-checking of the information is required and often this is done through verification by inspectors or observers or the requirement for daily radio reports.

Patrol vessels

'Fisheries patrol vessel' is a very broad term for vessels in a variety of sizes with many different configurations and these vessels, along with patrol planes, inspectors and observers are seen as the conventional MCS configurations. The advantage of patrol vessels is that they are able to monitor and enforce fisheries legislation on the fishing grounds. Factors such as the fleet to be monitored, the sea and weather conditions and possible hostile situations will determine the capacity and configuration required for a patrol vessel. Patrol vessels carrying fisheries enforcement officers can be the only way to obtain certain vital and legally acceptable evidence of infringements. It is also the principle platform that can be used to conduct an arrest of a vessel in coastal areas or at sea.

Patrol vessels can be costly to buy and to operate, but they are, in many ways, irreplaceable as a deterrent tool. Patrol vessels are slow platforms covering relatively small areas, so efforts must be made to optimize their operations through good adaptive planning and regional or international cooperation. An example of the benefits of authorities working together to utilize patrol vessels better is given in the example of the chase and arrest of the Viarsa 1 in 2003. On the 7 August 2003, Australian Customs and Fisheries patrol vessel Southern Supporter spotted the Uruguay-flagged Viarsa 1 in Australian territorial waters near Heard Island. Suspecting the vessel of illegal fishing for toothfish, the Australians ordered the crew to stop. They fled, and this began a chase across the Southern Ocean that lasted for three weeks. As the chase progressed the Southern Supporter was joined by the South African salvage tug *John Ross*, polar icebreaker *SAS Agulhas* and Falkland Islands-based British fisheries patrol boat *Dorada*. On the 28 August, after a 3900nautical mile (7 200 km) chase, the pursuing vessels surrounded *Viarsa 1* off Cape Town. A boarding party of Australian personnel flew to South Africa and boarded the oil tanker *SAS Drakensberg*, which met the other ships on the 3 September. *Southern Supporter* and *Viarsa 1* arrived in Fremantle, Western Australia, on the 3 October where legal proceedings took place.

Patrol aircrafts

There is a wide range of aircraft available with different performance abilities which are suitable for maritime and fisheries surveillance. Air operations are very useful for surveillance of

large areas and can be utilized in trans-boundary, regional and high-seas operations. They can also be used to sight fish schools, whales, and reef destruction. This MCS component is the only one that can provide an overall picture of a large fishing zone within a short timeframe. Correct utilization and appropriate information sharing of aircraft sightings will improve deployment of patrol vessels and observers.

The ability of airplanes to cover large areas for searches is demonstrated in the example of a Canada and US aerial patrol that identified 10 vessels suspected of illegally fishing with drift nets in the international waters of the North Pacific in September 2007. A Canadian Forces plane captured images of 90 international fishing vessels suspected of breaking the 15-year-old United Nations ban on using drift nets. Millions of square kilometres over the North Pacific were searched during the two weeks. Cameras on the Aurora long-range patrol plane captured images of all the vessels, 10 of these were observed to be either rigged for or engaging in high-seas drift-net fishing at the time.

Helicopters are more limited than fixed wing aircraft in terms of monitoring large areas effectively, but they have the advantage of being able to hoist personnel to and from a vessel and thus undertake a vessel arrest. Helicopters are normally significantly more expensive to operate than a small fixed wing aircraft. In a larger fishery a helicopter can be carried by the patrol vessel to facilitate inspections and arrests.

Observer programmes

Observer programmes provide the opportunity to have full-time monitoring of certain controls such as bycatch or discard regulations. Observers are also able to collect time, date and position information for activities and catches (including biological data) and through this monitor for area and season restrictions and provide valuable information for the scientific organization. Observer programmes also contribute to deterrence and can increase transparency among fishers.

Some organizations prefer to keep observers for scientific purposes only, in order to ensure the integrity of their data, as they believe that fishers will be suspicious of them if they also perform compliance tasks. However, in management regimes with limited resources, it is recommended that observers at least report compliance issues for statistical purposes, as they will generally observe these anyway. This information can then feed into compliance assessments and assist MCS managers to deploy a platform such as patrol vessels and planes to the places where they are most needed.

Observers require training, manuals and suitable equipment and supervision to perform their task adequately. Vessels need to be large enough to accommodate observers, and possibilities need to exist to place and remove (in port, via the patrol or other vessel) observers from vessels. Observers are generally a low-cost option for at-sea monitoring and surveillance and have many advantages such as providing continuous contact with fishers, a high deterrence impact and valuable data collecting. Observers do not normally have the power of arrest so they are only able to record and report any infringements.

Vessel monitoring systems

A VMS (see also Section 5.4.4) provides real-time or next to real-time position, course and speed (PCS) data through a communication link directly into a base station. This allows

operators to follow all vessel activity as it happens on vessels within the system. These data are sent from a unit on the vessel via a satellite to a shore receiving station that displays the vessels on electronic maps with an accuracy of around 100 metres. Satellite communication such as Inmarsat-C is most commonly used, although a range of other options are available, generally depending on the required coverage. VMS allows detection by authorized and participating fishers of fishing in illegal or closed areas, transshipments of fish and transfer of fuel. It is also a tool to assist in more timely and cost-effective deployment of patrol vessels and patrol aircraft.

Additional opportunities provided by a VMS include the manual entering of catch and effort data (from logbooks) that can be forwarded through the same system for assisting in management of quotas and stock assessment. It provides an emergency function built into the system to provide better safety at sea for fishers (see Box 14.7 for an example of an integrated system).

The validity of VMS information in court needs to be tested for each country. Legal experiences internationally suggest that additional information such as photographic evidence from a patrol vessel, plane or observer may be needed to secure sufficient evidence in cases of violations although fishing vessels have today successfully been prosecuted based only on VMS data. VMS monitors those vessels carrying active equipment onboard and will not detect poachers or unlicensed vessels that are not part of the system. The cost of VMS for smaller artisanal or in-shore vessels has in the past been prohibitive, but a trend towards less expensive units is emerging facilitating the opportunity to monitor small-scale operators and ski boats.

A VMS is an information system that demands technical support and skilled operators to be utilized efficiently. Adequate technical support and training needs to be built into the original plans for developing the system or alternatively the establishment of regional VMS centres may be an option. The Forum Fisheries Agency (FFA) of the western Pacific has a regional VMS centre where 17 member countries operate their VMS and share technical resources. The system is managed centrally from Honiara, Solomon Islands with vessel position data being downloaded by members as and when required.

Box 14.7 Icelandic Fisheries VMS

Icelandic fisheries have an integrated VMS programme. There are two tracking systems, one is mandatory for all vessels and is for safety purposes. The other is for fisheries control, in which certain vessels must participate according to their fishery and fishing area. Fisheries control authorities have full access to all data in both systems. The system monitors 1608 vessels divided into 950 anglers, 573 multipurpose and 85 stern trawlers. The purpose of the VMS system is to provide vessel safety and to monitor compliance with fisheries regulations of Iceland, international regulations such as NEAFC and NAFO, and in waters of other states where bilateral tracking agreements are in force (i.e. Greenland, Faroe Islands, Norway and Russia). All costs for shipboard VMS equipment are the responsibility of the vessel owner/operator. For communications costs in the mandatory tracking system for safety purposes, there is a fixed charge per year. In the fisheries control system, the vessel is billed directly for communications. The costs of communications from the VMS, as well as running and maintaining the VMS centre, are carried by the authorities.

Satellite imagery and remote sensing

The future may open up for additional remote sensing tools that will primarily be useful to supplement the VMS in terms of detecting IUU fishing as well as being able to secure more adequate evidence for prosecution of these illegal activities. Satellite images are taken from satellites and include radar or photographic images. Radar images have proven particularly useful as they provide good pictures regardless of cloud coverage or light conditions (day or night) and they detect fishing vessels longer than 35 metres at a 95% probability, while photographic images are limited by these conditions. A picture cannot be ordered as a reaction to an incident as the beam programming requires at least 28 hours advance notice, but ordered pictures can be made available to fisheries officers in near real time. As fishing vessels move slowly when they fish, the comparison of VMS and satellite images will highlight the presence of illegal fishers and can prompt response from the fishing authority.

Active C-band synthetic aperture radar (SAR) sensors such as those carried on RADARSAT-1 and ERS-2 are particularly effective for ship-detection applications because they use microwave signals. Ship targets are composed of sharp edges and highly reflective materials, such as steel, which cause very high returns to the SAR sensor onboard the satellite. In SAR images, ships appear as bright point echoes against the generally darker sea background.

The present limitations will certainly be reduced as countries and organizations continue to explore the use of satellite imagery. Potential savings are directly related to aircraft and patrol vessel costs as their efficiency can be increased significantly as the planning and operational deployment of these units will improve. There are also ongoing pilot programmes in relation to other remote sensing proposals such as use of webcameras, engine and motor sensors and weight sensors, although it is too early to assess the impact such equipment may have on a future MCS system.

Beach patrols

In artisanal or recreational fisheries, beach patrols may be required to check for fishing licences, bag limits, size restrictions (of fish), gear restrictions or for gathering information. These patrols can be performed randomly or as part of a sampling strategy. They can be performed on foot, on bikes or in vehicles. They will also provide an important interaction with the artisanal or recreational fisher working from the shore (e.g. beach seines, and pole and line fishing) to allow the transfer of information directly to the fishers.

Navy and coastguard

The navy is not normally designed, educated or trained for fisheries MCS operations. Navy organizations can be a valuable asset to assist in monitoring border violations of unlicensed vessels and assistance during hot pursuit, but it is seldom efficient or cost-effective for monitoring catch or gear controls.

A coastguard is normally designed around the UN Convention on the Law of the Sea with basic police tasks to perform with an emphasis on border violations, fisheries enforcement, search and rescue operations and customs and immigration tasks: it is therefore often more capable of fisheries protection tasks than the navy. An example of ongoing discussion is in relation to the establishment of an integrated coastguard between the members of the Maritime

Organisation of West and Central Africa.[1] These discussions are very much based upon LOSC as a reference point to define tasks and responsibilities acceptable to the negotiation partners.

14.3.3 During landing

The place of landing, whether it is a small landing site or a large port, provides a bottleneck in fishing operations where vessels can be checked, documents such as logbooks collected and the fish being landed can be identified and weighed. Monitoring of landings is one of the most important elements of MCS operations when output controls are in place. Landing controls are relatively inexpensive and sampling systems can be developed to suit the local conditions. It is important to remember that monitoring of landings does not detect discarded or transshipped fish or fish sold prior to landing. Only physically landed fish can be monitored without knowing where or how the fish has been caught.

14.3.4 Post landing

Control measures of trade units dealing with fish may be another valuable site where catch data can be verified. Inspections of fish markets, transport providers and sales organizations can provide valuable information about the catches. This type of operation generates valuable information for biological and economical cross-checks as well as validation of other MCS information. It is also a viable operation for control of illegal fish, especially undersized and protected species. This is especially valid in small-scale and semi-commercial domestic fisheries where high-value catches such as lobster, tuna, sharks and swordfish are caught. Roadblocks or border checks are another method that can be useful for checking licences and permits as well as the catch itself. Cooperation with others along the chain of custody, such as transporters, processors and traders provides a useful opportunity to identify illegal fish.

14.4 Facilitating for MCS

Once the core MCS components have been configured, as discussed in Section 14.3, the MCS system can be further improved to facilitate easier, more efficient and more cost-effective MCS operations. Often relatively simple arrangements can result in substantial improvements in the MCS solution.

14.4.1 Administrative options

Vessel marking system: A vessel identification system must be in place to identify fishing vessels. The FAO standards for marking of fishing vessels are recommended as an easy and proven system to follow (FAO Standard Specifications for the Marking and Identification of Fishing Vessels). Malaysia successfully implemented its vessel marking system by using an incentive system: registration was free within a certain timeframe, after which registration became costly.

[1] Web reference: http://www.mowca.org

Banning of certain transhipments: Banning of transhipments at sea or outside the port limits assists in inspections and limits the possibility of mixing legal and illegal fish, or other illegal activities. This option can be applied to all fishing vessels, for vessels operating in selected fisheries or to foreign vessels.

Briefing and vessel clearing: In a commercial fishery it can be very valuable to have the captain report to the fisheries authority at the start of each fishing season in order to be briefed about the conditions of a license and to provide an opportunity to collect documentation. At the same time the vessel will be available for clearing by inspectors.

Checkpoints for vessels leaving a zone: If a foreign fleet is operating, then the offloading of catch can be restricted to specific domestic harbours, or vessels can be channelled into checkpoints at certain positions to allow vessel inspection before it leaves the zone with fish onboard. The inspectors are then able to decide if they will inspect the vessel or not. The compliance advantage of this is that the fishing vessels are always prepared for inspection whether it is conducted or not with the deterrent effect this has.

Limitation of landing sites: For artisanal or small-scale fisheries many countries have thousands of landing sites making it difficult to control or to adequately sample the catches. If there is a particularly valuable, protected or overexploited fishery or fish species, then landing sites can be limited for this one fishery or fish: this will facilitate easier deployment of inspectors or data collectors to sample the fishery. This would require careful consideration of the social implications and should be supported with spot checks at other landing sites and markets as a deterrence against violating this regulation.

Special courts: Many courts are not familiar with fisheries violations; this often results in low fines or lost court cases. An educational programme or seminars that focus on fisheries legislation and related infringements for court staff and judges, stressing the importance of fisheries management to the country, the possible economical gains that illegal fishing has for offenders and the requirement and effect of high deterrence can be worthwhile. Alternatively it is possible to train and allocate special judges or courts such as 'green' or environmental courts to handle fisheries' violations.

Coastal zone separation: Conflict between fishers using different gears, between small-scale and commercial fishing vessels or different resource users is a common problem. The MCS activities in a coastal fishery can be complex due to the multiplicity of resource users and the often-difficult access to the resource and landing places. The involvement of other managers in the coastal zone is important, and the use of zones for different users or fishing types can be useful. This can also decrease tensions and conflicts between the different users and facilitate self-regulation.

Joint committees: It is important to consult all interested parties when designing and implementing the MCS system, joint committees can be formed that meet on a regular basis to allow dialogue and exchange of information. This type of cooperation is valuable within all fisheries ranging from artisanal to large commercial fisheries.

14.4.2 Information management and sharing

MCS systems produce large amounts of data through the different monitoring and surveillance activities, such as logbook data, VMS data, landing data and vessel data. Some of these data are required almost immediately for surveillance activities and to coordinate the deployment of MCS components. Other data are needed less urgently but over a longer time-series.

Data and information management is vital. It is very easy to collect too much data, which becomes a burden to compile, check, retrieve and store. An information strategy and plan is a vital element of the MCS strategy and plan. It will determine how much and what data are collected, how they are compiled, shared and processed into useful information.

It is important to consider both information sharing inside MCS and dissemination of the outputs within the fishery management organization. The deployment of inspectors, observers, patrol vessels and planes can be improved if seasonal scientific fishery statistics are available to surveillance personnel. Stock assessment often suffers from a lack of basic data which can be enhanced by observers', data collectors' or inspectors' information. As it is known that the probability of violations generally increases when profit is low and market conditions difficult, the analysis of economic data on catch value and market trends will give an indication of the financial status the fishing fleet is operating under. The market situation will also influence the fishers' perception of what is fair and not fair in terms of management measures and resource rent and consequently have an impact on compliance.

Although it is not essential to have an electronic system for information management, it is usually the only feasible choice due to the volume of data. It is important to plan the database system with the capability of the organization in mind, both financially and in terms of personnel skills; this is especially relevant when the previous systems have been manual. Implementation and the training of personnel to maintain a computerized system will take time. An example is that of the Indian Ocean Tuna Commission who have developed a system called Fisheries Information and Statistical System (FINSS). The system is available as 'open source' software to permit development by the user community. The system is modular and thus allows the addition of new modules. It can be easily customised to provide input interfaces that are identical to paper forms and that are capable of generating new codes for species and species aggregates, vessels, etc. The software manages to 'bridge' the dataflow between FINSS and different VMS databases in order to cross-check statistical data and, particularly, to have a single 'master' vessel register.

14.4.3 Management options

Policy decisions relating to fisheries and MCS are normally firmly rooted in government organizations; however, the operational aspects need not be. To improve the efficiency and to reduce the cost, contractually engaged private MCS operators are gaining acceptance. Examples include the observer programmes of Namibia, South Africa, Canada, United States and Australia, air surveillance in Canada, patrol planes and certain coastguard vessels and fisheries protection vessels in Mozambique, the Falkland Islands and Norway. The question to be asked is which functions of the MCS organization are core functions and which are not. Core functions would include activities such as designing strategies; fining and arresting violators; interpreting VMS output; and observer violation reports. These are usually kept within the fishery management authority itself, while training programmes, observer programmes and the operation of airplanes or patrol vessels are common functions to outsource or privatize.

14.4.4 International and regional cooperation

Regional cooperation in both sharing assets for MCS and also in sharing intelligence and information is steadily increasing. FFA of the Western Pacific provides an example of how

regional cooperation can strengthen national MCS systems within the tuna fishery (Box 14.8). Another example of international cooperation is in relation to implementing Regional Fishery Management Organization schemes, such as the NEAFC Scheme of Control and Enforcement that led to the prevention of the Panama-flagged *Polestar* from offloading its illegal catch around the world. The vessel was one of the five vessels on the NEAFC Blacklist still at large after having been sighted several times engaged in illegal transhipping activity in the NEAFC Regulatory Area. In 2006 the *Polestar* was refused entrance into ports in Europe, North Africa, North America, South Korea and Japan and finally ended in Hong Kong. Hong Kong authorities informed NEAFC that they had no domestic legislation to prohibit landings, but promised to inspect the landings and make the information available to NEAFC Contracting Parties. Again in 2007, the *Polestar* was handling cargo in contravention of the NEAFC regulatory scheme and this resulted in Germany refusing to allow it to discharge its cargo, ordering it to leave port and fining it. Later in Morocco the vessel was again detained before heading for Las Palmas where the port authority denied the vessel entry. This type of cooperation,

Box 14.8 Tackling regional collaboration in MCS – the Western Pacific Example

The shared tuna fisheries of the western Pacific are managed under the umbrellas of the FFA and the Western Central Pacific Fisheries Commission (WCPFC). The FFA provides guidance on management of the fishery within the national waters of the 17 FFA island state members, while the WCPFC provides the management framework for the high-seas waters. The catches of tuna within this overall western Pacific area are estimated at around 2.2 million tonnes per year. These are caught by vessels from a registered vessel list of over 1000 licensed vessels that are flagged by nearly 30 countries. This magnitude of fishing over such a large area provides a challenge for national MCS systems and opens the door for regional cooperation through the platform of the FFA.

In response to this, the FFA countries have chosen some innovative ways to ensure that fisheries in the western Pacific operate by the rules, and that the tuna fishery within their EEZs and the adjacent high-seas waters are legal. The concept behind the regional monitoring and compliance programme is to support and strengthen national MCS operations and to ensure benefits from the regional cooperation in order to strengthen the successful implementation of national tuna fishery management plans. There is also an overlap and synergy between strong MCS systems applied nationally within the respective EEZs of the FFA countries and the impact that this has on the compliance within the WCPFC convention area (high seas surrounding the islands).

Legal and technical elements of the FFA MCS system are applied nationally or regionally and include a harmonized approach to minimum terms and conditions for foreign vessels such as a vessel register for these vessels; a treaty on cooperation in fisheries surveillance and law enforcement (the Niue Treaty); and a Lacey Act-style arrangement allowing regional cooperation relating to penalties for fish caught illegally in the EEZ of another FFA member. regional collaboration on Port State enforcement, harmonization of national laws, observer programmes, aerial surveillance, maritime surveillance and a vessel monitoring system are also essential elements of the system.

possible because of international and regional cooperation, makes illegal fishing less and less profitable for IUU operators as their operational costs increase in search of lenient ports.

14.5 System performance and planning

Measuring performance of the MCS system against the strategic targets should be an annual activity that involves feedback from involved and interested parties. Stock can be taken and planning can take place through an analytical assessment of parameters. The type and level of detail included in an analysis will depend on the information that is available. An assessment of the Namibia MCS system (Bergh and Davies, 2004) is presented in the following sections as an example of the type of analysis that can be undertaken when information is available. Namibia has an industrial fishery with only two ports for fish landings and a well-developed MCS system that makes MCS a more simplified task.

14.5.1 Cost analysis

The chances of detecting violations of fisheries regulations are related to the amount of resources used for monitoring and surveillance, and how efficiently these resources are used. Determining the cost of operations by each MCS component provides useful information for analysis and operational planning. In the example given (Figure 14.1) where the cost of each component is presented as a percentage of the whole MCS organization; this allows a comparison of the cost of enforcement by MCS component across the entire EEZ.

However, in order to compare compliance and enforcement with costs, the average cost per event within each component is required. For example, it may be necessary to determine the cost per observer day at-sea, or cost per at-sea inspection by the patrol vessel, or cost per aerial observation of a fishing vessel, or cost for monitoring each transshipment, or the cost of a beach patrol, these costs can then be compared for each fishery (Figure 14.2).

Another useful approach is to determine the returns from a fishery in order, over the long term, to be able to assess if changes in compliance levels correlate to changes in benefits

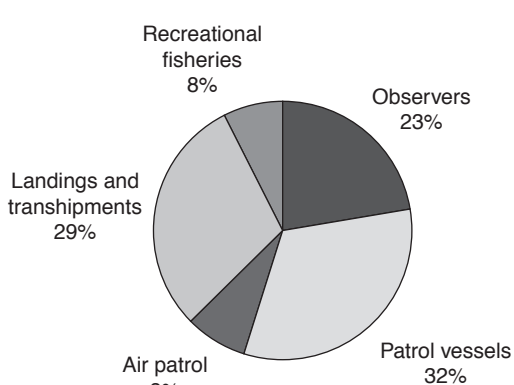


Figure 14.1 The division of MCS operational costs per MCS component (Namibia, based on an average 1999–2001).

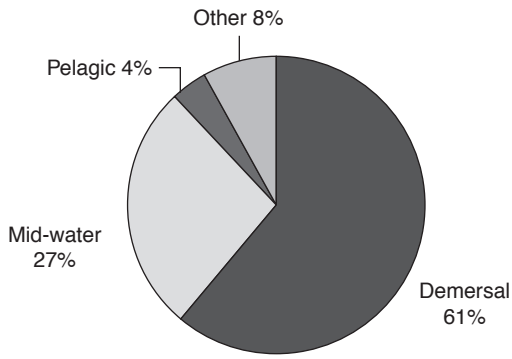


Figure 14.2 The percentage of MCS operational costs by fishery (Namibia, 1999–2001).

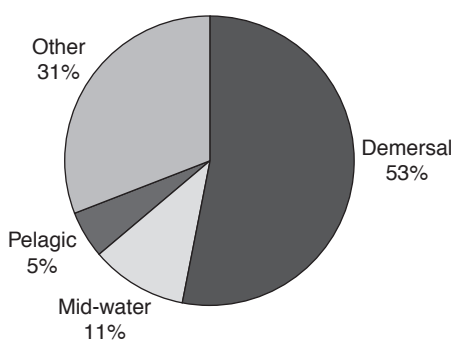


Figure 14.3 Percentage of landed value by fishery (Namibia, 1999–2001).

from the fishery. When making comparisons, it must be kept in mind that profit or benefits can be defined in many ways: analytically the direct revenue generated to government can be considered, but in economic terms, profit includes indirect benefits to the country such as employment opportunities, food security, foreign exchange earnings and business synergy. In the third example (Figure 14.3), a calculation was made of the financial value of the landed catch by fishery and presented graphically in a similar manner to the cost of MCS by fishery to facilitate an easy comparison.

14.5.2 Assessing compliance

Assessing compliance is vital: the level of compliance (compliance level) serves as an indicator of the effectiveness of specific control measures that have been established as well as the overall success of the system.

To estimate compliance an estimate of the number of observed infractions is required. This, for various reasons, is not an easy task; difficulties are faced in areas such as defining the type of offence (e.g. from a minor mistake in reporting to a deliberate misuse of gear), in

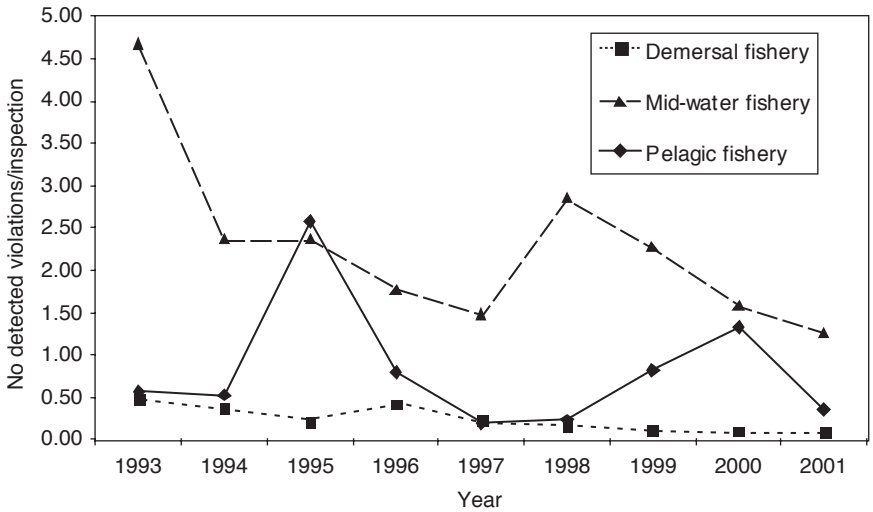


Figure 14.4 The average number of violations detected per inspection from the patrol vessels for three fisheries (Namibia, 1993–2001).

assessing the level of sampling, or in determining if all violations are detected during one inspection. However, two methods of estimating compliance are commonly in use: one is to compare the number of detected infringements in relation to the percentage of the population being sampled (vessels, fishers, gears, etc.); the second is to use surveys to formalize stakeholder opinions and views. The quality of the estimate will depend on the data available. For example, it may be possible to calculate compliance by control measure (or against a specific regulation) within a fishery, or it may only be possible to do this across a whole fishery. The resultant estimate can be compared both to the target levels and across time to provide a useful trend in compliance.

Figure 14.4 shows the trends in compliance over three fisheries: this analysis provided information that was used in MCS planning and resulted in changes to MCS operations that significantly reduced the violations on the mid-water fishery.

The survey technique can be used on various stakeholders such as fishery personnel, the fishers, associated fishing industry, the processing sector and coastguards to gauge their perception of the level of compliance in the fishery. Survey questionnaires should be designed in a simple and clear manner that will easily facilitate analysis. Survey results may be the only information available in some MCS organizations and this can be useful for indicating problem areas and general trends.

14.5.3 System performance

With estimates of the cost of the MCS system in hand and knowledge of how well it has achieved acceptable or target levels of compliance, the fishery manager is able to gauge the performance of the MCS system. There is no defined way to do this but, as can be seen from the examples, by calculating costs and compliance levels, trends and problem areas become more apparent and provide a basis for planning.

The following questions may also be useful in assisting in measuring the system performance and effectiveness of the MCS system, especially if limited quantitative information is available:

- What are the objectives of compliance in the different fisheries and are these being achieved?
- What were the expectations of the system; have these been defined and, if so, how?
- Are all the MCS strategies being implemented?
- Have there been changes in the fishing fleet or habits of the fishers that are not covered under the present MCS operations?
- Is there new technology or other means that can improve the MCS system?
- Do the fishers accept and comply with the fisheries legislation (if not find out why)?
- Are the staff performing as expected? (If not, find out why – it could be lack of resources, management skills, training, support.)

14.5.4 Risk assessment and planning

To assist in prioritizing MCS activities, a risk assessment of possible infractions against regulations and associated control measures can be calculated based upon the assumption that risk is a function of the consequence of an infraction multiplied by the probability that it will take place. The probability can be determined using a variety of information sources such as the economical situation within a fishery, the perceived level of deterrence within the fishery and the compliance level. It is important to note that any uncertainty should serve to increase the ranking of probability. The estimate of probability that an infraction will take place can be categorized into a scale from one to five such as the following:

1. Rare – Will only take place in an extraordinary situation
2. Unlikely – Could take place occasionally
3. Possible – Might take place occasionally
4. Likely – Will take place frequently
5. Almost certain – It is generally expected to take place.

A simple and effective method for assessing the impact of non-compliance or the severity of the consequence of making an infraction would be to categorize the impact on a scale of one to five as with the probability. This will require consultation with other stakeholders, such as scientists, economists, fishers and industry. The biological and economic impacts are both important and can be assessed together or separately. Criteria that could be used are:

1. No importance – Minor impact (possibly receiving a verbal caution)
2. Low importance – Limited impact (possibly receiving a written caution or small fine)
3. Medium importance – Potential impact on the fishery (possibly receiving a court action)
4. High importance – Impact on fishery (possibly receiving a court action and suspend license/season)
5. Very high importance – National and international impact on fishery (possibly receiving a court action and closure of fishery)

The probability and consequence results can then be multiplied together to get an overall risk assessment for that infraction of between 1 and 25. These risk values can be categorized into five risk status levels from insignificant to critical (Table 14.3).

Table 14.3 Risk status and responses.

Risk status	Risk values	Management response	MCS response
Insignificant	1–3	None.	None.
Low	4–6	Management should be made aware of the risk and the steps taken to reduce it.	Ensure that adequate monitoring of the infraction is taking place so that the trends in the infraction rate and compliance levels can be regularly monitored.
Moderate	7–10	Management should be made aware of the risk and plan to reduce it as well as the plans to increase the MCS efforts if the risk moves into a high risk status.	Compliance levels to be regularly monitored and a check made that the risk does not become a high-risk status. Efforts increased to reduce non-compliance within the routine work of the organization and especially through awareness programmes.
High	11–19	Management decision required. Detailed compliance strategy to be developed.	Increased effort, targeted operations with available MCS components. Increased landings control and post harvest data verification.
Critical	20–25	Urgent management decision required. Detailed compliance strategy to be developed and additional assistance and funds may be required immediately. Consideration of closure of the fishery.	Urgent response. Increased effort, targeted operations with available MCS components, consideration of hiring or leasing additional tools (such as aeroplane or patrol vessel) for a limited period. Increased landings control and post harvest data verification. Regional cooperation to be negotiated if applicable.

Having completed a risk assessment for each infraction, these can be compiled by fishery with the possible infractions grouped into the five categories from insignificant risk to critical risk. A pattern is likely to emerge. This assessment can guide actions for each threat level such as targeted operations, increased inspection rates, deployment of observers or inspectors, increased monitoring or even closure of a fishery if the risk is too high. Approaches to tackling these risks will form the basis of the annual MCS plan for each fishery.

14.6 Synthesis and outlook

14.6.1 Synthesis

MCS has historically often been perceived as a somewhat isolated element of fisheries management dealing primarily with the enforcement of legislation. This chapter has revealed that MCS, in fact, relates to all of the activities performed by a fisheries management authority in relation to the actual fishing operations. Setting effective fishery management strategies requires an integrated approach with a full understanding of the needs and constraints of the

management system including those that an MCS organization has in implementing the management measures. The MCS organization must also understand the principles of fisheries management to be able to carry out their operations and contribute useful information to the management process.

MCS is not intended to be a policing function where fishers are treated as criminals. The prime function of MCS is to increase compliance to agreed management measures by increasing deterrence and voluntary compliance and thus decreasing violations. A strategic balance between the two aspects of deterrence (or enforcement) and voluntary compliance should be achieved for each fishery. Participatory management involving fishers and other interested parties is seen as a key tool required by all fisheries (artisanal, small-scale and commercial) in order to ensure an increase in compliance.

Many MCS solutions exist for a given fishery; selecting and compiling the components in the most cost-effective manner is not an easy task. The value of cross-verification and achieving a balance between the different dimensions (before fishing, while fishing, during landing and post landings) is an important element to consider when designing the MCS solution. This will not only provide the organization with several different sources of information, but also increase the overview of the fishing sector both from an information and deterrent point of view.

Large complicated fisheries often demand complex MCS solutions. Vessel marking, transshipment and landing sites are three of the options proposed in order to assist with the facilitation of these complex MCS systems, while low-cost and low-technological options have been introduced for artisanal and small-scale fisheries with limited human or financial resources.

MCS system performance needs to be regularly assessed in order to ascertain if it is achieving the strategic targets in the most cost-effective and efficient manner. The level of compliance of fishers to the regulatory system and the impact of any non-compliance on the fishery are the parameters used to make risk assessments. This estimate of the overall risk can be combined with estimates of the value of the fishery and the cost benefit of different MCS components as factors that help the fishery manager to establish priorities to assist in allocating the MCS resources. It is suggested that an improvement in compliance over time is the indication of a successful MCS organization and system and that defining appropriate compliance targets and monitoring compliance levels is an essential element of any MCS strategy.

14.6.2 Future outlook

Over the last decade, the MCS manager on the ground has seen little change in the practical options available for combating illegal fishing. What has changed is the approach to MCS, in that it is now viewed as an interlinked and integrated element of the fishery management system. Another trend that is changing the approach to MCS is the emerging awareness that MCS operations need to be viewed from an analytical and integrated manner, in terms of planning, implementing and reviewing in order to maximize benefits and reduce losses from the fishery. Further research to develop simple analytical tools for the MCS manager is required; the main hindrance for this research is the lack of available data on MCS operations and the outcomes from these operations.

Another area of change for the MCS manager has been in the growth of the regional and international arena, and the need for national managers to engage in a far wider and more

far-reaching sphere of discussions than previously. For example, the range of international fisheries instruments that now define the role that states and RFMOs should, or could, play in effect ively combating illegal fishing has increased in the last decade. One of the most recent is the Model Scheme on Port State Measures.[2] This scheme is presently voluntary but there have been calls to adopt a binding instrument under the auspices of FAO (Section 5.4.7). The Scheme provides minimum standards for a range of activities and requirements; it sets out inspection procedures, information to be included in the results of Port State inspections, elements of a training programme for Port State inspectors and the basics for an information system on Port State inspections. This recent emphasis on Port States to take firmer control of fishery-related activities has come about due to the failure of flag states to effectively control the fishing oper ations of their vessels. The result is that greater demands and requirements are being made of, in many cases, developing countries to strengthen their MCS organizations and systems.

Trade and marketplace measures include all policies and practices that are used to track and regulate trade in seafood products from the time the fish are caught to when they are sold to final consumers. These measures include various MCS elements such as catch monitoring, control measures, verification of product labelling and tracking, and any other arrangements that may help MCS managers and others differentiate between legal and illegal seafood products. The proliferation of trade and marketplace measures, including consumer demands, will continue to put increasing pressure on the MCS organization to comply with international standards in the MCS operations that they perform.

Another area of global development is that of a proposed Global Record of Fishing Vessels involved in illegal activities. The aim is that knowledge gained on illegal vessels by one country can be shared with and benefit others. Already a number of countries and regional organizations operate non-compliant lists (known often as black lists) of vessels believed to be involved in illegal fishing activity; however under the new proposed global record, these diverse and varied lists will need to be standardized on a global level. The benefits may be great, but again, the practical implication is the need to strengthen further and have more resources for MCS operations.

International and regional cooperation in MCS may hold one of the solutions to this ever-increasing pressure on national MCS systems. Fish stocks, fishers, fishing operations and fisheries trade are either by-nature or by-impact transboundary. Due to this, national fisheries policies and MCS strategies cannot be formulated in total isolation. Regional fisheries management approaches and cooperation provide a framework for cooperation among countries in facing the major challenges of tackling IUU fishing and developing MCS approaches that can benefit each other.

Sources and recommended reading

Bergh, P.E. and Davies, S.L. 2004. Against all odds: Taking control of the Namibian fisheries. In: *Namibia's Fisheries: Ecological, Economic and Social Aspects*. Samaila, U.R., Boyer, D., Skogen, M.D. and Steinshamn, S.I. pp. 289–318.

Davies, S.L. 2002. *Guidelines for Developing an At-Sea Fishery Observer Programme*. FAO Fisheries Technical Paper No. 414. Rome, FAO. 118p.

[2] Web reference: http://www.fao.org/docrep/010/a0985t/a0985t00.htm

EJF. 2005. *Pirates and Profiteers: How Pirate Fishing Fleets Are Robbing People and Oceans*. Environmental Justice Foundation, London, UK. 24p.

EJF. 2007. *Pirate Fish on Your Plate – Tracking Illegally-Caught Fish from West Africa into the European Market*. Environmental Justice Foundation, London, UK. 28p.

FAO. 1981. Report on an Expert Consultation on Monitoring, Control and Surveillance Systems for Fisheries Management. Rome, 27–30 April 1981. FAO/GCP/INT/344/NOR. Rome, FAO. 115p.

FAO. 1997. *Fisheries Management*. FAO Technical Guidelines for Responsible Fisheries No. 4. Rome, FAO. 82p.

FAO. 1998. *Fishing Operations, 1. Vessel Monitoring Systems*. FAO Technical Guidelines for Responsible Fisheries No 1. Supplement 1, Rome, FAO. 58p.

FAO. 2001. *International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing*. Rome, FAO. 24p.

FAO. 2007a. *Model Scheme on Port State Measures to Combat Illegal, Unreported and Unregulated Fishing*. Rome, FAO, 59p.

FAO. 2007b. *The State of World Fisheries and Aquaculture 2006*. Rome, FAO. 180p.

Flewwelling, P. 2003. Recent Trends in Monitoring, Control and Surveillance Systems for Capture Fisheries. FAO Fisheries Technical Paper No. 415. Rome, FAO. 200p.

Furlong, W.J. 1991. The deterrent effect of regulatory enforcement in the fishery. *Land Economics*, 61: 116–129.

Hersoug, B. and Paulsen, O. 1996. *Monitoring, Control and Surveillance in Fisheries Management*. University of Namibia, Windhoek, Namibia. 378p.

High Seas Task Force. 2006. *Closing the Net: Stopping Illegal Fishing on the High Seas*. Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN and the Earth Institute at Columbia University. 116p.

Kelleher, K. 2002. *The Costs of Monitoring, Control and Surveillance of Fisheries in Developing Countries*. FAO, Rome. 47p.

Kuperan, K. and Sutinen, J.G. 1998. Blue water crime: Legitimacy, deterrence and compliance in fisheries. *Law and Society Review*, 32(2): 309–338.

Laurec, A. 1999. Monitoring fisheries for better research and/or better enforcement. In: *Proceedings of the International Conference on Integrated Fisheries Monitoring*. Sydney, Australia, 1–5 February 1999. Rome, FAO. 378p.

MRAG. 2005. Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries, DFID, London. 180p.

MRAG. 2006. Promotion of models generating national economic benefits through the control of foreign fisheries. MRAG, London. 34p.

OECD. 2003. *The Costs of Managing Fisheries*. OECD, Paris, France. 175p.

Raakjaer Nielsen, J. and Mathiesen, C. 2003. Important factors influencing rule compliance in fisheries – lessons from Danish fisheries. *Marine Policy* [Amsterdam] 27(5), September 2003. 409–416.

Roheim, C. and Sutinen, J.G. 2006. *Trade and Marketplace Measures to Promote Sustainable Fishing Practices*. ICTSD Natural Resources, International Trade and Sustainable Development Series Issue Paper No. 3: International Centre for Trade and Sustainable Development and the High Seas Task Force, Geneva, Switzerland.

Smith, A.R. 1999. Monitoring, control and surveillance in developing countries and the role of FAO. In: *Proceedings of the International Conference on Integrated Fisheries Monitoring. Sydney, Australia*, 1–5 February 1999. Rome, FAO. 378p.

Sutinen, J. and Andersen, P. 1985. The economics of fisheries law enforcement. *Land Economics*, 61(4): 387–397.

Web resources

The Stop Illegal Fishing Programme: http://www.stopillegalfishing.com
The Marine Stewardship Council: http://www.msc.org
Environmental Justice Foundation: http://www.ejfoundation.org
Greenpeace: http://www.greenpeace.org
High Seas Task Force: http://www.high-seas.org and http://www.closingthenet.info
Illegal Fishing info: http://www.illegal-fishing.info
Internet Guide to International Fisheries Law: http://intfish.net
One Fish: http://www.onefish.org
The International MCS network: http://www.imcsnet.org
EU Combating illegal fishing: http://ec.europa.eu/fisheries/cfp/external_relations/illegal_fishing_en

Chapter 15

Special Considerations for Small-Scale Fisheries Management in Developing Countries

John Kurien and Rolf Willmann

15.1 Why small-scale fisheries need special consideration

There is a global resurgence of concern and empathy for small-scale fisheries today. An important reason is the greater attention by the international community to the twin and inter-related goals of eradication of poverty and achieving food security for all.[1] Small-scale fisheries contribute more directly to attaining these goals than large-scale fisheries even though the economic contribution of the latter is often significant at the national level.

This continued importance and even predominance of the small-scale sector, especially in many developing countries, primarily highlights certain characteristics pertaining to their collective appropriateness to the social–ecological setting. It also points to their resilience, despite the benign neglect which they have often faced. Both these dimensions warrant closer examination. This is the bright side of an emerging global picture of small-scale fisheries.

There is also a dismal side to the picture. Despite several decades of development efforts, small-scale fishing communities and their dependants have largely been left behind in the march to socio-economic progress in developing countries. They are also among the most severely affected by the HIV/AIDS epidemic in many parts of the world for reasons thought to lie in aspects such as demographics, high mobility, a cash-oriented economy, and fishers' life style, as well as inadequate access to medical services (Allison and Seeley, 2004). The numbers involved are also large. According to global estimates reported to the FAO, about 90% of the 42 million fishers and fish farmers are engaged in small-scale fisheries and aquaculture. The vast majority are in Asia. Further, about 250 million people (4% of the world's population) live in these households, who depend primarily on small-scale fisheries and aquaculture. If the incidence of poverty among fishery-dependent people was as high as the average in their respective countries, then there would be some 23 million fishery-dependent people living on less than $1 per day (FAO, 2002).

These two sides of the picture are at the core of the global attention to small-scale fishing communities. It prompted the growing assertion of their rights to their national governments

[1]The 1995 UN World Summit for Social Development expressed the commitment to combating poverty as an ethical, social, political and economic imperative of humankind. The 1996 World Food Summit pledged political will and commitment to achieving food security for all and to reducing the number of undernourished people to half their present level no later than 2015. Both of these goals were reaffirmed in the 2000 UN Millennium Declaration and Millennium Development Goals (MDGs).

and at international fora over the last two decades, a process observable in both developed and developing countries alike.[2] It has also provided the basis and urgency for a global reconsideration of the significance of small-scale fisheries. This provides the rationale for the special considerations warranted for the management of these fisheries.

In recent years, the issue of fisheries as an important contributor to food security and poverty alleviation has been receiving growing attention. The importance and complexity of the small-scale fisheries sector, in this context, are increasingly recognized. One of the objectives of the FAO Code of Conduct is to 'promote the contribution of fisheries to food security and food quality, giving priority to the nutritional needs of local communities' (Article 2 (f)). The Code also makes direct reference to fishers and fishworkers in the 'subsistence, small-scale and artisanal fisheries' and their right to 'a secure and just livelihood, as well as preferential access, where appropriate, to traditional fishing grounds and resources in the waters under national jurisdiction' (Article 6.18).

15.2 Characterizing small-scale fisheries

It is now generally agreed that there is no universally applicable definition of small-scale fisheries. However, there are numerous attributes which are shared by small-scale fisheries across countries. Based on the vast amount of literature which now exists on small-scale fisheries in developing countries, we can highlight some stylized characteristics (Smith, 1979; Thomson, 1980; Kurien, 1996; Berkes *et al*., 2001; Johnson, 2006). We may say that a small-scale fishery is more than likely to have several of the following attributes:

- Basically a household enterprise undertaken in pursuit of a livelihood leads to a culturally conditioned way of life in which women play a significant anchoring role.
- Operators largely work as share-workers or owner-operators of their fishing units.
- Use of small craft and simple gear (though not necessarily simple techniques) of considerable diversity, relatively low-capital investment and low-energy intensity of the operations.
- The fishing operations are skill-intensive and the operators have an intuitive understanding of the rhythms of the aquatic *milieu* and the behavioural characteristics of the fishery resources in it.
- These skills and knowledge are passed down from generation to generation.
- Operators live in decentralized and spatially dispersed settlement patterns but with relatively high-population densities prevailing even when located in rural areas.
- Operators generally fish close to their home communities in relatively nearshore waters in single day/night operations and largely in keeping with certain seasonal patterns.
- Selectively known for skilfully venturing into deeper waters and distant shores in pursuit of migratory fish resources.
- Resources fished are largely in spatially open access regimes but with certain notional customary norms usually relating to artefacts used for harvesting, times of access and allocation arrangements.

[2]Notable examples were the international conference of fishworkers and their supporters held in 1984 in Rome (ICFWS, 1984) and the conference of the international collective in support of fishworkers held in 1994 in Cebu (ICSF, 1994).

- Integrally linked to locally oriented processing activities and hinterland market networks contributing to local food security but also increasingly cater to export market demand.
- Women are an integral part of the up- and downstream productive activities, often being in the forefront of pre-harvest activities and post-harvest processing and marketing.
- Considerable financial dependence on middlemen and those who buy their harvest. This dependence is now reinforced by increasing capital needs for motorization and adoption of larger craft and greater amounts of fishing gear.
- The fishing, post-harvest activities and marketing may all be part-time and seasonal, and combined gainfully with work in agriculture, trade and other occupations.
- Compared with other sections of society, relatively socially insular, economically disadvantaged and with low-employment mobility out of fishing.
- Often, part of larger indigenous communities and ethnic minorities that warrant greater 'positive discrimination' in the socio-economic and cultural context of many developing countries.

These attributes characterizing small-scale fisheries do not preclude either the absence of any of the aforementioned attributes or the presence of any other attributes, which are specific to particular small-scale fishing communities. Moreover, these are not static characteristics; they are in the process of a dynamic evolution which has been greatly influenced by the patterns of fisheries development adopted in different developing countries. The diversity, spatial scattering and the location specificity of the characteristics call for special management approaches which are not amenable to gross generalizations.

15.3 A vision for small-scale fisheries

Making sweeping generalizations about the characteristics of small-scale fisheries is neither a legitimate nor a feasible proposition. But proposing a possible future vision for small-scale fisheries is a desirable option. It helps focus the strategies that should be adopted in order to bring small-scale fisheries back to the centre of the fisheries development and management discourse in a country.

There are two visions which are worthy of consideration in our current context.

The first has been articulated by the FAO/UN Advisory Committee for Fisheries Research (FAO, 2004). This is a vision for small-scale fisheries in human development terms. It is a vision in which the contribution of small-scale fisheries to sustainable development is fully realized and where:

- they are not marginalized and their contribution to national economies and food security is recognized, valued and enhanced;
- fishers, fishworkers and other stakeholders have the ability to participate in decision-making, are empowered to do so and have increased capability and human capacity, thereby achieving dignity and respect; and
- poverty and food insecurity do not persist where the social, economic and ecological systems are managed in an integrated and sustainable manner, thereby reducing conflict.

The second vision is that of the International Collective in Support of Fishworkers (ICSF) which is a pioneering international NGO that has consistently advocated the role of the small-scale

fishing communities as central to the pursuit of fisheries development and management in developing and many developed countries also. For the ICSF, their vision of small-scale fisheries is one which envisages:

- a future in which fishing communities and fishworkers lead a life of dignity, realizing their right to life and livelihood, and organizing to foster democracy, equity, sustainable development and responsible use of natural resources (http://www.icsf.net).

15.4 Substantive contribution of small-scale fisheries

Both these visions are essentially normative and give focus to the larger picture which we need to hold before us. However, there are more substantive – but most often undervalued and unrecognized – dimensions pertaining to the current role and contribution of the small-scale fishery in the overall socio-economic, cultural and political context of developing countries which merit consideration.

Undervaluation of the contribution of small-scale fisheries is reinforced by poor data on this sector. This is partly due to the orientation and biases inherent in national economic databases and also lack of attention to socio-cultural foundations of economic activity. However, these data and information gaps are slowly being bridged by local and countrywide case studies including those on inland fisheries where small-scale producers predominate and studies on the contribution of small-scale fisheries to food security and poverty reduction. Seven areas where the contribution of small-scale fisheries to the economy and society can be significant are considered in the following sections.

15.4.1 Socio-economic performance

The desirable economic and social features of small-scale fisheries have been well documented (Kurien and Willmann, 1982; Panayotou, 1985; FAO, 2005b; Béné *et al*., 2007). In developing countries which are short of investment funds, the presence of small-scale fisheries ensures that the fish harvested are produced in a cost-effective manner combining the salubrious blessing of natural resources, scarce financial–capital resources and abundant labour resources in an optimal manner. The returns from the small-scale fishery, measured in terms of physical output per unit of investment, unit of energy consumed and unit of cost incurred, commonly indicate better performance than the medium or industrial fishery. Though the individual micro-level fishing unit is small, when aggregated at the macro-level national or provincial scale, the sector is often the single most dominant one in the fishery, contributing the single largest share of fish production, the quantity exported, the quantity intended for human consumption and so forth.

15.4.2 Local economic development

Small-scale fisheries contribute more directly and more quickly to local economic activity in the form of cash and employment. This happens due to the innate nature of fish – fishers cannot live by fish alone; the perishability of the product is high and cost of storage can be

significant, making it necessary to sell or barter the surplus quickly. Moreover, compared to agriculture, there is significant labour absorption in the related upstream (input supplies for harvesting) and downstream economic activities (post-harvest and marketing), making small-scale fisheries a strong driver for poverty reduction, particularly in more remote, rural and coastal locations. The returns to labour in the small-scale fishery, particularly due to the prevalent income-sharing mechanisms (rather than wage) which it adopts, are significant. Their contributions to rural development can therefore be significant, though not adequately recognized and accounted for in formal state economic accounting formats (Kurien and Willmann, 1982; Ninnes, 2003; Kura *et al*., 2004; Smith *et al*., 2005; Béné *et al*., 2007).

15.4.3 Foreign exchange earnings

Small-scale fisheries do make significant contributions to national economies through the generation of foreign exchange derived from international trade. With developing countries accounting for an increased share of global fish exports, the contribution of small-scale fisheries within this context is becoming increasingly important, which needs to be separately accounted for and more adequately highlighted (Mathew, 2001; Kurien, 2005). With the growing consumer preferences in the developed world for fish, which is harvested using passive methods and in a seasonal manner, there is an ever-increasing niche in which only small-scale fishing can fit.

15.4.4 Food security

Small-scale fisheries account for the major share of the fish which is consumed locally in developing countries. An added positive factor is the decentralized nature of the fish supplied through small-scale fisheries because of their geographically spread-out production structure. The distances between the points of landing and the points of final consumption are generally shorter and the distribution costs lower. Fish produced by small-scale fisheries are, therefore, more available and affordable to poorer consumers.

Fish provides at least 30% of animal protein intake to one billion people and about 56% of the world's population derives at least 20% of its animal protein intake from fish (FAO, 2002). In many Asian countries, this share is often above one-third and in some countries even above one half, and can reach 90% in isolated parts of coastal, island and inland areas. Fish is highly nutritious, supplying indispensable micro-nutrients, vitamins, iodine, polyunsaturated fatty acids like omega-3 and trace elements generally not found in staple food. The contribution that fish can make to the nutritional status of young children and lactating women is particularly significant in developing countries (International Food Information Council, 2008).

15.4.5 Poverty prevention and safety-net function

Small-scale fisheries do contribute to poverty reduction at the household level. But at the present time, the most important contribution of small-scale fisheries to poverty alleviation is probably through their role in poverty prevention. Though the large majority of households involved in fishing activities (full-time, temporary or occasional fishers) in developing countries have not generated high economic returns, they have helped them to sustain their livelihoods and prevented them from falling deeper into deprivation. This is particularly true

in situations of economically or institutionally restricted access to other capital (e.g. financial capital such as credit) or production factors (such as private land). The relatively easy and free access to fishing grounds allows poor people to rely more heavily on local riparian resources to obtain the goods and services they need to sustain their livelihoods or to gain access to paid employment. Inland fisheries are particularly important in this context. This safety-net dimension of fisheries is of greater importance and relevance to poor and marginalized households – generally those with limited access to land and other resources (Béné, 2003; FAO, 2005b; Béné *et al*., 2007).

15.4.6 Unfathomed knowledge base

One less explicitly recognized contribution of the small-scale fishery is the substantial innate knowledge base of the nuances of the local ecosystems and resource which it possesses (Johannes, 1981; Ruddle and Johannes, 1990). This knowledge is often codified in the form of sayings, proverbs and songs, and sometimes exhibited in customary practices which may be surrounded by religious ritual (Kurien, 1998). The knowledge also extends readily to technological innovations in craft, and more often, in gear designs which exhibit considerable technical sophistication attuned to the specifics of the ecosystem. This enormous inter-generational corpus of knowledge is at the heart of the fisher's ability to sustain a livelihood in what are often adverse economic, social and political circumstances. It is a hitherto unvalued a stock of knowledge from which a stream of benefits has been flowing to them and the society.

15.4.7 Maintaining culture and traditions

In many small island nations and archipelago states, small-scale fishing activities are an important area where the culture and traditions of the communities continue to be expressed and preserved. If small-scale fishing activities are destroyed, many of these aspects of human cultural diversity will disappear. There are serious justice and ethical issues involved (FAO, 2005a). These cultural mores provide a strong sense of identity and cohesion in these communities. This often forms the basis for the resilience demonstrated by small-scale fishing communities when confronted with strong socio-economic forces from outside. It is important to retain the essential elements of this community fabric. It is also recognized that the social institutions which tend to develop around them are valuable and necessary to preserve ecosystem diversity in marine and other riparian contexts (McGoodwin, 2001). The economic and existence value of their actions is yet to be assessed.

15.4.8 Some disturbing tendencies

While we highlight these undervalued contributions of the small-scale fishery, we are mindful of many disturbing tendencies that have become amply evident in many countries. There are growing number of instances, where people displaced by droughts and conflicts enter fisheries as a last resort of survival, upsetting traditional fishing and resource-sharing practices. In other cases, in the struggle to make ends meet, small-scale fishers resort to destructive and unsustainable fishing methods, leading to a vicious circle of low income and indiscriminate harvesting practices. The use of poisons and dynamite, and adoption of fine meshed nets and mini-trawls are but a few of the examples of these trends, which detract from the potential contribution, which can be made by the small-scale fishery.

15.5 Management objectives for small-scale fisheries

While the social and cultural contributions of small-scale fisheries can hardly be overestimated, the management objectives for small-scale fisheries are not that different from those of large-scale fisheries, especially when we think about the need to maintain fish stocks and associated ecosystems in healthy conditions and avoid wasteful use of the means of production, in particular, over-investment into vessels, engines, nets, fuel, etc. There could be some trade-offs, especially in the short-term, between assuring gainful and professionally satisfactory employment opportunities to as many fishers as possible while avoiding over expansion of the fishing fleet leading to economic and biological overfishing.

The poor living conditions that often characterize many small-scale fishing communities are both partly an outcome of inadequate fisheries management (resulting in depleted fish stocks, overcapacity, etc.) and a constraint in improving fisheries management. It is a constraint because people living on the edge of survival should not be excluded from fishing without creating alternative sources of food and livelihoods for them (FAO, 2005b).

Effective management of fisheries aims to move fisheries towards use of aquatic resources that will eventually approximate an optimal position on economic and social accounts. This is closely tied to the biological health of the resources in question. In this way, benefits accruing from use of the fisheries resources are maximized for society as a whole. But it is equally important to ensure that there is an equitable distribution of the benefits that do accrue, resulting in an increase in the contribution made by small-scale fisheries to poverty alleviation and food security. Thus, optimizing benefits from the resource through effective fisheries management and ensuring an equitable distribution of those benefits are both important issues (FAO, 1997, 2005b).

The involvement of the fishing communities in the setting of management objectives would allow them to place relative weights to these different objectives. Important, therefore, is the process of management decision-making that can transparently address trade-offs between management objectives as well as equity considerations in the allocation of resource access and use among different groups and communities. The conditions for effective partnerships across various stakeholder groups in fisheries management have been examined by Pinkerton (Chapter 11). All too often, the approach taken is top-down and solely guided by considerations relating to the harvesting side of a fishery. The positive impacts are often overlooked which a well-managed fishery has on the post-harvest sector. These can include a more steady harvest throughout the year, better product quality at the time of landing and larger individual fish sizes fetching higher market prices. More steady and quality-oriented harvesting schedules throughout the year or season can multiply post-harvest employment and income opportunities adding much greater value to the resource.

It is important to prioritize management objectives and assess their relevance to the specific context of the small-scale fishery of a country. One way to do this will be to assess how they will help to further the contributions which small-scale fisheries make to the economy and the community (discussed in Section 15.4).

15.6 Management approaches for small-scale fisheries

In most developing countries there is no special distinction made between regulatory regimes (management approaches) required for the small-scale fishery and any other sub-sector which

may exist in the fishery. The department or service which is responsible for fisheries may have a general regulatory framework in which they view all the fishing units as being part of one total system. In this context, apart from a legal framework, little else may exist in terms of specific physical arrangements for monitoring, regulation or control of fishing activities. In cases of emergencies/accidents arising during fishing activities, the help of the navy or coastguard is obtained. Unfortunately, such 'one norm for all' regimes have often resulted in the aquatic realms covered by them ending up as unregulated state-sponsored open access regimes.

The experience so far of structured and planned approaches to small-scale fisheries management has arisen primarily from considerations such as the need for conflict resolution *vis-à-vis* the larger, industrial scale operators. The motivations have therefore been primarily social and political with fishery management consequences that were incidental to such actions.

If a country wishes to consider a management approach that is tailored to the needs of the small-scale fishery, it must develop a specially focused strategy to achieve this. The approach which must be taken for management of small-scale fisheries will depend largely on the geographic, socio-economic and political systems in the country. Countries where governance is more centralized will adopt entirely different approaches compared to countries where a more federal structure and decentralized form of governance is the norm. Island economies will view the small-scale fishery from a more holistic perspective due to socio-cultural compulsions that may not be important in large continental economies. Economies where the contribution of fisheries to the gross domestic product (GDP) is substantial may view the emphasis that they will give to small-scale fisheries with a different rationality.

What is enumerated in the following sections are four 'approaches' which we have gleaned from the actual actions taken in countries. In actual practice, they may be perceived not as management approaches but rather as actions taken in the course of fisheries development agendas and the associated compulsions for governance of the sector.

15.6.1 Preferential access approach

The most frequently practiced special treatment accorded to a small-scale or artisanal fishery in a country is preferential access accorded to it in the nearshore coastal waters.[3] Following the promulgation of the exclusive economic zones (EEZs) (200 nautical mile) in national law, several countries have designated reserved inshore zones for use by small-scale fishers. These zones have been legislated either in national fisheries legislation or in local government acts in the course of the strengthening of decentralized governance structures (1991 Philippines Local Government Code; 1999 Indonesia Local Government Law). In general, the jurisdiction of this second tier of government normally extends up to the 12 nautical mile 'territorial sea' (1982 United Nations Convention on the Law of the Sea). It is within this large zone that preferential access rights may be accorded to the small-scale fishing units. This may in turn be reallocated to those units which do not use mechanical propulsion on their crafts and those which do. The monitoring, control and surveillance (MCS) activities are not continuous in

[3]FAO's Committee on Fisheries at its 25th session observed that 'Substantial achievements have been realized through such measures as constitutional recognition of the rights and interests of small-scale fishers and legislative and other provisions to strengthen their participation in policy and management decision-making processes. Other enabling measures have been the allocation of exclusive fishing zones for small-scale fishers and provision of education including literacy and leadership training'. (FAO, 2003).

nature generally due to the high cost involved. They are usually restricted to situations where conflicts may arise between small-scale fishing units and other larger operators, for example when bottom-trawling units violate the reserved zones.

15.6.2 Community rights-based approach

This approach to management is a transition from the mere allocation of large spatial zones towards the recognition of rights and obligations of small-scale fishers over the resources in a well-defined localized spatial territory (e.g. territorial use rights in fisheries, TURFs [Christy, 1982]). More often than not this territory is adjacent to the physical land-based habitat of the community. Over the last two decades, since the 1980s, there has been an upsurge of demands from small-scale fishing communities and their organizations and supporters worldwide for recognition of their customary and traditional rights (Kurien, 1988, 2000; ICSF, 2007). These pressures from below; the growing international literature on the need for people's participation in natural resource management (Christy, 1982; National Research Council, 1986; Berkes *et al*., 1989; Ostrom, 1990; Baland and Platteau, 1996; Charles, 2002; Kurien, 2007); the economic and social sense of the 'subsidiarity principle' and the realization of the greater economic viability of private–public partnership arrangements have contributed to granting of such rights. Added to this has been the greater emphasis on devolution of economic and political governance in many countries. As a result, the explicit recognition being accorded to community-based rights in fisheries in developing countries is now on the increase (Shotton, 2000; WHAT, 2000; Kuemlangan, 2004). The countries which have accorded specific national level recognition for such initiatives are, however, few. One of the major impediments is that current laws give little scope for conferring exclusive rights to communities. But with the increasing trend in decentralization of political governance in many developing countries, the scope for governance of fishery resources by village groups, with an element of benign sponsorship by the systems of local councils and local government authorities, is increasing.

15.6.3 Co-management approach

The hurdles in the path of exclusive transfer of rights to communities/fisher groups have created the space for a new set of co-management initiatives (see Chapters 3 and 11). In these arrangements, the state and the communities come together through legal and quasi-legal arrangements in 'partnering' for fisheries management – taking a share of both the rights and responsibilities in these efforts (Jentoft, 1989; Pinkerton, 1989; Pomeroy and Williams, 1994).

These arrangements can be more readily accommodated within the legal framework of existing property rights and also take into consideration customary norms and rules which may exist, and which have considerable social legitimacy (Nielsen *et al*., 2003). The important distinction is that the property rights to the resource continue to be legally vested with the state (or its representative) and the *usufruct* (use) rights – which include importantly organizing the rights to regulate access, allocate, conserve and rejuvenate the resource can be vested in the hands of a community or fisher/user group. Such an arrangement provides the scope for clear-cut assignment of roles and responsibilities without 'grey areas' on sensitive and potentially legally convoluted matters. For example, the transfer of property rights over natural resources to a user group (however legitimate their claims) may be viewed as constitutionally invalid because the resources belong to the 'people or the public' of the country as a whole.

The example of Japanese fisheries cooperatives indicates the great diversity and ingenuity of the co-management arrangements which groups of fishers have designed within the framework of the fishing rights held by cooperatives. There are several hundreds of these arrangements, each designed for specific fisheries and the conditions of the participating fishers. The roles of government include scientific research and advice and support towards compliance efforts (see various examples in Christy, 1999).

Another successful local-level management example is the inshore shellfish fishery in Chile where TURFs were incorporated into the Fisheries Act of 1991. The positive experiences in an initially small number of caletas (i.e. fishing villages) led to the wide-scale implementation of shellfish TURFs in 1998. Apart from restored resources abundance, the TURF system led to various other benefits including better product quality and marketing practices and, most importantly, strengthened fishers' organizations stemming from shared responsibilities and appropriate incentives (Castilla *et al*., 1998; Hilborn, Orensanz and Parma, 2005) (cf. Chapter 6).

15.6.4 Ecosystem approach

The ecosystem approach to fisheries (EAF) should be the overarching approach to fisheries management including small-scale fisheries (FAO, 2003b). As in large-scale fisheries, also small-scale fishing activities, though often to a much lesser degree, affect other components of the ecosystem in which the harvesting occurs; for example, there is often bycatch of non-targeted species, physical damage to habitats, food-chain effects or changes to biodiversity. In the context of sustainable development, responsible fisheries management must consider the broader impact of fisheries on the ecosystem as a whole, taking biodiversity into account. The objective is the sustainable use of the whole system, not just a targeted species.

Implementing EAF could add a significant additional burden, and the challenge may be particularly formidable in small-scale fisheries, where the difficulty and costs of the transition to effective management may outweigh the available capacity and short-term economic benefits derived from it (Cochrane, 2000; Mathew, 2001). Particular problems are likely to be encountered in regions where poverty is widespread, alternatives to fishing are scarce or non-existent, and where the traditional systems have broken down. In such situations, the short-term economic necessities, at both national and local levels, may be too overwhelming for serious consideration of change even when the long-term benefits are apparent (FAO, 2003b).

In order to assist the implementation of EAF in the small-scale fisheries of developing countries, efforts are needed to tailor it to weak formal institutional settings and data-poor situations through appropriate models and methods (Johannes, 1998; Section 13.9). Participatory and adaptive approaches will be needed, drawing on existing traditional rights and management systems whenever possible. There may also be advantages in integrating fisheries management into coastal area management where it could benefit from economies of scale and the existing networks for participation (FAO, 2003b).

15.7 Institutional arrangements for small-scale fisheries

In most developing countries today, several types of institutional arrangements (laws, rules and norms) are essential if small-scale fisheries are to be reinstated back into the fishery management processes and its implementation.

In some countries (e.g. Philippines and many of the island states in the Pacific), specific rights for small-scale and artisanal fishers are enshrined in the constitution. In some others (e.g. Cambodia) there are specific legal arrangements with endorsements from national parliaments and legislatures that give specific rights to small-scale fishing communities in relation to fishery resources and their management. Notable are legislations that reserve inshore zones for small-scale fisheries. However, in general, institutional and legal arrangements for fisheries management do not always include special provisions for small-scale fisheries. Weak institutional capacity is also the result of weak organizations and representation of small-scale fishers and fishworkers, which is often reinforced by low levels of educational status in fishing communities.

Legislation is often crucial in ensuring that certain rights, which cannot be eroded through social, economic and political marginalization, are enshrined for small-scale fishers and fishworkers. Formal legislation is therefore often very important when the intended results relate to exclusion of certain groups (e.g. industrial fishers), civil rights and/or access rights. Processes for legislative development are different in different countries, but better compliance can be fostered by legislation that involves all stakeholders in its development, as stakeholders can then claim ownership over such laws. Legislation has the potential to marginalize and create conflict, as well as to provide a framework for managing conflict issues. This raises the importance of ensuring that legislation is carefully tailored to the needs and conditions in individual countries and situations (Kuemlangan, 2004; Béné *et al*., 2007; Chapter 5).

Given the specificity of the conditions of small-scale fisheries both between and even within countries, the thrust for institutional arrangements should be to create framework legislations. These frameworks must primarily enable that rights given to small-scale fishers enjoy security, exclusivity and a degree of permanence (Kuemlangan, 2004).

However, the legal framework should also, as a minimum, ensure that powers are vested, or entities designated, to invoke such rights when the need arises. The provisions of any framework law that provide for these must allow

- designation of communities that will be involved;
- clear provisions on the allocated rights and responsibilities in fishing and fisheries management;
- the possibility to specify the areas under which these allocated rights will operate;
- freedom to devise the appropriate institutional and governance frameworks;
- delineation of the coordination functions needed across vertically and horizontally nested management areas;
- flexibility to respond to changing needs and priorities.

15.8 Making a management plan for a small-scale fishery

The role and development of management plans are discussed in detail in Chapter 16. Consistent with the process described there, making a management plan for small-scale fisheries requires a participatory, inter-disciplinary, integrated and inclusive planning process. Attempting to initiate such a process cannot be undertaken without taking cognizance of the socio-political context of the country in question.

In many countries making a new or different management plan for small-scale fisheries, despite the numerous platitudes about the need to do so, can be met with resistance

and indifference. If fishers' participation is to move from merely the right to be heard to the opportunity to define the objectives and priorities of the plan, then the manner of organizing this process is crucial; it is also difficult. But a beginning needs to be made. Countries such as Cambodia and Philippines have made progressive steps in this direction (Dickson, 2002; Try *et al*., 2002; Kurien *et al*., 2006). Some broad suggestions on the approach which can be adopted are indicated as follows:

1. The overall fishery management framework, as well as the principles and objectives behind the approaches and institutional arrangements involved, must be articulated in simple terms. Easy-to-read documents which provide the essence of the management framework and the planning process should be available in the language of the fishers.
2. Organized efforts need to be made to ensure that these documents are effectively distributed and reach the communities. If there are no genuine and representative organizations of small-scale fishers, then this task may be entrusted to civil society organizations that have the capacity and the empathy to do so.
3. There must be structured opportunities for communities to discuss the documents. The spatial and governance levels at which this needs to be done will be determined importantly by the political and administrative structures in the country. It should also take into consideration the structure and extension of the resources and the ecosystem. Participatory opinion assessment approaches such as focus group discussions and discussions with key informants (e.g. traditional fisher community leaders, men and women known for their skills in fishing, processing and marketing and community youth leaders) should be used to obtain more specific and nuanced suggestions and critiques about the framework and its principles. Public hearings may provide for even wider consultation.
4. A collation of community responses must be prepared into a coherent document. This can form the basis for more 'formal' processes of consultation with a smaller and more representative group of the small-scale fishing communities. Achieving this is easier said than done. This is particularly so if there are no associations or organizations which genuinely represent the fishers. Also, in countries with large numbers of small-scale fishers who are geographically very widely dispersed across thousands of kilometres of coastline (e.g. Indonesia, Philippines, India, Brazil, Chile, South Africa and Mozambique), this can be an extremely costly and time-consuming exercise even if it can be undertaken in a genuinely representative manner. In such contexts, NGOs and other 'articulators' of the interests of small-scale fishers such as social science researchers, community organizers and other such persons, may have to join the process and be the proxy voices of the community. It is also likely that there are officials in the fisheries departments who have a demonstrated interest in the small-scale fishing communities. They should be closely involved.
5. These inputs should be structured into the important components of fisheries management framework such as regulation, allocation, conservation and rejuvenation. The areas in which the approach of the small-scale fishers is different from the broad framework initially presented should be specifically noted. For example, input regulations designed along spatial and seasonal lines may be preferred to regulations which make technical specifications. Extractive marine reserves may be preferred over no-take marine protected areas. Coastal sea zones with free access using specified gears may be preferred over individual access rights. Community monitoring and enforcement may be preferred over the use of a government fishery surveillance apparatus.

6. Based on these inputs, the fisheries management framework can be appropriately reworked and modified – within the purview of the current legal arrangements and policy guidelines. If any of the suggestions is considered to be 'incompatible' with what can be feasibly incorporated, this points to the need for a review of the framework. Such 'incompatibilities' are important junctures in the process of management planning. They often highlight gaps between the evolving ground reality in a fishery and the existing management framework. If they remain unresolved, they can also become sources of conflict.
7. A finalized management plan needs to be discussed with the communities. This is necessary for awareness creation and to obtain greater credibility for repeating the process of participatory planning in the future. This will also be a major step in ensuring compliance with the management plan, as there is a sense of ownership over the process by which it was formulated.
8. When such a plan is finally 'put to the test', there is need for participatory monitoring of its application. There are likely to be numerous changes and adjustments which will have to be made when the management tasks are implemented. The results and reactions will need to be weighed against the objectives which were set out at the outset. This forms the basis of an important feedback loop – learning and relearning – ensuring that the management system which evolves from the plan remains vibrant and dynamic.

15.9 Implementation of small-scale fisheries management

The success of a management plan is judged by its effectiveness when implemented and this hinges essentially on the participation of small-scale fishers in the variety of activities essential for implementation. These include making regulations, communications, compliance incentives, surveillance and enforcement, dispute settlement mechanisms and the monitoring and evaluation process.

15.9.1 Making norms and regulations

Norms and regulations have to be perceived to be legitimate to be effective. Their content should stress fairness. Broadly it can be said that the norms and regulations for a management regime for small-scale fishers should consider six criteria:

1. They must have the support of the majority of the small-scale fishers if they are to be economically, socially and politically acceptable.
2. They must be amenable to gradual implementation.
3. They should be sufficiently flexible to allow for adjustment to changes in the socio-economic conditions and biological conditions even within a country.
4. They should encourage the fishery to function at optimal costs and provide incentives for improvements achieved in economic and ecosystem efficiency (e.g. through tactical changes in the pattern of fishing, innovative changes in fishing technology, expansion of fishing area and resource rejuvenation).
5. They should take full account of the enforcement and monitoring costs involved and devise ways for recovery of them.
6. They should take full cognizance of the employment and distributional implications and weigh them against the other objectives of fisheries management.

15.9.2 Communications

Quick and reliable flow of communication on every aspect of the management process is vital if implementation is to be successful. Credibility of communications is vital for creating trust between participants of a management system/regime. The communication mechanisms to ensure this must be in place. These will vary depending on the level of management. At the level of the local community (within a local regime) word of mouth communication and first-hand visual observation and understanding of various facets of the management process are the most apt. Written records at this level have a limited use. However, visual and pictorial aids can play an important role in communicating ideas effectively. Between regimes, communications are best achieved through oral mediation and arbitration processes between representatives. This may then be followed by a written record of agreements. Decisions thus taken need to be widely communicated such that all the participants in both regimes are made aware of them.

15.9.3 Compliance incentives

Even in the most ideal situations, compliance with norms and regulations can rarely be said to be totally voluntary. The greatest incentive for compliance is that almost everyone else does so. Default would be easily detected. The individual must perceive the benefits of compliance to be greater than the cost of not doing so. Compliance is also a function of the nature of penalties meted out for non-compliance. At the local level the effectiveness of fines and suspension of rights to fishing often combined with peer pressure and social sanctions are well known. It is important to stress that the sanctions be graduated, and as far as possible meted out by the participants themselves. The process of deciding the sanctions must be democratic and fair. Only such measures will ensure that voluntary compliance is increased and deviant behaviour minimized.

15.9.4 Surveillance and enforcement

The key to success of surveillance (observing and identifying) and enforcement in a small-scale fishery management system is that it should be a natural by-product of fishing in the managed territory. Ideally the enforcers should be from among the participants or appointed by them. This would make surveillance a low-cost side-benefit and enforcement would thus become more effective. The technology used by the enforcers (craft size and facilities) should not be grossly different from that of the fleet to be managed. Enforcers must be at the fishing ground regularly and not just during crisis and conflict. The relationship between enforcers and the fleet should be like that between shepherd and sheep: maintaining discipline and order in a caring manner.

15.9.5 Dispute settlement mechanism

Dispute resolution processes should be an integral part of any management system. Disputes, unless resolved with reasonable efficiency and equity, can destroy management systems and ruin the fishery. There are a variety of dispute settlement mechanisms which can be adopted

in the management of small-scale fisheries, the choice of which depends on the level at which the dispute arises and the nature of the management institution involved. Mediation, conciliation and arbitration are yet other strategies used for dispute settlement. These methods can also be effectively used in settlement of disputes between local-level groups as also between the local level and the state. The state may, however, have recourse to legal measures – but more as a last resort when all else fails.

15.9.6 Monitoring and evaluation

Monitoring the processes and actions of the aforementioned five activities and evaluating their effectiveness in implementation provide the basis for a feedback loop in this management plan. This will be the basis for the iterative revisions needed to keep the management plan relevant over time in a process of adaptive management (Section 13.8). This is a dynamic process in which the only constant factor is change. The overall plan needs to be evaluated to assess if it is management by exception or management by norms and regulations. Finding the right balance and building flexibility within the boundaries of each of the activities will become a major challenge ahead.

15.10 Capacity building for small-scale fisheries management

The centrality of capacity building in order to foster small-scale fisheries management needs to be re-emphasized. Capacity building is needed for five representative groups:

1. small-scale fishers and their organizations and other fisherfolk in fishing communities;
2. government staff who deal closely with small-scale fishers, in particular the departments of fisheries, at all levels of governance – national, provincial and local;
3. scientific community relating with fisheries issues;
4. managers, policy makers and planners broadly involved in (a) natural resource development and management, (b) trade and commerce and (c) planning and coordination;
5. civil society organizations such as small-scale fisher support groups, environmental groups, consumer organizations, trade and policy advocacy groups and human rights activists.

Small-scale fishers and their organizations and members of their communities will need various forms of capacity building to move towards new regimes of fisheries management. Many fisher organizations and NGOs in developing countries have taken systematic measures to facilitate this.[4]

Officials of state departments of fisheries in many developing countries either have been trained into the 'industrial fisheries' mould or have little formal exposure to fisheries (being

[4]The International Collective in Support of Fishworkers (ICSF), an international NGO committed to supporting small-scale and artisanal fisheries, is engaged in various kinds of capacity building activities including awareness-raising, networking and information dissemination and organizational development (http://www.icsf.net).

from forestry, agriculture or animal sciences). Often the 'unlearning' that is needed to understand and empathize with the needs of a small-scale fishery is hard to make without adequate support and appropriate exposure. Formal training may be required. Visits to situations where a transition towards small-scale fisheries management is underway can also greatly facilitate learning and commitment.

The focus on policy makers needs special attention because grasping the nuances of small-scale fisheries is not necessarily an easy task even for planners and policy makers who are otherwise well up on natural resource management. There is also a need to make more concerted efforts to obtain a better understanding of the tropical fishery and developing-country socio-cultural dimensions in which many of the small-scale fisheries operate. Issues such as the economics of small-scale operations, its possible association with retaining biological and cultural diversity, the greater spatial spread of economic activity and its role in fostering the economics of scope which accompany this may warrant a closer investigation (see Chapter 3).

Capacity building for the scientific community can include facilitating methodologies to include the knowledge of the fishers into conventional biological research and fishery resources assessments (Finlayson, 1994).

Civil society groups, and in particular environmental groups, need to be made more aware of the need to balance the preservation of nature with the concerns of those such as small-scale fishers, who depend on it for livelihood. A socially just ecosystem approach provides a good motto for the direction that needs to be taken for capacity building.

Capacity building requires external support. However, there is a very strong case for mutual learning partnerships to be developed. Exchanges between fishers and the scientists are one sure opportunity for creating a paradigm shift in co-evolution of knowledge systems and technology blending. Multi-stakeholder partnerships and platforms which permit each to share their different perspectives on management are an effective mechanism for obtaining the greatest learning synergies (Chapter 11).

The scope for a science and social science for small-scale fisheries in the broader realm of fisheries education, in the formal and informal setting, is worth pursuing.

15.11 Emerging issues

There are numerous emerging issues which will lead to greater focus matched with new and increased roles for small-scale fishers in national economies. Many of these arise from concerns which emanate from broader national and international compulsions and pressures.

15.11.1 Vulnerability due to climate change

There is increasing evidence for the continued poverty among small-scale fishing communities despite 'fisheries development' having been pursued for many decades. The vulnerability of these communities is likely to further grow with climate change impacts such as sea level rise, increased storm and wave action, rising sea temperatures and acidification causing habitat degradation. Targeted policies and support measures will be needed for greater resilience and adaptive capacity to climate change. Multi-sectoral approaches will be required to develop capabilities and entitlements across a broad spectrum of livelihood opportunities and provide

for greater safeguards against emergencies. Assigning stronger rights of access to resources and increasing roles in their management will be critical. The role of the state, market and community in achieving this will also need closer scrutiny.

15.11.2 Ethical concerns

The global debates taken up at the United Nations and other international fora on the need for fairer and more inclusive economic development and the protection of human rights will result in attention, focusing on many small-scale fishing communities that have remained socio-economically and culturally marginalized over the last few decades. The presence of numerous support groups and civil society organizations which espouse the cause of small-scale fishers and larger issues such as human rights, poverty, global hunger, indigenous people's concerns and food sovereignty (to name a few) will add pressures at both the national and international levels to act concretely on these matters with a greater sense of urgency.

15.11.3 Greater emphasis on community governance

The trends towards greater devolution and decentralization of governance in many developing countries and the emphasis on community involvement in planning and development will give new impetus to the participation of small-scale fishing communities in resource management. When their roles are structured into state-sponsored decentralized resource planning initiatives, they acquire a 'formal and legal' status. Both the political and economic compulsions favouring more participative community governance make for greater urgency to assist small-scale fishers to enhance their capabilities to involve themselves creatively in these initiatives. However, since the activity of small-scale fishers will tend to straddle the relatively small riparian boundaries of decentralized governance units (such as districts), defining the role and creating the mechanisms for coordination between decentralized governance structures will be a major emerging challenge.

15.11.4 New consumer preferences

The role played by discerning consumers in modulating the way trade and business are conducted will further increase in future. The concerns for global resource sustainability and the calls for adopting responsible and sustainable consumption patterns will play a growing role in the world's fisheries sector. These concerns will be voiced primarily in the realm of international trade. With fish being one of the most widely and extensively traded primary commodities, the echoes will reverberate loudly in the harvesting realms of the sector. The role of small-scale fisheries in catering to the international consumer preferences will be both more keenly tracked and increasingly recognized. Herein lie both opportunities and threats.

15.11.5 Biodiversity conservation

Implementing the Convention on Biodiversity (CBD) further enhances the possibility of small-scale fisheries and fishing communities receiving greater attention as one among the

principal agents in the goal for conservation of coastal marine biodiversity. The Convention recognizes the need for full and effective participation of indigenous and local communities. The programme of work on marine and coastal biological diversity under the CBD, recognizes the need to protect the preferential access rights of fishers and fishworkers, particularly those engaged in subsistence, small-scale and artisanal fisheries, to traditional fishing grounds and resources, and should contribute to poverty alleviation. Given the greater international commitment to the CBD processes, this recognition of small-scale fishing in it is likely to become a legal instrument with considerable influence in the immediate future.

Sources and recommended reading

Allison, E.H. and Seeley, J.A. 2004. Another group at high risk for HIV. *Science*, 305: 1104.

Baland, J.-M. and Platteau, J.-P. 1996. *Halting Degradation of Natural Resources. Is There a Role for Local Communities?* Published for FAO by Clarendon Press, Oxford University.

Béné, C. 2003. When fishery rhymes with poverty: A first step beyond the old paradigm in small-scale fisheries. *World Development*, 31(6): 949–975.

Béné, C., Macfadyen, G. and Allison, E.H. 2007. Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Fisheries Technical Paper No. 481. Rome, FAO. 125p.

Berkes, F., Feeny, D., McCay, B.J. and Acheson, J.M. 1989. The benefits of the commons. *Nature*, 340: 91–93.

Berkes, F., Mahon, R., McConney, P., Pollnac, R. and Pomeroy, R. 2001. *Managing Small-Scale Fisheries, Alternative Directions and Methods*. International Development Research Center, Ottawa, Canada.

Castilla, J.C., Manrıquez, P., Alvarado, J., Rosson, A., Pino, C., Espoz, C., Soto, R., Oliva, D. and Defeo, O. 1998. Artisanal 'caletas' as units of production and co-managers of benthic invertebrates in Chile. In: *Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management*. Jamieson, G.S. and Campbell, A. (eds). *Canadian Special Publication of Fisheries and Aquatic Science*, 125: 407–413.

Charles, A.T. 2002. Use rights and responsible fisheries: Limiting access and harvesting through rights-based management. In: *A Fishery Manager's Guidebook. Management Measures and Their Application*. Cochrane, K.L. (ed.). pp. 131–157. FAO Fisheries Technical Paper No. 424. Rome, FAO. 231p.

Christy, F.C. 1982. Territorial use rights in marine fisheries. Definitions and conditions. FAO Fisheries Technical Paper No. 227. Rome, FAO.

Christy, F.C. 1999. Common property rights: An alternative to ITQs. Paper prepared for the FAO/Western Australia Fishrights99 Conference on the use of property rights in fisheries management, Fremantle, Australia, 11–19 November. In: *Use of Property Rights in Fisheries Management*. Shotton, R. (ed.). pp. 118–135. FAO Fisheries Technical Paper No. 404/1. Rome, FAO.

Cochrane, K.L. 2000. Reconciling sustainability, economic efficiency and equity in fisheries: The one that got away? *Fish and Fisheries*, 1(1): 3–21.

Dickson, J.O. 2002. Current status of small-scale fisheries in the Philippines. In: *Interactive Mechanisms for Small-Scale Fisheries Management* – Report of the Regional Consultation. Bangkok, FAO.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome, FAO. 41p.

FAO. 1997. *Fisheries Management*. FAO Technical Guidelines for Responsible Fisheries No. 4. Rome, FAO. 82p.

FAO. 2002. *The State of World Fisheries and Aquaculture*. Rome, FAO.

FAO. 2003a. Report of the twenty-fifth session of the Committee on Fisheries. Rome, 24–28 February. FAO Fisheries Report No. 702. Rome, FAO. 88p.

FAO. 2003b. *The Ecosystem Approach to Fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome, FAO. 112p.

FAO. 2004. Advisory Committee on Fisheries Research. Report of the second session of the working party on small-scale fisheries. Bangkok, Thailand, 18–21 November 2003. FAO Fisheries Report No. 735. Rome, FAO. 21p.

FAO. 2005a. *Ethical Issues in Fisheries*. FAO Ethics Series 4, Rome, FAO.

FAO. 2005b. *Increasing the Contribution of Small-Scale Fisheries to Poverty Alleviation and Food Security*. FAO Technical Guidelines for Responsible Fisheries No. 10. Rome, FAO. 79p.

Finlayson, A.C. 1994. *Fishing for Truth: A Sociological Analysis of Northern Cod Stock Assessments from 1977 to 1990*. Institute of Social and Economic Research. St. John's: Memorial University of Newfoundland, Canada. 176p.

Hilborn, R., Orensanz, J.M. and Parma, A.M. 2005. Institutions, incentives and the future of fisheries. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360: 47–57.

International Conference of Fish Workers and their Supporters (ICFWS). 1984. Report of the International Conference of Fishworkers, and Their Supporters, Rome, 4–8 July. Aquatic Commons. Online http://aquacomm.fcla.edu/268/

International Collective in Support of Fishworkers (ICSF). 1994. The Cebu Conference: Proceedings. Aquatic Commons. Online http://aquacomm.fcla.edu/275/

International Collective in Support of Fishworkers (ICSF). 2007. The Siem Reap Meet Proceedings: Asserting Rights, Defining Responsibilities: Perspectives from Small-Scale Fishing Communities on Coastal and Fisheries Management in Asia. Online http://www.icsf.net

International Food Information Council. 2008. Brochure on Fish and Your Health. Online http://ific.org/publications/brochures/fishbroch.cfm, accessed on 16 April 2008.

Jentoft, S. 1989. Fisheries co-management – delegating government responsibility to fishermen's organisations. *Marine Policy*, 13(2): 137–154.

Johannes, R.E. 1981. *Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia*. University of California Press, Berkeley and Los Angeles.

Johannes, R.E. 1998. The case for data-less marine resource management: Examples from tropical nearshore finfisheries. *Trends in Ecology and Evolution*, 13(6): 243–246.

Johnson, D.S. 2006. Category, narrative, and value in the governance of small-scale fisheries. *Marine Policy*, 30: 747–756.

Kuemlangan, B. 2004. Creating legal space for community-based fisheries and customary marine tenure in the Pacific: Issues and opportunities. FishCode Review No. 7(En). Rome, FAO. 65p.

Kura, Y., Revenga, C., Hoshino, E. and Mock, G. 2004. *Fishing for Answers: Making sense of the global fish crisis*. World Resources Institute, Washington.

Kurien, J. 1988. Studies on the role of fishermen's organizations in fisheries management. The role of fishermen's organizations in fisheries management of developing countries (with particular reference to the Indo-Pacific region). FAO Fisheries Technical Paper No. 300. Rome, FAO. pp. 29–48.

Kurien, J. 1996. T*owards a New Agenda for Sustainable Small-Scale Fisheries Development*. (Monograph for UN Department for Policy Coordination and Sustainable Development, New York), SIFFS Monograph, Trivandrum.

Kurien, J. 1998. Traditional ecological knowledge and ecosystem sustainability: New meaning to Asian coastal proverbs in ecological applications. *Ecosystem Management for Sustainable Marine Fisheries*, 8(1), Suppl: S2–S5.

Kurien, J. 2000. Community property rights: Re-establishing them for a secure future for small-scale fisheries. pp. 288–294. In: *Use of Property Rights in Fisheries Management. Proceedings of the FishRights99 Conference. Fremantle, Western Australia, 11–19 November 1999. Mini-Course Lectures and Core Conference Presentations*. Shotton, R. (ed.). FAO Fisheries Technical Paper No. 404/1. Rome, FAO. 342p.

Kurien, J. 2005. Responsible fish trade and food security. FAO Fisheries Technical Paper No. 456. Rome, FAO. 102p.

Kurien, J. 2007. The blessing of the commons: small-scale fisheries, community property rights, and coastal natural assets. In: *Reclaiming Nature: Environmental Justice and Ecological Restoration*. J. Boyce *et al*. (ed). Anthem Press, UK and USA.

Kurien, J. and Willmann, R. 1982. *Economics of artisanal and mechanized fisheries in Kerala. A study of costs and earnings of fishing units*. FAO/UNDP Small-Scale Fisheries Promotion in South Asia Project RAS/77/044, Madras, Working Paper (34): 112p.

Kurien, J., So, N. and Mao, S.O. 2006. *Cambodia's Aquarian Reforms: The Emerging Challenges for Policy and Research*. Inland Fisheries Research and Development Institute, Department of Fisheries, Phnom Penh, Cambodia. 34p.

Mathew, S. 2001. Small-scale fisheries perspectives on an ecosystem-based approach to fisheries management. *Paper Presented at the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem*. Reykjavik, Iceland, 1–4 October.

McGoodwin, J. 2001. Understanding the cultures of fishing communities: A key to fisheries management and food security. FAO Fisheries Technical Paper No. 401. Rome, FAO. 287p.

National Research Council. 1986. *Proceedings of the Conference on Common Property Resource Management*. National Academy Press, Washington, DC.

Neiland, A.E. and Bene, C. (eds). 2004. *Poverty and Small-Scale Fisheries in West Africa*. FAO/Kluwer Academic Publishers, Boston, Rome.

Nielsen, J.R., Degnbol, P., Viswanathan, K.K., Ahmed, M., Hara, M. and Abdullah, N.M.R. 2003. Fisheries co-management – an institutional innovation? Lessons from South East Asia and Southern Africa. *Marine Policy*, 28(2): 151–160.

Ninnes, C. 2003. Improving the collection, analysis and dissemination of information in small-scale fisheries. *Paper Prepared for the Advisory Committee on Fisheries Research (ACFR). Working Party on Small-Scale Fisheries*. Bangkok, Thailand, 18–21 November.

Nomura, I. 2007. *Artisanal and Small-scale Fisheries Management Regimes in Asia: Possible Options Towards Responsible Fisheries*. Keynote Address at 'Asserting Rights, Defining Responsibilities: Perspectives from Small-scale Fishing Communities on Coastal and Fisheries Management in Asia', Report of the proceedings of the Asian workshop and symposium held in Siam Reap, Cambodia, Chennai Online http://www.icsf.net

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, New York.

Panayotou, T. (ed.). 1985. *Small-Scale Fisheries in Asia: Socioeconomic Analysis and Policy*. International Development Research Centre, Ottawa, Canada.

Pinkerton, E. (ed.). 1989. *Cooperative Management of Local Fisheries: New Directions for Improved Management and Community Development*. University of British Columbia Press, Vancouver, 299p.

Pomeroy, R. and Williams, M. 1994. *Fisheries Co-Management and Small-scale Fisheries: A Policy Brief*. International Centre for Living Aquatic Resource Management, Manila. 15p.

Ruddle, K. 1994. *A guide to the literature on traditional community-based fishery management in the Asia-Pacific tropics*. FAO Fisheries Circular No. 869. Rome, FAO. 114p.

Ruddle, K. and Johannes, R.E. (eds). 1990. *Traditional Marine Resource Management in the Pacific Basin: An Anthology*. UNESCO, Jakarta.

Shotton, R. (ed.). 2000. Use of property rights in fisheries management. *Proceedings of the FishRights99 Conference. Fremantle, Western Australia, 11–19 November 1999*. FAO Fisheries Technical Paper No. 404/1. Rome, FAO. 342p.

Smith, I.R. 1979. *A Research Framework for Traditional Fisheries*. International Center for Living Aquatic Resources Management, Manila. 45p.

Smith, L.E.D., Nguyen Khoa, S. and Lorenzen, K. 2005. Livelihood functions of Inland fisheries: Policy implications in developing countries. *Water Policy*, 7: 359–383.

Thomson, D. 1980. Conflict within the fishing industry. *ICLARM Newsletter*, 3: 3–4.

Try, I., Vansereyvuth, S. and Somony, T. 2002. Small-scale fisheries management in Cambodia. In: *Interactive Mechanisms for Small-Scale Fisheries Management*. Report of the Regional Consultation, Bangkok, FAO.

United Nations. 1982. *United Nations Convention on the Law of the Sea*. UN Doc. A/Conf.62/122.

Willmann, R. 2000. Group and community-based fishing rights. In: *Use of Property Rights in Fisheries Management. Proceedings of the FishRights99 Conference. Fremantle, Western Australia, 11–19 November 1999*. Shotton, R. (ed.). pp. 51–57. FAO Fisheries Technical Paper No. 404/1. Rome, FAO. 342p.

Willmann, R. 2004. *Restoration and Management of Small-Scale Fisheries: Meeting the Challenge*. 7th Asian Fisheries Forum, Penang, Malaysia. 30 November–4 December 2005.

Wilson, D.C., Nielsen, J.R. and Degnbol, P. 2003. *The fisheries co-management experience: Accomplishments, challenges and prospects*. Fish and Fisheries Series 26, Kluwer Academic Publishers, The Netherlands.

World Humanity Action Trust (WHAT). 2000. Governance for a Sustainable Future, London, England. Online http://www.earthsummit2002.org/es/issues/Governance/whatgov1.pdf

Chapter 16

Fisheries Management Plans

David J. Die

16.1 Introduction

Planning is an essential part of the management process regardless of whether one deals with the management of a fishery or the management of a car assembly line. The management plan is the main instrument that specifies how management is to be conducted in the future. In many fisheries, fishery management plans (FMPs) are often also instruments not just for planning but also for operational management. These plans do not just document the way to reach management goals in the future (strategic) but also describe how to manage the fishery in the present (tactical). This dual purpose of FMPs is not recognized universally; in fact the only mention of an FMP in the FAO Code of Conduct is in Paragraph 7.3.3 where it states:

> Long-term management objectives should be translated into management actions, formulated as a fishery management plan or other management framework.

The FAO Technical Guidelines for Responsible Fisheries (FAO, 1997), however, clarify that FMPs have a tactical component to them that defines day to day management:

> The management plan provides detail on how the fishery is to be managed and by whom. It should include a management procedure which gives details on how management decisions are to be made in accordance to developments within the fishery . . .

In fact these FAO guidelines give a very specific definition of an FMP:

> A fisheries management plan is a formal or informal arrangement between a fishery management authority and interested parties which identifies the partners in the fishery and their respective roles, details the agreed objectives for the fishery and specifies the management rules and regulations which apply to it and provides other details about the fishery which are relevant to the task of the management authority.

In deciding upon a definition that acknowledges formal or informal arrangements, FAO draws attention to the fact that having a formal document describing an FMP may not be the only way to achieve the objectives of management. It acknowledges the fact that in some fisheries there are management arrangements that are successfully achieving the management objectives of specific fisheries but are not formally collated into a document called an FMP. Although such situations are discussed briefly later, the focus of this chapter remains the description of the process of how to develop a formal FMP. This is done by broadly following the FAO Guidelines (FAO, 1997) regarding the development, implementation and review of FMPs. Also, some examples are presented to highlight how components of those guidelines can be

found in the FMPs developed for some important fisheries around the world. The examples are not meant to be comprehensive but rather serve to highlight how FMPs have been developed and implemented in real fisheries.

16.2 Designing a management plan

16.2.1 What should a management plan contain?

The institutional arrangements pertinent to a fishery are essential in defining the contents of its management plan. The international, national and even regional institutional context within which a fishery takes place (Chapter 6) will influence the fishery policies and legislation that govern the fishery. In some countries, like the United States of America or Australia, there are specific references to the need to develop management plans in their fisheries legislation (e.g. Queensland, Australia: Fisheries Act; United States of America: Magnuson-Stevens Act). That same legislation may specify the main sections that a management plan should contain. At a minimum, FMPs should contain:

- a description of the fishery especially its current status and any established user rights:
- the management objectives;
- how these objectives are to be achieved;
- how the plan is to be reviewed and/or appealed; and
- the consultation process for review and appeal.

More details on the exact contents of real FMPs can be found in the examples presented in Section 6.6 and for more detail on FMPs developed for small-scale fisheries in developing countries refer to Chapter 15. Additionally other chapters in this book cover in detail several subjects that are essential in the development of an FMP. For details on how to develop operational management objectives refer to Sections 12.4.1 and 13.4.2, and for an in-depth presentation of tools used to achieve management objectives refer to Chapters 7, 8, 9 and 14. For a discussion on the type of scientific information that must be collected and used to evaluate the biological, ecological, social, and economical status of a fishery read Chapters 2, 3 and 4, respectively, as well as Chapters 12 and 13. For an in-depth summary on the existence and allocation of user rights refer to Chapter 10 and for a review on how to develop an implement successful monitoring, control and surveillance see Chapter 14.

16.2.2 International fisheries policy requirements

Nowadays one of the most basic requirements recognized in FMPs is the adherence to the internationally sanctioned United Nations Convention on the Law of the Sea of 10 December 1982 (LOSC), the FAO Code of Conduct and the precautionary approach to management (see Section 5.2.2). Such adherence tends to be recognized in the fishery policies of each state or in the statutes of international organizations in charge of coordinating fisheries management. For fisheries in the high seas and for those plans dealing with straddling stocks, the FMP must clearly specify the international regulatory and institutional context within which the plan is applicable (e.g. United Nations Fish Stocks Agreement). In such cases the FMP should have clear links to both

the national fishery management policy and to the statutes of the commission or international organization in charge of coordinating the management of the international fishery. For example the Australian FMP for Southern Bluefin tuna has as a first objective:

> . . . to ensure, by appropriate management and in conjunction with the Commission (the Commission for the Conservation of Southern Bluefin Tuna), the conservation of the stock of southern bluefin tuna . . .

A word of caution must be expressed in reference to national FMPs designed to manage fisheries for resources which, at least partially, are distributed in the high seas, or that are shared between two or more countries. Because these resources are not under the jurisdiction of a single nation the FMP, being a national instrument, will only be applicable within the exclusive economic zone of that nation. This does not mean that the FMP will be ineffective, but it does mean that the plan may have to define national objectives that are constrained by the objectives of other countries (see the FAO Code of Conduct, Paragraphs 6.12, 7.1.2 and 7.3.2).

16.2.3 National/state fisheries policy requirements

National fishery policies should be supported by a legal and institutional framework so that FMPs can be the main instrument of management. In that respect, every national fishery policy should define the range of minimum requirements that an FMP should fulfill. The national policy should therefore broadly determine the type of information required to be included in an FMP so that all FMPs achieve the goals of the national fishery policy. Because these goals are likely to be broad the information requirements are likely to be vague. However, it remains the responsibility of those preparing each FMP to make sure that the specific objectives of an FMP comply with the national fisheries policy.

16.2.4 Fishery-specific requirements

The minimum requirements specified by national fishery policies still tend to leave considerable leeway about the contents of an FMP. As a result even within a single fisheries jurisdiction there are large differences between the FMPs developed for different fisheries. This should be considered a strength of the policy because it ensures that the FMP is developed to suit the specific needs of the managers of each fishery and is not just a bureaucratic requirement.

It is essential that the plan specify how the management objectives (operational objectives) of the plan are to be met. If possible each management objective should be examined individually and the management measures that are designed to help achieve that objective should be identified and explained. Here the plan needs to be very specific on how objectives and measures link up and which performance indicators are going to be used to measure the achievement of management objectives. This must be done by structuring the plan in a way that requires the development of performance indicators (Chapter 12). The indicators must cover all objectives of the plan, so in general there will be indicators of the biological status of the stock but also social and economic indicators of the health of the fishery and the ecosystem.

In general, the plan will not specify the exact way the indicators are developed, but it must require their development. As an example, forecasts on the economic impact of fisheries

management actions could be used as an indicator of the success of a plan in trying to achieve its objective of maximization of economic returns.

The FMP should ideally make reference to the characteristics of the natural environment within which the fishery takes place and to how changes in this environment may affect the management of the fishery. If there are traditional management structures or established rights that have been historically used, these should be recognized and included in the FMP (see Section 10.3.1). These descriptive sections of the plan should contain the most critical information on both the natural environment and the traditional management structures. It is not necessary to be overly detailed in their presentation, because the emphasis should be on information that is essential to give context to the objectives of the plan. Examples of this are information used in defining the unit of stock, the definition of the ecosystems and habitats that support the main target and bycatch species, and biological information that supports stock assessments. Additional examples are a description of historically established community management practices, and the marine institutional context existing prior to the development of the FMP.

Management objectives in an FMP often conflict (e.g. resource conservation versus. maximizing economic returns or promoting development). The plan must acknowledge this conflict and address it through requiring a process by which conflicts between objectives can be resolved, as discussed in Section 3.5 This could be achieved by specifying some of the indicators associated with conservation objectives as constraints (even though conservation groups may consider them as targets), whereas indicators of economic performance might be identified as targets. This will result in the development of operational objectives and will lead to appropriate target and limit reference points.

16.2.5 Who should design a management plan?

Which authority is responsible for the development depends on the institutional arrangements existing in the country or state that has to develop the plan. In general, it will be the authority in charge of the management of the fishery for which the plan is being developed (see Chapter 6). In cases where the fishery falls under the mandate of more than one government authority, there must be a policy or an agreement between them defining which entity has responsibility. In any case, the responsible authority must make sure that all interested parties in the fishery should participate in its development (FAO Code of Conduct, Paragraph 7.1.2; FAO, 1997) because broad participation of interested parties ensures judicious choices in the design of the plan and is likely to facilitate its later implementation (see Section 11.1).

All interested parties should be offered the opportunity to participate in the development of an FMP, and this will also include involving community organizations. There are, however, marked differences in complexity between fisheries and uneven participatory capacity among user groups. Thus, at a minimum, the main agency in charge of developing the FMP should invite the following groups to participate: the agency in charge of monitoring, compliance and surveillance, the research community that can provide scientific advice that will support management decisions, and representatives of fishermen, fish processors, environmental groups and local government. For more complex fisheries the list can be much longer and include different levels of fishery governance (local, state, national, international), other government departments involved in marine management (environmental protection, port authorities, at sea security, transport, mining, etc.), different subsectors of the community of fishers (industrial, artisanal,

recreational) and many other NGOs with an interest in renewable marine living resources. As the list of contributors to the plan grows it is important to distinguish clearly between those that have the responsibility of leading the development of the plan (typically a small group led by representatives of the fishery management authority, fishermen, environmental groups and scientists) and those that are contributors to it. For more detail on how to involve these organizations refer to Chapter 11. The identification and consultation with interested parties should be one of the first steps to be conducted in the development of an FMP. The earlier the interested parties are involved in this development the greater the sense of ownership of the final FMP they will have. By participating in the process they will be more aware of their rights and responsibilities towards resource management and will tend to comply better with management provisions. All steps in the consultation with interested parties (e.g. comments on discussion paper) should be formally structured and described within the FMP document. In cases were there are substantial differences in the capacity of interested parties to participate in this process, the plan should include capacity building. Section 10.1.4 discusses further the concept of 'management rights' the right to participate in the management process and Section 11.6 details equity issues related to the capacity of different types of interested parties to participate in the management process.

Increasingly there is a requirement to attempt to coordinate the management plans of all marine resources, including fisheries. Other agencies are developing their own marine resource management plans and fishery managers increasingly recognize the need to influence the management of impacts on the ecosystem and protect those habitats and resources that are critical for the health of the fishery. This need to coordinate management is an integral part of the ecosystem approach to fisheries (EAF) management and leads to having to make sure that the groups participating in the public consultation process include all management agencies that have responsibility for management of activities or resources that may be related to, or affect, fishery resources or to the environment that supports them (FAO Code of Conduct, Paragraphs 10.1.2 and 10.1.5). Because these agencies (e.g. offshore mining and oil, transport, coastal zone development) are developing management plans directed at achieving their sectoral goals, it is likely that goals from different agencies will conflict and any process of consultation aimed at reducing such conflict can be difficult and lengthy. Often other marine management agencies have different perceptions about the importance of resources within the marine environment to those of the fishery agencies. This often creates differences between what other agencies think is desirable and what the fishery agency thinks is achievable. One way to resolve these differences is through well-structured negotiations established within the consultation process for the FMP.

The development of an FMP requires information about the fishery and the social, economic and natural environments within which the fishery operates. The gathering of information, in the form of data or expert knowledge, is the responsibility of the management authority. More detail on which information should be collected and how it should be presented to those in charge of the development of the FMP is discussed at length in Chapters 2, 3, 4, 12 and 13.

16.2.6 Timetable for developing a management plan

In theory, the development of a management plan is the first management action that any responsible fishery agency should take when it starts managing a fishery (FAO, 1997). In practice,

however, management plans were only recently developed for even the most important fisheries of the world. The first step in the development of an FMP is usually to create a working group that develops a discussion paper. Public comments are then sought through meetings and letters and analyzed and formally responded to. Next a draft management plan is developed and released. Public comments are again sought, analyzed and formally responded to. After that the final management plan is developed and sent to the appropriate minister for approval before coming into effect. More details of each of these steps can be found in the following paragraph.

When an FMP is about to be developed, it is best to put it out as an initial document for public comment that describes, in layman's language, the reasons for developing the plan and the proposed contents of the plan. This document is similar to that of an FMP but must be easy to read and often will contain more background fishery information than the FMP. This document, often referred to as a discussion paper, should aim at two things, informing the public and interested parties about the plan and seeking their comments. Important information such as current legislation or summaries of the knowledge about the status of the fishery should be included as appendices to the discussion paper. These documents can have a list of specific questions attached to each of the major issues identified by the group developing the FMP. These questions are often part of a formal questionnaire included with the discussion paper and designed to elicit comments by interested parties. General comments, other than those sought through the questions, should also be solicited in the questionnaire. It is important that the management authority encourages representatives of all interested parties to take time to review the discussion paper and make their comments to this authority. Participation of all interested parties is essential and should be facilitated by the management authority as much as possible. This is especially important because the group of people involved in the initial development of the discussion paper have the opportunity and responsibility to define the scope of the final plan. Initial investment in the consultation process will save a lot of resources later and will help the plan to have the highest possible initial acceptance when it is implemented.

Once the discussion paper is formally released, the public and interested parties should be given a set time to make comments, for example three months. During this time, it is advisable to organize meetings between the management authority and interested parties (e.g. meetings in the major fishing ports) to seek comment and promote discussion. Transparency during this process will later help during the implementation of the plan. After the comments have been collated the management authority should formally answer these and revise whichever sections of the plan the authority deems appropriate.

The public consultation period is also a period of negotiation and the effort required by the developers of the plan in this process should not be underestimated. This is due to the fact that consultation inevitably leads to the presentation of opposing views about the management process. These opposing views must always be measured against the management objectives established for the plan and the national fisheries policy. The fishery management authority must therefore make sure that the special interests of some interested parties do not override the principles contained in the national fishery policy.

The first draft management plan is then released and new comments are sought, again specifying a time frame of a few months. The draft management plan is likely to be quite a different document from the discussion paper especially because of the legal language that is to be included in certain sections. It is therefore harder for people to understand and comment on this document. This highlights the benefits of releasing initially a discussion paper. The fishery management authority should, again, devote attention to ensuring that the draft management plan is understood and well accepted by the interested parties. After the second period of comment is finished, and

unless there are extraordinary circumstances that require another review of the plan and a third round of consultation, the final plan draft should be prepared and submitted to the ministry of fisheries, or equivalent, for approval. To ensure that delays in this process do not undermine the capacity of the fisheries authority to conduct good management, it should be at all times emphasized to the public and interested parties that FMPs are to be reviewed periodically and that it is not precautionary to delay necessary management actions when the status of resources requires conservation measures. The fisheries ministry must also be firm in this respect and should avoid political interference getting in the way of the implementation of a plan that has been developed through the appropriate consultation process.

16.3 Implementation of management plans

Once the FMP has been approved it is important to inform the public of its contents. A good strategy is to summarize the major points of the plan in easy-to-read leaflets or brief documents that can be distributed to interested parties. These documents will serve the purpose of informing the public of the contents of the new plan and are likely to generate comments from the public that can be considered during future reviews of the plan. Hopefully these documents will also ensure greater compliance with the regulations by explaining the reasons why these regulations are in place.

Management plans have to consider the likelihood that they will be complied with and the enforcing requirements to ensure such compliance (FAO Code of Conduct, Paragraphs 7.7.2 and 7.7.3). A management plan that cannot be properly enforced may damage the credibility of the management authority and therefore undermine the management of other fisheries (FAO, 1997). It is essential that during the development of the plan, fishers and other interested parties affected by plan rules are asked whether these rules are likely to be complied with (see Chapter 11). The plan should also emphasize the consequences of non-compliance and may often include a description of the penalties (loss of license, fines) when serious offenses occur. In addition to the details on monitoring, control and surveillance provided in Chapter 14, Chapter 10 specifies how to implement a system of user rights, and how such a system can help compliance. Chapter 11 describes how community groups can facilitate the implementation of the plan and help in the compliance of plan rules. Ultimately FMPs should follow the principles of precautionary fishery management and consider the likely level of compliance by users of the resource. FMPs should therefore establish management strategies that can be effective and reach the plan's objectives at the expected level of compliance. Although the management plan does not need to contain all the detailed actions that will make it an operational tool, it must define the parameters within which the fishery agency will implement the strategies presented. In many cases, especially in developing countries, the FMP can go a long way towards defining the operational tools that will help managers achieve the plan's objectives. It can therefore become the main tool to implement, monitor and improve management strategies.

16.4 Reviewing and amending management plans

Factors of importance to fisheries change through time; therefore, FMPs must be periodically reviewed. If possible, during the development of the management plan such changes

should be predicted and included in the section of the plan that defines the review process. For example if it is known that a new management measure (e.g. establishment of a marine reserve) may take several years to have a detectable effect, the plan can call for a review of the measure after the required number of years have passed.

16.4.1 Mechanisms for review

The mechanism for review should be specified in the plan itself. In general, the consultation process should parallel the initial process used to develop the plan but is likely to be shorter in time and should only require one draft review document seeking comments from interested parties and the public, and a final draft to be submitted for approval. Major reviews may require public meetings, where interested parties can air their views about the proposed amendments to the plan. Because of the need for public consultation, it is best, whenever possible, to break down amendments to the plan into small and discrete components, rather than attempt to change all the shortcomings of the FMP in a single amendment. This strategy has been successfully used in the United States to modify management plans of complex multispecies fisheries such as the Gulf of Mexico Reef fish fishery or the South Atlantic Snapper-grouper fishery. In both of these fisheries, an amendment has been prepared almost every year by the respective management councils. Some of these amendments are developed and approved within a few months but others may take longer. Sometimes the councils are considering more than one amendment at a time. By breaking down the process of review into small steps the management councils are successfully and continuously improving the plan. Chapter 11 details processes that can help the review process at community level and provides useful concepts on how reviews may be implemented in artisanal fisheries.

16.4.2 Review strategy

Often, plan reviews are motivated by changes in the socioeconomic status of the fishery or the biological status of the fish stock. It is to be expected that, after the initial development of a plan, it will take several years to close the information gaps that may have been identified during its development. Therefore, a major review of an FMP is unlikely to happen until several years have passed and people have had time to review and evaluate the need for, and effects of, possible new management regulations. It must be remembered, however, that the lack of scientific information cannot be used as an excuse for inaction and that the precautionary approach calls for management action on the basis of the best information available (FAO Code of Conduct, Paragraph 7.5.3). FMPs therefore must be reviewed whenever it is precautionary to review the plan, not just when new data become available. It is therefore recommended that within the FMP a regular schedule for reviews is defined. At a minimum, a plan should be reviewed every five years.

16.4.3 Changing management measures without amending the FMP

In some instances the process of review of a management plan takes too long for it to be an efficient way to make an urgent change of a management measure. This is often due to the

fact that FMPs are often legislated documents that require a specific and lengthy procedure to change them. It is therefore advisable to build within the plan the facility to make changes that do not require amending the plan. In Australia, for example, regulations that have to change at short notice such as the start and end of the fishing season or annual changes to a total allowable catch are introduced through executive rules (in Australia these are referred as 'directions') by the fishery management agency. These rules have legal standing but do not require amendment to the plan. This is achieved by defining, within the FMP, the nature and conditions by which these rules can be introduced.

16.5 FMP within the context of the EAF

Initially, fishery management was limited to the control of harvesting the target resource, without consideration of any effects of harvesting on other resources. Later, management of bycatch species was introduced into the fishery manager's agenda. Finally, the management of indirect impacts on other marine species that depend on fishery resources as a source of food and the impact of fishing gear on marine habitat have now become an important part of fishery management (e.g. FAO Code of Conduct, Paragraph 7.2.2.). All these issues are part of the EAF, within the context of ecologically sustainable development (ESD) and must be considered during the development of an FMP.

The United Nations World Summit on Sustainable Development and many countries have accepted that broad EAF considerations must be part of fishery policy. In practice, however, this has not always translated into operational changes to FMPs, partially because most issues relating to fishing impacts on non-target species or marine habitat are poorly understood and studied. There tend also to be few management measures that can alleviate negative impacts on the environment, for example habitat destruction produced by trawls, without severely disrupting fishing operations.

This lack of information does not mean that EAF issues can be ignored during the development of an FMP. It is essential that these issues be at least identified within the plan. If there is no information to quantify the importance of the impact or on the capacity of managers to control it, the plan should at least specify how such information will be obtained in the future and provide a timetable of actions to gather such information (see Article 12 of the FAO Code of Conduct and Section 13.5.2).

In cases where the management of the coastal environment or non-fisheries marine resources is not the responsibility of the fisheries authority, it is essential to link the FMP to other management plans such as coastal zone management plans (FAO Code of Conduct, Paragraph 6.9). At the minimum the FMP should clearly define the agencies responsible for management of the coastal and marine environment that may be affected or have an interest in the FMP. Ideally, the FMP should be developed to help reach the objectives of coastal zone management plans for the areas where the fishery is taking place. This might be achieved directly with instruments of management that are available through fishery legislation, such as prohibiting the cutting of mangroves or damage to seagrass beds. Fishery agencies must be part of coastal area management processes in order to make sure that, when appropriate, the FMP becomes one more instrument to achieve the objectives of these processes. This will also help to ensure that other sectoral management plans developed within these processes help to achieve the objectives of the FMP.

16.5.1 Bycatch

Management plans are generally developed for individual stocks or groups of stocks or species that are the target of particular fisheries. Few such fisheries, however, harvest the target species without catching other species (bycatch). It is recognized that removal and disposal of bycatch also needs to be managed. In some cases management of bycatch can have some very specific objectives such as those established for protected species that are incidentally caught by fishing gear (e.g. sea turtles, seabirds, marine mammals). These objectives are generally to minimize bycatch and promote survival of those animals caught. Although management of such protected species is sometimes the charge of non-fisheries agencies, these agencies need to be part of the team developing the management plan for the fishery that captures the protected species. In any case the development of management measures aimed at protecting these species needs to consider the fishery constraints of implementing protection measures, because the success in the implementation of these measures often hinges on the cooperation of fishermen and fishery managers.

Bycatch, however, does not just relate to protected species. Most of the bycatch is made up of either undesirable species, that are typically discarded, or species that are marketable but that are of lesser value or abundance than those that are the main target of the fleet. Both of these types of bycatch require management and consideration must be given to them within the management plan.

Those species that are retained and marketed may be the target of other fleets and fisheries. If they are, then there should be a management plan that defines their uses and administration and such a management plan should be cross-referenced in a special section on bycatch. This is especially important when there are specific management measures that regulate removals of such bycatch species. Cross-referencing of rights and regulations for removal of bycatch species creates such complexity in management that sometimes it is better to remove the rights of harvesting certain bycatch species from individual fleets. In such cases the bycatch species, although it has a market value, is not allowed to be landed by a particular fleet because another fleet or fleets have exclusive rights of harvest.

Many bycatch species of market value are landed in such small quantities by all fleets that they are not considered in any single management plan. At a minimum, the management plan should establish procedures for monitoring the catch of these species because often these are the species that in the future become important to the market as the abundance of target species is reduced or as the fleets diversify their activities towards other fishing grounds and new fishing techniques are introduced which may harvest them more effectively.

Finally, in many cases, fleets catch many species that have no market value and are discarded. The principles of precautionary management and ecosystem-based management clearly establish that fleets must try to reduce such catch to a minimum and promote survival of discards. Therefore, all management plans should have procedures that establish monitoring of such catch and a plan to reduce it. This needs to be done through a combination of management measures including gear, catch handling and fishing strategy modifications that will both reduce the catch and improve the survival of unwanted bycatch. Because these modifications are not always unique to a single fishery fleet, often countries or fishing commissions establish a specific national or international management plan for bycatch which coordinates the measures developed for the ensemble of fleets.

16.5.2 Trophic chain effects of harvesting

The effects of harvesting in trophic chain structure and functioning are the subject of intense scientific debate and have recently been mentioned as requiring attention by fishery managers. The scientific idea is in principle simple, as fishing removes a few selected species, other components of the trophic chain may increase or decrease in response to those removals. Such responses may negatively impact the overall productivity of individual species or of the ecosystem as a whole, and thus fishery management should take them into account when establishing management strategies. The reality is that, in the marine environment, there are few examples of scientific studies that support clear links between harvest of certain species and trophic cascading. The few examples that do exist are mainly descriptive and report a general lowering of the average trophic level of species present in the catch, generally associated with the targeting of piscivorous fish by most of the world fleets. What is lacking are studies that prove the usefulness of management alternatives to revert such trend. Such ecosystem level effects of harvest are better dealt with within the context of how the FMP implements ecosystem-based management principles. The final section of this chapter discusses how this may be done.

16.5.3 Impacts of fishing gear on habitat

Most fishing gear has some impact on marine and estuarine habitat (Section 7.5). The most common impact is the direct modification of habitat caused by active gears such as bottom trawls or destructive fishing practices such as dynamite fishing. These practices often remove attached benthic organisms and either kill them, damage them, or at the minimum translocate them. These impacts have been now quantified through scientific studies and have been demonstrated to change the diversity and productivity of benthic communities. Other impacts of gear such as ghost gear (lost gear which continues to fish, or becomes structure) and pollution (such as that caused by lead weights) are less understood and quantified, yet it is clear that, again on the basis of precautionary management, it is best to eliminate all destructive fishing practices. The destructive effects of active gear should also be minimized by modifying their design and/or restricting their use to areas where structured benthic habitat is absent. Similarly, in the case of trophic chain effects and management of bycatch, the management of impacts of fishing gear on habitat are best treated in the context of integrated strategies directed at ecosystem-based management and are discussed in detail at the end of this chapter.

16.5.4 Integration of management plans within coastal area management

Although many people wrongly consider ecosystem-based management as a biocentric approach it is well documented that the human components of the ecosystem are an integral part of the approach, thus the importance of considering all other human uses of the ecosystem (e.g. Section 13.5 and Figure 13.8). The principles of integrated coastal area management are therefore an essential part of the development of an ecosystem-based fishery management approach, especially for coastal fisheries where the presence of multiple uses of coastal resources can alter the ecosystem and its productivity. FMPs should therefore always have a clear link to integrated coastal management plans for the relevant coastal areas.

16.6 Examples of management plans

Five examples of existing FMPs are now briefly presented to help to put this in the context of current fisheries management. These examples were chosen to represent a wide spectrum of existing FMPs. The first example is for a single industrial fishery in a developed country; in contrast the second example corresponds to a mixture of industrial and artisanal fisheries in a developing country. The third example refers to a plan for a single species caught as part of a multispecies artisanal fishery. The next example demonstrates how to design plans for newly developing fisheries and the final one is an example of a plan focused on ecosystem considerations. Refer to Section 15.8 for more detail on the special considerations required for the design of FMPs for small-scale fisheries. For other examples of FMPs consult the web resources presented at the end of this chapter.

16.6.1 The Australian Northern Prawn Fishery management plan

The Northern Prawn Fishery (NPF) is a fishery with only one species group as target, where the only gear used is the trawl and that operates offshore of a very remote part of the world, in Northern Australia. Although the FMP was only developed in 1995 by the Australian Fishery Management Authority (AFMA), the NPF has been closely managed since the 1980s. This plan is therefore an example of an FMP for a well-managed industrial fishery. This plan was made in accordance with the Australian Fisheries Management Act of 1991. Its purpose is to make sure that the policy objectives of the AFMA are met in the NPF and that bycatch in this fishery is reduced to a minimum. This is translated in the plan by specifying that the objective of the plan is 'ensuring that the exploitation of fisheries resources and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development and the exercise of the precautionary principle, in particular the need to have regard to the impact of fishing activities on non-target species and the long-term sustainability of the marine environment; and maximizing economic efficiency in the exploitation of fisheries resources' (Anon., 1995).

This plan is made under clear guidelines established in the Australian Fisheries Policy, and as a result the plan itself is limited to a description of the operational management details for the fishery and does not cover general fisheries policy.

The FMP starts with a list of legal definitions of terms that are used throughout the plan (Table 16.1). The next section covers the objectives, management measures and performance measures or indicators. The NPF is a fishery managed by input controls, including limited licenses (see Chapter 9 for a broad discussion on the issue of input controls). Section two of the plan focuses on fishing rights and covers the types of rights that exist, how they are to be transferred and the obligations of fishing rights holders (see Chapter 10 for a more detailed discussion on fishing rights). The last section of the plan contains a detailed description of the managed area and a list of all amendments.

16.6.2 The Barbados FMP

The Barbados Fisheries Act (1993–1996) required the Chief Fisheries Officer to develop a management plan for the fisheries of Barbados. In 1997 the Fisheries Advisory Committee,

Table 16.1 Outline of the Australian Northern Prawn Fishery FMP of 1995.

1. Introductory provisions
   a. Name of plan
   b. Commencement
   c. Interpretation
   d. Objectives
   e. Measures
   f. Performance criteria
2. Statutory fishing rights
   a. Gear statutory fishing rights
   b. Types of statutory fishing rights (fishing licenses)
   c. Who may fish in the NPF area
   d. Boat nomination and replacement
   e. Cancellation of statutory fishing rights
      i. Directions by AFMA (length of fishing season, etc.)
      ii. Transfer of statutory fishing rights
      iii. Expiry of statutory fishing rights
3. Miscellaneous
   a. Certificates, delegation, leasing arrangements of statutory fishing rights Schedule 1 Area of the NPF

Table 16.2 Outline of the Barbados FMP.

1. Guiding principles (mission, goals, fisheries policy and country profile)
2. Fishing industry profile (overview of fisheries, fishing industry, intersectorial linkages)
3. Fisheries management (fisheries planning process, coastal zone management, fisheries legislation, regional fishery agreements, organizational framework, research and statistics, monitoring control and surveillance, inspection, registration and licensing)
4. Fisheries development (visions from harvest, postharvest and state sectors)
5. Management and implementation (one section for each fishery managed under the plan)
6. Fishery management options
7. Glossary

in consultation with the fishing industry and the general public, completed the FMP (Anon., 1997). Although the fisheries of Barbados, like those of many other developing countries, are highly diverse, the government decided to develop a single management plan for all of them. This contrasts with many other countries where FMPs are developed for individual fisheries. As a result, the FMP for Barbados has much broader goals than those found in other plans. These goals appear at the beginning of the FMP document (Table 16.2) and include meeting human-nutrition, social and economic needs, whilst integrating fisheries policy within coastal zone management and considering traditional knowledge of fisheries and the special interests of local (coastal) communities. Other goals of the Barbados FMP are more commonly seen in

other plans, such as maintaining or restoring populations to the levels that can produce maximum sustainable yields, promoting the use of selective fishing gear to minimize wastage and bycatch, researching, monitoring and controlling fishing operations and fish resources, protecting endangered species and fragile ecosystems and finally cooperating with other nations in the management of shared, straddling and migratory stocks. The plan contains an overview of the fishing industry which, obviously, includes the whole variety of fishing practices and resources found in the country: from shallow water trapping for reef fish and lobsters to oceanic gillnets for flying fish, handlines and longlines for coastal and oceanic pelagics and hand gathering of sea urchins.

There is then a description of the fisheries management process used to develop and implement the FMP, and the need to link the FMP to the coastal zone management plan is identified[1]. The plan then describes the legislation that directly influences the plan, and includes a history of previous and existing bilateral fishing agreements with other nations. The next section of the plan defines the organizational framework of the fisheries sector in Barbados, including government and nongovernmental fisheries-related organizations and any fisheries programmes administered by international organizations. The section ends with a description of the research, monitoring, surveillance, licensing and inspection activities conducted in Barbados.

The plan then presents an analysis of issues of importance to the harvest, postharvest and government sector. For each issue a series of optional management actions are identified and implementation strategies are proposed, including a description of resources required. Although the goals of the plan are broad, an in-depth analysis of all issues allows the government to address them one by one within the priority order established by the policies of the government of Barbados and as a function of the resources available for its implementation. It is expected that as some of these issues are resolved they would disappear from future versions of the plan. Again the plan is a living document.

The final part of the FMP includes sub-plans for each of the eight major fisheries of Barbados. These sub-plans are brief, 2–3 pages long and include concise descriptions of the target species, bycatch, ecology, fishery, management unit, resource status, catch and effort trends, specific management policies, objectives and approaches already in place for such fisheries and a list of development opportunities and constraints. This descriptive part is followed, as in the main part of the FMP, by a list of issues and the proposed actions identified to address them, together with the resources required. At the end, the plan includes a list, with non-technical descriptions, of fishery management options used in the FMP and a glossary.

16.6.3 The Queen Conch FMP for Puerto Rico and US Virgin Islands

The Magnuson-Stevens Act of the United States of America requires that Regional Fishery Councils develop FMPs for resources within each region. The Caribbean Fishery Management Council developed a plan for the management of queen conch within the waters of the USA Caribbean in 1996 (Anon., 1996). Other similar plans are in effect for Corals and Reef Associated Plants and Invertebrates, Shallow Water Reef Fish, and Spiny Lobster.

[1]Interestingly the FMP acknowledges that the link between the FMP and the coastal zone management plan has not been made, but at least by identifying the need, it highlights its importance. This also shows that FMPs are live documents that may not always have all the issues sorted out before they are adopted.

Table 16.3 Outline of the Queen Conch FMP for Puerto Rico and US Virgin Islands.

1. Executive summary
2. Definitions
3. Introduction
a. Description of resource
b. Description of fishery
c. Problems in the fishery
4. Management objectives
5. Management measures and alternatives
6. Recommendations to local governments and other agencies
7. Related management jurisdictions, laws and policies

Queen conch are caught throughout the Caribbean, where they are a valuable resource for artisanal fishers. The resource seems biologically overfished in many countries, including the USA Caribbean. A fundamental problem of the management of this resource is that the stock is shared by many countries; therefore, management may need to be coordinated across several countries. The Queen Conch FMP recognizes this explicitly in its executive summary, highlighting the need for both local management actions and regional cooperation.

The FMP starts with a list of definitions of all technical terms used in the document and is followed by an introduction that defines the context (USA fishery legislation and Caribbean Fishery Management Council's management programme) and scope of the plan (Table 16.3). The next two sections are the lengthier part of the plan where all the relevant information on the biology of conch and its fishery is summarized. These sections must contain whatever information is required to show that the best information available has been used to support the management plan. They present details on the life history, population parameters, conch habitat, history of the fishery, fishing fleet, processing sector and the most current assessment of the status of the fishery at the time the plan was developed.

The next chapter of the FMP discusses the most important issues facing the fishery, including the presence of overfishing, the limits on enforcement, the legislative setting, the limitations of current databases, the dependence on communication with and education of interested parties and the importance of habitat quality.

Section five of the FMP starts presenting the management objectives:

1. 'to optimize the production of queen conch. . .
2. to reduce adverse impacts . . . such as harvesting immature and reproducing individuals. . . .
3. to promote the adoption of functional management measures that are practical and enforceable. . . . and the promotion of international cooperation in management . . .
4. to generate a data base that will contribute to the knowledge and understanding of queen conch biology. . . .
5. to recommend habitat improvements to federal and local governments . . .
6. to provide as much flexibility as possible with the management. . . .'

It is important to point out that such objectives are probably too broad to be associated with measurable quantities. As such it is likely that more specific objectives should be defined so that their implementation, or lack of it, can be easily quantified.

The rest of the section defines why conch has been assessed to be overfished and presents the rebuilding plan to recover the stock. The development of the rebuilding plan is a requirement of the US Magnuson-Stevens Act. The plan then details the alternative management measures that are to be used to manage the stock of conch. For each alternative the expected consequences of using the measure are detailed. The alternative of not doing anything is also presented including its consequences. Among the measures included in this list are size limits, sale restrictions, bag limits, seasonal closures and gear restrictions. This section also contains information on the process by which the above measures may get changed in the future. The final section of the plan includes information on all the US federal and local (USA Caribbean) legislation and policies that impinge on the operations of the queen conch fishery. Examples of these are the Federal and Local Endangered Species Acts and the National Environmental Policy Act. For each of these policies or acts a summary of its relevance to fishery management is provided.

16.6.4 Western Australian plan for developing new fisheries

Many countries still see fisheries development as one of the pillars of their fisheries policy. In developing countries, the need for creating socioeconomic opportunities, generating employment and obtaining hard currency often creates even greater pressure for maintaining this 'fishery development' agenda. Although FAO statistics have shown that the prospect for development of new fisheries is small (FAO, 2000), at small scales there will be an ongoing need to have procedures in place that ensure the orderly development (or re-development) of new fisheries (FAO Code of Conduct, Paragraph 7.5.4).

Several states in Australia have created management procedures specially designed for this. These procedures, whether in the form of a formal FMP (as it is often done in Queensland) or as a set of general principles, as done in Western Australia, can be a useful guide to how to proceed with developing an FMP for new fisheries in a responsible way (Halmarick, 1999).

Western Australia's guide defines first what constitutes a new fishery:

> '. . . a fishery for which there is little or no exploitation, there is potential for development . . .'

Then it states an important principle that is:

> '. . . there should be no assumption that the existence of a fish resource will guarantee that commercial access to this resource will be granted.'

This clearly establishes that the management authority has the responsibility to define which new resources are to be developed and which not. Whether a new fishery is developed or not should be consistent with the national fisheries policy and should especially consider the possible interaction of this development with existing fisheries.

The next section of the guide then clearly defines the constraints under which development can take place, the principles of ESD and the precautionary principle.

Then the document sets out the rights of developers, recognizing that these 'pioneers' should benefit from developing a new fishery. This should clearly establish what rights may

Table 16.4 Steps required for the development of a new fishery in Western Australia.

1. Expression of interest – opportunity advertised
2. Ministerial decision – on whether to agree to the development or not
3. Application – people apply according to guidelines established by management agency
4. Assessment of applications
5. Notification of approval/refusal
6. Implementation – fishing starts
7. Review and assessment – permits are continued, modified or rescinded

be conferred on those engaging in fishing on fisheries that have not yet been brought under formal management.

The rest of the document contains sections detailing the process for creation of a new fishery, seeking expressions of interest from prospective participants and establishing the conditions of operations (Table 16.4). The Western Australian FMP emphasizes that these conditions are to have a limited life of three years, after which an assessment of whether the fishery should continue will be made.

16.6.5 FMP for the Cayos Cochinos Monument, Honduras

Like many National Parks, Cayos Cochinos Monument was created to protect its ecosystems, in this case a series of islands and the surrounding marine area. Although most such parks have a general management plan that regulates their uses, the importance of fishing activities in Cayos Cochinos pushed the coalition that manages the park (the Honduras Coral Reef Fund an NGO, the Honduran Directorate of Fisheries and the representatives of the local communities of the islands) to develop an FMP. The resulting plan has therefore a strong emphasis on the conservation of ecosystems and may be considered to have many of the elements that are supposed to be present in plans that adhere to ecosystem-based management.

The preamble of the plan starts with a brief analysis of the fishery activity within the park followed by a summary of the principles of responsible fishing practices and of fishery management based on ecosystem considerations. The main chapters are then, a description of essential fish habitats for the area, the fishery context within which the park exists (nationally and internationally), a detailed description of the institutional management arrangements that govern the park, its fishery regulations, the fleets and fishing communities that operate within the park and of the information available for its two most important target groups, the reef fish and the spiny lobsters. Then follows an analysis of the community's perception of fishery management in the area of the park and an evaluation of the status of the fishery which includes a special mention of the impacts of industrial fishing within the park (Table 16.5).

Like many other plans for marine protected areas the next section, describing management options, is structured under the principle of zoning which defines which activities can be conducted in each zone. The difference is that in this plan the activities represent different types of fishing activities because the plan only purports to the management of fishing and not of others such as diving and boating. The plan follows with a list of management alternatives by which the proposed zoning can be introduced. Such options include rotational closures to parts of the park so that the resources can recover to a more sustainable state before permanent zoning is established.

Table 16.5 Outline of the FMP for Cayos Cochinos, Honduras.

1. Introduction
2. Methods and general concepts
   a. Analysis of fisheries
   b. Sampling
   c. Fishery production in the greater Caribbean and Honduras
   d. Principles of responsible fishing
   e. Ecosystem-based fishery management
   f. Co-management and community participation
   g. Scientific support
3. Body of the plan
   a. Characterization of the fishery in Cayos Cochinos
      i. Resources
      ii. Institutional analysis
      iii. Fishery management
      iv. Fishing communities and fishing fleet
   b. Management alternatives
      i. Conservation measures
      ii. Fishery regulations

The final section of the plan clearly establishes the responsibilities of each of the coalition members in the implementation of the plan.

16.7 Synthesis and emerging issues

FMPs are clearly one of the most important instruments for fishery management and are increasingly used around the world. They are well suited to operationalize the objectives included in national and international fishery policies. There are, however, a number of issues that may alter the future role and structure of FMPs. These issues are often the result of a push to change the paradigm of fishery management. Two such issues, the role of NGOs in the development of FMPs and the change in the contents of FMPs driven by ecosystem-based fishery management, are discussed later.

Increasingly NGOs are getting involved in supporting or leading the development of FMPs and marine protected area management plans. The Cayos Cochinos Plan presented in the previous section is an example of this. The NGOs involvement in the development of FMPs often stems from the desire to give an alternative voice to the general public in the development of plans. Alternatively it may reflect the commitment by NGOs to help those countries and regions where the capacity and resources to develop such plans are lacking. Development of such plans can be immersed in the national fishery policy framework of a country or outside of it. Often NGOs will take the initiative to develop the plan as a proof of concept and later work to get it accepted by the authorities responsible for fishery resource management.

Other times, NGOs will develop the plan and implement it only with the help of local communities, without buy in from the central government administration. In other cases, like the case of the Marine Stewardship Council, NGOs form alliances with seafood producers to influence the development and modification of FMPs to promote market-control mechanisms that support sustainable management.

Increased involvement of NGOs goes hand in hand with ecosystem-based management, the widely acknowledged new paradigm for fisheries management. It is not yet clear, however, how this paradigm will change the management structures that support current management. It has been proposed that current FMPs that focus on species or groups of species should be substituted by integrated ecosystem-based FMPs that would shift the focus from overfishing species or stocks to overfishing ecosystems. The reference points that would support such characterizations of overfished ecosystems are only now been developed, although some of the more progressive fishery councils already use them to monitor ecosystem health. Additionally many governments recognize the need to manage habitats that support fish production (essential fish habitat, EFH) and offer protection to these (mangroves, sea grasses and coral reefs). The US legislation regarding EFH and the EFH plans developed by some fishery councils are an example of this. It is clear that there are ways by which management under the current framework of FMPs has started operationalizing certain aspects of ecosystem-based management; for example, harvest limits can be precautionarily reduced below purely single-stock reference points on the basis that there must be some allowance given to ecosystem function, and certain fishing gears may be forbidden because of the widespread impacts they cause on the ecosystem.

All these measures are only components of what ecosystem-based FMPs may contain. It is recognized, however, that the change in paradigm, from one where the stock is the unit managed through the control of fisher's activities to one where the ecosystem is the managed unit through the control of activities of all users of the ecosystem, will be done incrementally. This is likely to start with the implicit recognition of the need to consider certain ecosystem processes within FMPs, as it is mostly done today. After that, explicit measures aiming at operationalizing ecosystem-based management will be incorporated in the FMP. Finally, the collection of FMPs may be substituted by a single ecosystem management plan. Every effort directed to support such incremental change will benefit marine resource management.

FMPs have to be developed in a way that fits the capacity and needs of each country/fishery. They are documents that should first serve to address the most pressing fishery issues whilst examining all relevant aspects of the fishery to be managed. To achieve its goals properly they must be developed to fit within the available legislative and policy framework of each nation or state. Their development must follow a structured process involving all important stakeholders who should be given time to review and contribute to the FMP document. In developing them, it is essential that strategies that will facilitate their implementation are considered. They must be living documents and be periodically reviewed to reflect changes in the circumstances of the fishery. In summary, FMPs are an essential tool of fishery management that should help managers achieve their objectives and are ideal vehicles to achieve the shift to the new paradigm of ecosystem-based management.

Sources and recommended reading

Anon. 1995. Northern Prawn Fishery Management Plan. Attorney-General Department, Australian Government, Canberra. 32p.

Anon. 1996. Fishery Management Plan, regulatory impact review and final environmental impact statement for the queen conch resources of Puerto Rico and the United States Virgin Islands. Caribbean Fishery Management Council. 56p.

Anon. 1997. Barbados Fisheries Management Plan. Schemes for the management and development of fisheries in the waters of Barbados. Fisheries Division, Ministry of Agriculture and Rural Development, Barbados. 67p.

Anon. 2003. *Plan de Manejo Pesquero del Monumento Natural de Cayos Cochinos*, *Honduras*. World Wildlife Fund Centroamerica, San Jose, Costa Rica. 98p.

FAO. 1997. Fisheries Management. FAO Technical Guidelines for Responsible Fisheries. No. 4. Rome, FAO. 82p.

FAO. 2000. *The State of World Fisheries and Aquaculture*. FAO,. Rome. 142p.

Halmarick, L. 1999. Developing new fisheries in Western Australia. A guide to applicants for developing fisheries. Fisheries Management Paper, 130. Fisheries Western Australia, Perth, Australia. 40p.

Web resources

The following is a list of links where copies of FMPs for many fisheries can be downloaded. If the page does not link directly to FMPs, use the search engine provided and the words 'Fishery Management Plan' to locate the link to the various plans. For New Zealand plans use 'Fishery Plan' in your search

Australia	
Queensland Department of Primary Industries	http://www.dpi.qld.gov.au/
New South Wales Department of Primary Industries	http://www.dpi.nsw.gov.au/
South Australian Government	http://www.pir.sa.gov.au/fisheries/fisheries_council
Tasmanian Government	dpiw.tas.gov.au
Western Australian Government	www.fish.wa.gov.au
Canada	
Pacific Region	http://www.pac.dfo-mpo.gc.ca/
Gulf Region	http://www.glf.dfo-mpo.gc.ca
New Zealand	
Ministry of fisheries	http://www.fish.govt.nz
United States	
Caribbean Fishery Management Council	www.caribbeanfmc.com
Gulf of Mexico Fishery Council	http://www.gulfcouncil.org/
Mid Atlantic Fishery Management Council	www.mafmc.org
New England Fishery Management Council	www.nefmc.org
North Pacific Fishery Management Council	www.fakr.noaa.gov/npfmc/
Pacific Fishery Council	http://www.pcouncil.org/
South Atlantic Fishery Management Council	http://www.safmc.net/
Western Pacific Regional fishery Council	http://www.wpcouncil.org

Part VI
Conclusions

Chapter 17

From Past Management to Future Governance: A Perspective View

Serge M. Garcia and Kevern L. Cochrane

17.1 Introduction

The modern fishery manager faces a difficult legacy. The last 60 years have demonstrated the capacity of the sector to increase production and more than match the growing demands fuelled by development and demography. They have equally demonstrated in most places that, for various reasons including poor implementation of scientific advice, conventional management had been unable to avoid a significant degradation of fishery resources. Nonetheless, significant expectations are maintained regarding the continuing role of fisheries as a source of livelihood and food security while maintaining biodiversity and ecosystems. To match these expectations, fishery managers are expected to help in rebuilding depleted resources, rehabilitating damaged habitats and restoring fisheries livelihoods and economy despite institutional and market imperfections, ecosystem vagaries and climate change. Facing significant stakes, the task of the modern manager is to draw on lessons learned, using evolving institutions, to correct past mistakes and avoid new ones.

The core 'culprit', that is, the poor quality or absence of use rights, has been well known since Michael Graham formulated his *Great law of fishing* in 1936, predicting that unlimited fisheries would lead to their demise. During the last three decades, this and other causes have been listed repeatedly as every scientific discipline established its own diagnostic and elaborated its own prescription for cure. The reality of fisheries as complex and only partially predictable social–ecological systems is being slowly accepted and the multitude of problems experienced are progressively being understood as symptoms of a systemic 'disease' requiring systemic prescriptions which may not necessarily be complex, revolutionary or exorbitantly expensive.

In most fisheries, however, fisheries problems cannot be seen anymore as the result of simple and predictable cause–effect relations that can be easily corrected from the top with simple enforceable measures based on conventional bio-economy, limited data and few assumptions. Under an ecosystem approach, even in 'simple' fisheries, uncertainty becomes a permanent factor stressed by scientists to highlight risk, by society and environmentalists to call for immediate precautionary action and by industry worried by socio-economic implications. Stock assessment is still needed but must be supplemented by information on ecological impacts, socio-economic analyses and more participatory forms of governance. For longer-term management, ecological considerations including ecological economics are essential for maintaining productivity and resilience. The simple production objectives historically used as development metaphors (e.g. maximum sustainable yield (MSY)) have to be replaced, or supplemented, by a much broader multidimensional set of objectives and constraints regarding both the human and natural systems.

Operating in a policy field under tension between the long-term requirements for sustainability of the broader society and the short-term sectoral requirements for economic and social viability, the role expected from the 'manager' is changing. Charged by the state with the responsibility of implementing, at sectoral level, the various national policies (environmental, social and economic), the manager remains the institution ultimately responsible, on behalf of the state, for resource conservation in front of the national and international communities. However, in addition to implementing command-and-control management where appropriate, the manager has to establish and ensure the effective functioning of the interface between government, science, the sector and civil society, experimenting with adaptive and participative management. Managing risk under less than perfect information, the decision process is the main quality criterion and building system resilience is the ultimate goal. For the next decade and probably the first half of the 21st century, the manager will be co-steering the sector through a highly dynamic transition path towards improved sustainability, meeting numerous obstacles and opportunities, some of which are known and some unexpected. What the manager will be able to achieve and how will depend on the broader context of history and culture.

Looking a few decades backwards, this chapter reviews first the evolution of the fishery manager's role and of the management framework since the beginning of the 20th century and more particularly since WWII. The second part contains a synthesis of the emerging practice reflected in the different chapters of the present volume. Extrapolating modern trends, the last section gives a few clues on the possible scenarios of the future of fisheries governance.

17.2 Historical trends

World fisheries and their context have evolved very significantly during the last six decades and so has the perception of management needs and operational paradigm. The following sections present a sequential description of what has been, in reality, a mosaic of evolution patterns, differing between socio-political systems, levels of development, types of ecosystems and fisheries. The different phases of the general pattern described have been reached at different times in different countries and sometimes even in different fisheries in the same country. Understanding this history helps to put the previous chapters in context and gives some insights into likely future trends.

17.2.1 Early phase (1900–1945)

The first half of the century was, in the northern hemisphere, a period of innovation, and modernisation in the North Atlantic, interrupted by WWI and WWII. Before WWI, the possibility to overfish stocks was convincingly demonstrated as well as the need for science-based management. The separation of bio-ecology from socio-economics and politics started to be advocated in the early 1920s. By the end of the 1920s, the belief that future stocks could be predicted accurately had strengthened after the successful work of Hjort on herring and haddock. The development of the mathematical branch of fishery science strongly reinforced that belief from the 1930s onwards with the work of Graham, Russel, D'Arcy Thompson, Beverton and Holt. opening an era of quantitative analysis and modelling of single species stocks. The early management concerns related to the protection of young fish through

technical measures and to conflicts between fleets and countries. The London Overfishing Conventions (1937 and 1946) signalled the inefficiency of the technical measures alone. In 1936, Graham's Great Law of Fishing: *Fisheries that are unlimited become unprofitable* stressed the need to regulate fishing pressure. The concept of some long-term 'optimum catch' at some intermediate stock level emerged.

17.2.2 Post-war reconstruction and development (1945–1960)

Following WWII, the managers' priority was to rebuild fishing capacity and increase protein supply from fisheries in Europe and, soon, in the European colonies. The fisheries conventions in the North Sea and in the Northwest Atlantic started to function, opening formally the full albeit imperfect process of iterative, adaptive, science-based management. Fisheries expanded across the North Atlantic and Pacific and additional signs of local overfishing appeared towards the end of the period. Using the Beverton and Holt (1957) 'bible' it became possible to analyse different combinations of fishing pressure and size at first capture to design 'optimal' fishing regimes. A first formal proposal to restrict fishing capacity (limiting fleet tonnage), by Russel, emerged at the 1946 London Conference . . . and sank on the alleged difficulty of a universal definition and measure of fishing effort. The preference went to 'optimize' fisheries around the MSY solely through catch controls. The failure of that approach is history. The futility of complementary technical measures in the absence of capacity control was already stated at that stage . . . and effectively put aside for 50 years. The 1958 Geneva Convention on Fishing and Conservation of the Living Resources of the High Seas started a long process of attempting to control harvest in the global commons.

17.2.3 Geographic expansion (1960–1985)

Operating within a global industrial growth model, with massive economic support from governments, the fishery sector consolidated its positions and expanded to the South Atlantic and Pacific, the Indian Ocean and the Antarctic. Fishery research and management bureaucracies developed worldwide, at national and regional levels. In newly 'opened' areas, research focussed initially on the discovery, mapping and assessment of the potential of new resources. Stock conservation emerged progressively as the dominant global issue only in the early 1970s when the world catch started to level off.[1] The collapse of the Peruvian anchoveta fishery, the biggest in the world, and of the Atlanto-Scandian herring, in the 1970s, following the earlier collapses of the East Anglia herring fishery in the mid-1950s and the North Sea herring at the end of the 1960s, added strong concrete warnings. The scientific debate focussed on the relative roles of environmental fluctuations and excess harvest on fisheries collapse. Management concern shifted to ways and means to regulate total removals more effectively. The reinvention of the virtual population analysis (VPA, by John Gulland) and adoption of John Pope's cohort analysis finally allowed estimation of absolute values for stock sizes at a given time and age, albeit with limited precision. Combined with current biomass or recruitment surveys and a

[1] It is at that time that FAO published its first global review of the state of world stocks and estimate of the maximum global potential of 100 million tonnes (Gulland, 1971).

stock–recruitment relationship, this allowed scientists to forecast stock sizes and calculate the catches (and, indirectly, the related effort levels) to be allowed in order to meet the optimum catch objective of management. Biology-based management continued to dominate scientific advice as it was easier to agree on fish biology and conservation than on socio-economic plans and performance criteria, particularly but not only between market-driven and centrally planned economies across the iron curtain. However, social and economic considerations still entered decision-making, even if informally, and scientific advice was not always, or not often, well followed. Entangled in the impossibility of properly calibrating effort in different fleets, direct effort control, again, was left aside. Being a source of error in catch-based assessments, unrecorded bycatch became an issue well before becoming a societal concern. In the 1970s, the issue of pollution and its impact on productivity and fish quality started to emerge but disappeared from the fishery management 'radar' soon after the establishment of the United Nations Environment Programme (UNEP) in 1972. The sharing of the total allowable catch (TAC) among states and the tailoring of efforts to national shares became key issues. Limited entry licensing systems started to be tested and implemented, heading towards the problem of technology-driven 'creep' in fishing capacity (Chapter 9).

The *new economic order of the oceans* started to be established in the early 1970s through the UNCLOS III process, the unilateral extension of exclusive economic zones (EEZs) in the 1970s, the adoption of the new law of the sea in 1982 and its entry into force in 1994. This long process definitively enshrined MSY as a concept and as a target reference for sustainability. It also raised the hope that the failures of international management could be resolved by shifting most common resources under EEZ management. This appeared later as a fundamental but insufficient move. More warnings about the risk of collapse were given from the mid-1970s onwards as overcapacity and overfishing spread globally from the North Sea to the Antarctic and from coastal areas to the high seas and deep seas. Despite the active development of the economic theory of fishing during these years, its direct use for management was limited to the EEZ of very few leading nations. The management emphasis remained largely on controlling the amount of harvest (with some consideration of effort but no limitation of capacity) and on conventional technical measures. Socio-economic objectives such as maximum employment or conservation of coastal livelihoods started being explicitly voiced in the late 1970s, stimulated by the desire to draw benefits from newly acquired EEZs, commonly counteracting the scientific proposals to cut back on harvest to rebuild stocks.

Towards the end of this period, the uncertainty attached to scientific assessment started being better recognized and estimated, and a risk assessment approach started being proposed (e.g. by John Gulland from his FAO vantage point) about 10 years before the formal adoption of the precautionary approach. Through the 1980s, for EEZ fisheries, and recognizing the difficulty of controlling fishing efficiency in limited entry systems, other user rights gained momentum, particularly individual transferable quotas (ITQs) and, to a lesser extent, territorial use rights in fisheries. Considering the cost and limited effectiveness of top-down technocratic management, the user pays principle was advocated in a few countries (Pownall, 1994: 139) calling on industry to bear the direct cost of enforcing regulations and some research costs. Participatory management involving various degrees of decentralization and devolution of state functions[2] started being advocated in relation to limited entry and fishing rights programmes (Pearse, 1982) as well as for artisanal fisheries.

[2]The benefits of which had been already demonstrated in the Northern Prawn Fishery management in Australia since the early 1970s (Pownall, 1994: 137).

17.2.4 The fisheries crisis (1985–1995)

Although local crises had emerged decades earlier, the global crisis emerged progressively from the mid-1980s onwards, underlined by the spectacular collapse of Canada's Atlantic Cod stocks in the late 1980s and early 1990s. The huge accumulation of fishing capacity resulting from the expansion phase as well as the post-independence development process led to the strong emergence of global concerns on fisheries culminating with the 1992 UNCED Earth Summit. The Convention on Biological Diversity (CBD) (1992), the United Nations Fish Stock Agreement (1995) and the FAO Code of Conduct (1995) were adopted, strongly structuring the institutional fishery management framework. The environmental NGOs and the media played a major role in raising awareness about the crisis, particularly the environmental aspects. Issues related to biodiversity conservation, ecosystem-wide impacts and rehabilitation, and climate change emerged. International attention mobilized around whaling, large-scale pelagic driftnet fishing, dolphin mortality in tuna fisheries, turtle mortality in trawl shrimp fisheries and shark and seabird mortalities in longline fisheries. The movement gained momentum, spreading to the depletion of straddling stocks, highly migratory species and deep-sea stocks; environmental degradation; irresponsible fishing techniques; discards; overcapacity and perverse subsidies, putting practically all negative aspects of fisheries in the limelight of public opinion. The need to manage fisheries in an integrated coastal areas management framework was openly discussed and reflected in Article 10 of the FAO Code of Conduct. Fishery debates at the United Nations General Assembly became regular. The debate on climate change enhanced societal concerns regarding the environment. The fisheries crisis with its significant social and economic disruptions accelerated the formal emergence of economic and social considerations in fisheries management in a context characterized by the collapse of the Berlin wall, the globalization of the market economy, trade liberalization and recognition of the importance of fishing rights.

During the last two decades, numerous analyses have listed the causes for the widespread failure of conventional fishery management,[3] concluding that in spite of recognizing sustainability as a central management objective decades ago, management systems did not manage to adjust extraction rates to resource productivity. A variety of reasons have been proposed for decades ranging from changing resources, fishermen's greed, non-fishery degradation of the habitat, natural predators, inadequate management, environmental oscillations, rising oil and fish prices, demography, corruption, deficient government policies, open access, mixed or ill-defined jurisdictions, scientific uncertainty, unclear objectives, weak and outdated legislation, lack of labour mobility, centralization, poor enforcement, weak administration, overcapacity, poor coordination of development and management policies, intra- and intersectoral competition, vested interests to institutional inertia, reflecting, overall, the systemic complexity of fisheries (Cochrane and Doulman, 2005; Reid *et al*., 2006; Garcia and Charles, 2007). Limited but enlightening exceptions have also demonstrated that effective management solutions existed.

17.2.5 The fisheries reform (1996–2015)

During the following decade (1996–2005) managers faced an *implementation challenge*. The 2002 World Summit on Sustainable Development (WSSD) and the Millennium Summit in

[3] It must be recognized, however, that in a large number of cases, conventional management did not really 'fail' but was simply not implemented properly or not implemented at all.

2000 could only confirm the United Nations Conference on Environment and Development (UNCED) concerns and observe the limited progress achieved despite intense institutional development. Top priority was put on the 2000 Millennium Development Goals (MDGs) and the 2002 time-bound fishery targets of the WSSD Plan of Implementation, focussing on overcapacity, overfishing and reduction of environmental impact. The MDGs drew attention to the importance of poverty alleviation and food security, underlining once again the need to combine environmental and socio-economic considerations. Strong support is provided by NGOs, scientists, advocates and the media. Parts of the fishing industry have joined in, for example, promoting ecolabelling schemes (e.g. the Marine Stewardship Council). New approaches and instruments are being tested: the FAO International Plans of Action,[4] the Ecosystem Approach to Fisheries (EAF)[5] and the precautionary approaches to fisheries (PAF) which now underpin all modern approaches.[6] A general consensus has emerged to extend and modernize the conventional management system that grew after WWII. The term 'governance' is now widely used and covers all activities from policy-making and strategic planning to operational management undertaken in a highly participatory environment.

In a fast globalization process, structural adjustments, elimination of tariff barriers, reduction of the states' economic interventions (subsidies), privatization of former state enterprises, 'privatization' of access rights and the use of economic incentives signal a progressive passage of development under a stricter market economy.

17.3 Emerging practices

17.3.1 A changing management environment

At the beginning of the 21st century, the management authority faces a much more complex task than it did 60 years ago, just after WWII. Societal concerns about competition and sustainability and environmental degradation steadily increase while others like poverty alleviation, food security, biodiversity conservation and climate change emerge (Garcia and Grainger, 1997; Millennium Ecosystem Assessment, 2005; Cochrane, 2008). Bio-ecological objectives are broader (Chapter 2). Social and economic objectives, measures and constraints are more formally recognized, modifying significantly the political landscape within which the fishery manager operates (Chapters 3, 4 and 11). The extension of EEZs puts 90% of the world resources under national jurisdiction, turning *de facto* global commons into national commons ready for further reallocation (Chapters 5 and 6). Fish trade flows develop rapidly, worldwide, turning fish into the most internationally traded commodity. Fishing capacity has grown largely out of any control raising pressure to unsustainable levels everywhere, shifting huge amounts of excess capital and equipment from the developed to the developing world and from coastal zones to open seas and raising capacity control as priority number one (Chapters 9 and 10). Certain vessels register under 'flags of convenience' to reduce costs, circumvent tax legislations and fishery management commitments, under the jurisdiction of states incapable or unwilling to comply with international rules (Chapter 14). Rich

[4] http://www.fao.org/fishery/ccrf/2,3
[5] http://www.fao.org/DOCREP/005/Y4470E/Y4470E00.HTM
[6] http://www.fao.org/DOCREP/003/W1238E/W1238E00.HTM

institutional developments are adding constraints and conditions to the freedom to fish in the high seas (Chapters 5 and 6) increasing the responsibility of the Flag and Port States. The role of NGOs has increased dramatically with a higher level of industry participation (Chapter 11) and a strong intrusion of the environmental concerns (Chapter 2). Simultaneously, the privatization process (Chapters 3 and 10) and the progressive suppression of subsidies reduce the grip and influence of the state on the sector.[7] The raising of quality standards by importing nations (in particular Japan, the United States and Europe) forces exporting countries to rapidly raise production standards and leads to the development of certification and ecolabelling, putting the performance of management and of the managing authority at the forefront. The nature, quantity and quality of the information necessary for management has changed raising concerns about capacity of existing institutions (Chapters 2, 12 and 13).

Drivers of change

The emerging driving forces include greater societal awareness, globalization of trade and of the market economy, the information technology revolution and climate change. The latter significantly affects the resources' subsystems and habitats, modifying resources distribution, abundance and resilience and changing the biological parameters used for resources' assessment (Chapter 2). It may also increase the vulnerability of coastal fishing communities through sea level rise, increased storminess in the coastal areas and potential loss of already fragile coastal entitlements (Chapter 15). The more conventional drivers are still at work, however, and continue to exert a powerful influence. Demography continues to increase demand for resources stimulating fishing pressure. Economic development, in developing countries and countries in transition, increases demands for fish from the new affluent sections of society. Technological progress keeps boosting fishing efficiency, calling for managers' constant vigilance and recurrent adjustments of fishing capacity.

17.3.2 From management to governance

The term 'governance' is repeatedly used in the book and Chapters 1, 3, 5, 6, 11, 12 and 15 have addressed some of its aspects. Chapter 6 stressed the fact that fishery governance is a complex system in which social, economic and political organization of interacting and interdependent groups, and organs, public and private, connected by doctrines, ideas and principles, intend to serve a common purpose: the regulation of the use of fishery resources, from different angles, at different levels and with different interests and expectations. The cross-references between chapters of this book illustrate the fact that management is a complex undertaking and an important component of an even more complex system of governance comprising policy-making, strategic planning and operational management (Chapter 6; Kooiman *et al.*, 2005; Reid *et al.*, 2006; Garcia and Charles, 2007). The governance component of the fishery system is delivered through a complex web of institutions of different nature (e.g. public or private) and with different roles (e.g. in administration and regulation), connected through formal or informal relations and feedback loops, some of which are institutionalized within the fishery sector while others are out of control of the fishery sector (Figure 17.1).

[7] But the state responsibility and liability established by UNCLOS remains prominent.

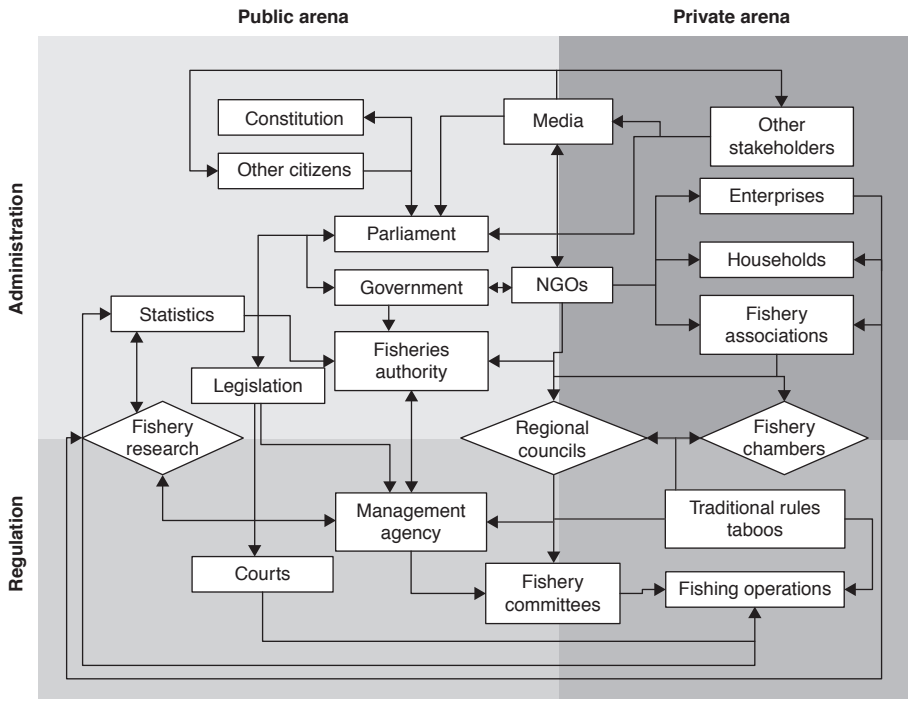


Figure 17.1 Schematic representation of fisheries governance infrastructure. (Adapted from Garcia [2007], compiled from different sources.)

Good governance acts at a range of time, space and institutional levels (Chapter 3) and involves representatives of the government, the sector and the relevant civil society institutions (Chapters 3, 5, 6, 11 and 15). It has been defined in various ways that can be synthesized as follows: governance is *a systemic concept relating to the exercise of economic, political and administrative authority. It encompasses (i) the guiding principles and goals of the sector, both conceptual and operational; (ii) the ways and means of organization and coordination of the action; (iii) the infrastructure of socio-political, economic and legal institutions and instruments; (iv) the nature and modus operandi of the processes; (iv) the actors and their roles; and (v) the policies, plans and measures* (Garcia, 2007)[8].

Ranging from management of a single fishery or area to long-term policy development and planning, fishery governance establishes the overriding principles and objectives of the fishery sector. It shapes the policy and regulatory frameworks (Chapter 5). It connects government with civil society, harmonizing individual, sectoral and societal perspectives. It maintains social order, legitimising and balancing stakeholder interactions (Chapters 6 and 11). It maintains productive social–ecological systems (Chapter 3), enforcing decisions and regulations and maintaining coherence across jurisdictional, space and timescales. It

[8] Kooiman *et al*. (2005) subdivide governance into three levels: meta, second order and first order governance relating to (i) establishment of high-level principles; (ii) building up of institutions and (iii) policy and operational management.

conditions the allocation of power, resources and benefits (Chapter 10). In a rapidly changing world, it develops the capacity of the sector to learn and adapt to circumstances, managing risk to ensure resilience (Chapter 3).

The systemic nature of modern governance requires adherence to a number of principles (some of which are highlighted in Chapter 3). Good governance is committed and demonstrates political will. It is legitimate, based on lawful, democratic and representative institutions and processes. It is credible through legitimacy and enforcement. It is context sensitive and adapted to local conditions. It is responsible for people and for ecosystems and fulfils its duty of care. It is equitable, for example, in relation to rights, duties and wealth distribution. It is transparent in relation to objectives, allocation, processes and performance. It is accountable to the sector and the public, and seeks to satisfy societal expectations and motivations. It is nested in an enabling national policy. Being aware of uncertainty and complexity, it is prepared for unexpected outcomes and as a precautionary measure dealing explicitly with the burden of proof, adopting adaptive management strategies and contingency plans. It is knowledge based, fosters scientific interdisciplinarity and integrates validated traditional knowledge. It is also value based and accounts for traditional values as well as emerging ethics. It is procedural and pays particular attention to processes in addition to norms and goals. It is multiscale in terms of time, space and institutional levels. It coordinates all its levels, from local to global. While targeting specific objectives and priorities, it remains flexible, reactive to feedback or surprises and adaptive. It develops quality controls and oversight mechanisms for checks and balances, facilitating public scrutiny. It resolves emerging conflicts with appropriate mechanisms and powers. It is effective and uses systems of indicators and audits to measure performance. It is participative and deliberative bringing in as many stakeholders as compatible with functionality, from data collection and analysis to decision-making and implementation. It is affordable, commensurate with formally identified expected costs and benefits. It is largely self-financed having trimmed its costs and secured sustainable revenues (e.g. fees, taxes) to cover costs. In addition to norms and rules to be enforced, it provides incentives and disincentives such as targeted subsidies and taxes. It communicates effectively and educates its constituency to develop a common understanding among all concerned. It produces success stories that can be used as promotion tools. It looks for alternative livelihoods for fishers in cases of overcapacity. Having applied all the above principles, it is fully supported by citizens and stakeholders concerned. Finally, being performance based, good governance requires that assessment, advice, monitoring and evaluation be systematically integrated elements of the management process as central elements of a recurrent, adaptive process (Chapters 3, 10, 12, 13 and 14).

Greater emphasis needs to be put on community governance (Chapters 3, 11 and 15). The trends towards greater decentralization and the emphasis on community involvement in planning and development give new impetus to the participation of small-scale fishing communities in resource development, planning and management as well as a more formal and legal status, enhancing their capacity to face the new responsibilities. Fishery resources and the activity of small-scale fishers frequently straddle local administrative boundaries and the coordination between decentralized governance structures is a major emerging challenge (Chapter 15).

17.3.3 Changes in approach: EAF

All chapters contain elements of the new management approach. The good governance principles listed earlier have significant implications in terms of the way in which management

is conducted. In international fisheries as well as large national ones, the conventional approach intended to maintain the supply (stock size) by directly and indirectly controlling fishing intensity through top-down control of harvest and some technical measures (e.g. mesh size regulations). In smaller-scale coastal fisheries, technical measures were used without any control of total removal or fishing capacity. The resources were *de facto* considered as sectoral commodities looking for a market. The new approach advocates the direct limitation and control of human activities in a complex social–ecological system to maintain a range of essential ecosystem goods and services for different groups of users with different interests (Chapters 3, 12 and 13). In this perspective, management operates as an integral part of broader governance and it uses social relationships to promote system resilience and adaptability to change. Its practices do not rely exclusively on predictions from equilibrium-based quantitative models, and it uses adaptive processes in which the best formal and informal knowledge are integrated (Chapters 3 and 13). Top-down decision-making is replaced by participatory management where possible, and the fishery business focus is broadened to the one considering sustainable livelihoods. The new management is intersectoral, considering the development and management of the fishery sector as a part of the broader national sustainable development, in synergy or competition with other economic development sectors.

These changes are imbedded in the EAF adopted in FAO in 2001 as the way to implement the FAO Code of Conduct, extending conventional management and formally aiming at the well-being of both human and natural subsystems. Gear regulations must address not only the protection of juveniles but also the protection of important associated or dependent species as well as the habitat (Chapter 7). Closed areas (zoning) aim not only at protecting juveniles or spawning concentrations, or shielding small-scale fisheries from competition with large-scale ones, but also at protecting particularly vulnerable non-target species and critical habitats (Chapter 8). If aiming at fishery management, they must be formally planned, established and managed with the people concerned. Similarly, closed seasons aim at protecting not only juveniles of the target species but also concentrations of vulnerable or emblematic species. Harvest limits must concern both target and non-target species in order to reduce bycatch and discards. Effort controls cannot be made as species-specific as catch controls but generic reductions and limitations of fishing capacity may have important systemic impacts on the whole ecosystem and are particularly recommended for complex multispecies fisheries. Once the link between the resource well-being and its surrounding biophysical habitat is established and communicated, fishing rights have the potential to improve the state of the resource, including its environment (Chapter 10).

Environmental issues will continue to attract international attention: the impact of fisheries on the ecosystem structure and functioning; the question of bycatch; the protection of emblematic and threatened species; the impact of climate change on population parameters, abundance and resilience. The impact of non-fishery activities on fisheries and on the marine environment through pollution and environmental degradation, despite the glaring examples of the Aral Sea, Black Sea, Baltic Sea, Adriatic Sea and Gulf of Mexico, is likely to remain on the back burner, away from the media frontlines and governments' first priorities, in part because the responsible sectors, contrary to fisheries, were not science driven and their records are either non-existent or not easily accessible.

17.3.4 Dealing with complexity

Many of the changes mentioned in this section of the chapter are required to deal with complexity and its consequences. With few notable exceptions, fishery management science has not yet

integrated the methods needed to deal effectively with complexity. The latter implies recognizing fisheries as linked social–ecological systems in which fishers and their ecosystem have a two-way feedback relationship. It calls for a formal recognition of uncertainty (e.g. through adaptive management and the precautionary approach), non-linearity (e.g. recognizing the existence of thresholds and the possibility of alternative system states), multiple scales in space, time and institutional dimensions and the possibility of self-organization. It calls for new ways to use information at different scales and to integrate fishers' knowledge. Fishery managers may resist confronting additional complexity considering that conventional management is complex enough. The advocated solution is to go beyond command-and-control measures and empower fishers to self-organize and self-manage themselves, under state stewardship, learning how to adapt and respond to change. For this, communities need networks and partnerships involving various levels of government and support organizations. Co-management and other participatory approaches are essential in this respect (Chapter 11).

17.3.5 An evolving role for the manager

The central function of the manager is changing from that of elaborating and enforcing centrally taken decisions to that of an intelligent interface between the state, the industry, science and society, managing the flow of relations with and among a complex web of specific or mixed institutions (Chapter 6). The manager must consider multiple objectives and options, under a risk-minimization strategy, complementing conventional forecasts with risk assessment and prudent foresight. Putting in place the mechanisms needed for integrated, interdisciplinary and participatory assessments, option analysis, decision and implementation may or may not be in the manager responsibilities' portfolio but it is a pillar of the new governance. Conscious of the close connections between policy-making and strategic planning (at sector and national levels) and operational management (at local and fishery levels), the manager becomes a key element of the sector governance. The concept of 'manager', itself, needs revisiting as, through participation and devolution, the management responsibility has become shared with other actors. The 'manager' is often going to be *de facto* a new institution, a team, a network and not a single individual (Chapter 1). The state remains ultimately responsible (liable) by virtue of its sovereign rights, delegating responsibility to this entity, but additional formalisation might be needed to identify specific roles and responsibilities of the various actors in the mechanism.

17.3.6 Management instruments

The management of fisheries requires first and foremost a management plan (Chapter 16) articulating objectives and means to achieve them such as (a) technical measures: gear regulation or fishing restrictions in time or space (Chapters 7 and 8); (b) economic and social measures (Chapters 3, 4 and 10) and (c) controls of inputs and outputs (Chapter 9). A mix of these measures is usually needed, tailored to the type of fishery and ecosystem, and no single panacea (fishing rights, harvest control rules or marine protected areas (MPAs) can, alone, ensure sustainability. In Chapter 9, for example, a combination of area-based effort or catch control and fiscal measures (taxes) is proposed as a means to modulate fishing pressure on a mix of species.

From command-and-control to co-management

Chapters 5, 6, 9 and 11 stressed the fact that command-and-control instruments may often seem remote from the interested parties and that, to fishers, the controls may appear driven by the whims of remote and misinformed bureaucrats. Decentralization, transparency and participation are therefore welcomed. Chapter 9 suggests also that there may be some virtue in moving the decisions and operation of effort and catch management out of direct political control and into the care of a benign and transparent public body, aiming at clear objectives established by the political system, judged on performance in this regard, but left to operate without political interference. There is also pressure for using more incentive-based measures such as use rights (Chapter 10) and to devolve authority to coastal communities or industry whenever possible (Chapters 3, 11 and 15), maintaining the important role of the state in terms of ensuring stewardship and protection of use rights.

Regulation of gear and technology

Until the early 1980s, these instruments had focused on improving catching efficiency and short-term economic efficiency as well as selectivity. The focus has now broadened to reduce (i) impact on non-target species (e.g. mammals, sharks, seabirds, turtles and other emblematic species); (ii) impact on critical habitats; (iii) fuel consumption and (iv) contribution to greenhouse gases, for example, through more efficient engines and refrigeration technology (Chapter 7). The incentive has been provided by the formal adoption of the ecosystem approach, the increased awareness of the public and consumers, and the raising interest in and emergence of ecolabels. The trend towards lower-impact technology can only continue to increase.

Closed areas and time restrictions

There are many compelling reasons for a fisheries manager to seriously consider using these measures as a complement to other measures for fishery management and biodiversity protection (Chapter 8). These measures are conceptually simple and may be used when other measures are not possible, for example, to protect sensitive life stages or habitats, representing a general insurance against unexpected negative events. They may however be ineffective or counter-effective when poorly planned or introduced without active participation of stakeholders.

MPAs are likely to be used increasingly in the future given the need to combine measures useful for fisheries purposes as well as to protect biodiversity (Chapter 8). Their careful planning and participatory setting is, however, a necessary albeit insufficient condition. There is little doubt that their full potential for fisheries will only be achieved where they will (a) be integrated into larger area-based management schemes including control of the impact of other environmentally deleterious activities; (b) be well designed to achieve explicit objectives appropriate for MPAs; (c) cover a large enough part of the ecosystems concerned to have a measurable impact; (d) encompass the areas most critical to key biological processes; (e) be properly enforced and (f) be accompanied by a reduction of fishing capacity in the surrounding area and other necessary management measures. The growing use of satellite vessel monitoring systems (VMSs) opens important perspectives for finer control of output or input controls than possible today, tailoring harvest or effort levels to specific areas (Chapters 9 and 14).

Harvest capacity controls

Fifty years of experiments, failures and transient successes have shown the absolute necessity as well as the difficulty of adjusting the harvest to the changing resource productivity, technology and market demand (Chapter 9). While reducing and controlling fishing capacity is the obvious key, countries and scientists are still struggling to find effective ways to do so. Eliminating the subsidies that contribute to the problem and introducing economic incentives and user rights is the agreed way to proceed at the sector level. At fishery level, using control rules preferably elaborated as operational management procedures (OMPs) provides the modern way of limiting total removals or total effort (Chapters 10, 12 and 13). An OMP prespecifies the harvesting rule that will be adopted, in various perceived circumstances, to fix the TAC (or allowable effort) based on the available data. Control rules can be established in data-limited as well as data-rich fisheries and comply with the precautionary approach in defining risk and elaborating pre-agreed courses of action through a principle of feedback control. Where sufficient capacity exists, candidate control rules reflecting different harvest strategies may be tested through simulations to check their likely performance against a set of management objectives. Where simulations are not possible because of, for example, insufficient information or capacity, control rules could still be systematically checked against the best available knowledge and information, including validated stakeholder knowledge. These rules may use observed as well as model-based indicators and can therefore be applied in a large range of fisheries. At present, however, their application to management seems to have been limited to large-scale fisheries (Chapter 13).

Illegal, unreported and unregulated fishing (IUU) remains a significant difficulty in this respect. Practised by fishers that (a) do not comply with the management measures prevailing in an EEZ or adopted in an area managed by a regional fisheries management organization (RFMO), or (b) fish illegally in an EEZ, IUU is a serious impediment to effective fishery management that needs to be confronted with determination (Chapters 5 and 14). In EEZs, this connects to the need for better compliance through more participative management systems providing financial and social incentives and putting in place effective deterrent surveillance systems and penalties. In the high seas, the solution passes through more responsible flag states and port states, regional collaboration between national control and surveillance systems, modernization and capacity building in enforcement systems (e.g. through on-board observers and satellite vessel monitoring systems).

Economic incentives and disincentives

These are being strongly advocated as an alternative to conventional command-and-control measures. Perverse incentives such as subsidies that can promote overcapacity need to be phased out and eliminated. Other subsidies used to reduce overcapacity or create alternative job opportunities might be tolerated. Fishing rights are generally considered as an effective way to encourage both short-term economic efficiency and long-term conservation and to reduce the sector vulnerability to global change. The role of the market in the conservation, consolidation and transfer of these rights needs very careful consideration (Chapter 10). The particular role of these rights in small-scale fisheries in the developing world is also generally advised as a means to improve entitlements, reduce poverty and, potentially, improve the ecosystem stewardship (Chapter 15). In a globalizing economy dominated by pro-market ideologies, the question of privatization can only grow and managers will need to consider

it carefully within their various types of fisheries, tailoring the theory to local realities, in a highly participative mode. An important consideration in that respect is the need to recognize that most fishery resources are already allocated in some way and that any 'introduction' of fishing rights is indeed, in most cases, a re-allocation, creating opportunities for some, together with the risk to accidentally sever more informal entitlements. Another important issue is that fishing rights may interact with other rights already allocated to other uses in the fishery area (e.g. to conservation, navigation or tourist industries) creating for the manager a need to 'navigate' the stormy waters of interaction and competing rights.

Trade-related measures

These are being rapidly introduced reflecting the globalization of fish trade and its impact on fisheries at the local, national and regional levels. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) listings of species threatened by international trade are likely to impact more of the fishing activities if the situation of the stocks does not improve. Ecolabelling, traceability and certification have potential in large-scale fisheries for high-value products for the international market. These trade-related measures have the potential to influence fisheries practices and management in the long term. Their applicability to small-scale fisheries requires further consideration and application (Chapter 15).

Indicators

Indicators have been used in fisheries for more than 50 years as a means to guide decision-making and monitor performance, and their more systematic use has been prompted by their prescriptions by UNCED (1992) and the United Nations Commission on Sustainable Development, the publication of the FAO Guidelines on the precautionary approach (FAO, 1996), the use of sustainability indicators for fisheries (FAO, 1999) and the EAF (FAO, 2003). While their use is still far from being generalized or perfect, indicators and reference values have been used for conceptual representation of the fishery system and description of its evolution, for communication with stakeholders and the public and for control of fishing operations (in control rules). These uses can only increase in the future. An integral component of the management system, a system of indicators, is a means and not an end. Its adequacy in an evolving context must be constantly questioned and tested. Its success rests in its conception, development and implementation in an active partnership with stakeholders, aligning and building coherence among the different 'visions' and understandings and providing a bridge between science disciplines, policy and society (Chapter 12).

Partnerships

As society and governments realize the poor performance of fisheries management and the growing complexity of managing fisheries in an integrated or ecosystem framework, the need to involve the stakeholders more directly in the management process is being generally recognized for both small- and large-scale fisheries, with the exception of high seas fisheries. Efforts towards more democratic forms of management have led to testing of various forms of participatory management, community-based management and co-management

during the last two decades. The issue is addressed fully in Chapter 11 but is touched upon also in Chapters 3, 9, 10, 12, 13 and 15. This underlines the centrality of the role expected from the stakeholders in modern fishery governance, beyond provision of information, as primary partners in the assessment, elaboration and analysis of management options, and in their implementation and performance assessment at fishery or community as well as sectoral levels. The willingness of stakeholders to participate is likely to be sustainable only if managers are able to recognize the value of fisher's expertise and treat their fisher partners with respect. The role of NGOs in mobilizing participation is essential and so is capacity building at the decentralized level. While it has been shown to work at fishery level (e.g. in limited entry and ITQ systems), participation in an EAF perspective needs to be area based or ecosystem based, requiring institutions for the purpose at the right level (Chapter 6). At that level, partnerships will necessarily involve multiple communities of users. Accountability and equity become crucial issues together with decisions about allocation of rights, benefits and responsibilities. In a multi-stakeholder environment, involving people with different backgrounds and interests to face multiple sources of risk is not a sinecure. The present trend indicates that ensuring effective partnerships will be an important task of the manager in the future, requiring human qualities and facilitation skills in addition to the usual scientific, administrative and legal competences. This need is largely agreed for EEZ fisheries and is slowly being recognized also for international and high seas fisheries despite institutional difficulties.

Simply listing the criteria for successful partnerships (Chapter 11) underlines the complexity of the task: dependency level, geographical and cultural identity, cultural homogeneity, clear community membership, local commitment and leadership, local willingness to establish a partnership, availability of traditional knowledge, existing mechanisms for consensus building and conflict resolution, enabling an agency competent and willing to organize and facilitate the process and last but not least, a strong political will at local and central levels. The role of environmental and fishery NGOs in establishing partnerships cannot be overstated. The responsibility to decide on what degree of participation is the most appropriate, that is between simple consultation and complete devolution of responsibilities, is a key managerial responsibility, and the decision will depend on local conditions.

Monitoring, control and surveillance

The Monitoring, control and surveillance (MCS) has usually developed to accompany the implementation of centrally developed fisheries policy and management strategies. The connection to the coast guards or the Navy has reinforced this top-down character. In small-scale fisheries, however, centralized MCS has shown its limits, helping in enforcing zoning regulations but often failing to enforce fishing regulations in a very dispersed exploitation system. Chapter 14 stresses the need to integrate MCS in management planning and implementation. The connection between the fishery manager and the MCS manager is fundamental and may require the development of mixed institutions, for example between the Navy and the Fisheries Department. The development of regional and global cooperation in MCS is also providing a broader platform for the manager and a potential source of experience and best practices. The clarification and strengthening of the role of the flag and port states in relation to illegal fishing, particularly but not only in the high seas, adds facets to the role of the manager in relation to the vessels fishing in the high seas and results in higher demands. The intrusion of trade measures, ecolabelling, catch traceability requirements, flag states'

certificates of conformity and verification of labels adds a significant, new burden and role for the state and its institutions in relation to processing and trade flows. The development of VMSs may be providing the tools needed to deal effectively with these tasks but the need for capacity building to face a more complex task cannot be overstated. The collaboration of the manager in regional or global efforts (e.g. to whitelist well-behaving vessels or blacklist contravening ones) and in contributing to the global records of fishing vessels is essential to curtail illegal fishing. In parallel, participatory management systems for small-scale and coastal fisheries should improve compliance and are expected to reduce MCS costs.

17.3.7 Selected emerging issues

The multi-functional nature of fisheries

Fisheries are a source of food, employment, income, development opportunities and coastal livelihood. They also represent a social capital, often ignored or undervalued. The current economic theory which emerged 50 years ago (Chapter 4) indicates how economists interpret the system available, the interaction between its components and the dynamics of the sector in the market. Departures of the reality from the economic model are called 'market failures' demonstrating the fact that the 'market' and economic models describing it only reflect the conventional market values and costs in fisheries, leaving out other, non-conventional, benefits and costs. The conventional criteria for economic 'efficiency' do not include equity, for instance, and rarely consider the societal costs of inequity. Another important aspect of the multi-functional nature of fisheries is the importance as social safety nets in countries with no social security or unemployment schemes. Chapter 4 addresses this issue in a capital-theoretic frame referring to the existence of very high or infinite discount rates (or infinitely rare alternative solutions) of many poor populations fighting starvation and marginalization, which they can only do in open access fisheries, albeit in a limited and unsustainable manner. The real value of the social safety net provided by fisheries may only become obvious to policy makers when such nets become necessary (e.g. for displaced populations during droughts or civil wars) or when they are suppressed (e.g. by privatization of fishing rights) to optimize the sector, possibly leaving to society the burden of costly alternative safety nets or of social unrest of disenfranchised populations (cf. Chapter 10). With the increased globalization and domination of the market approach and the projected increasing gap between affluent and poor people, this issue may become even more widely relevant.

It is becoming widely accepted that the best way to help the poor fishers out of poverty may not be to help them to become more effective fishers but to generate wealth in the fishery (by reducing the number of people and technology used and through value-adding technologies) and use a part of that wealth and other societal resources available to create alternative development and employment opportunities for them, recognizing poverty alleviation as a macroeconomic (systemic) issue and not a sectoral one. This would be particularly relevant in developing countries and countries in transition that are taking off in the wake of the 'marketization' of their economy, for example, in Asian countries where booming coastal aquaculture is offering increased opportunities. In such a perspective, however, the improvement of the economic situation in fisheries will unavoidably attract interests from people looking for livelihood and investors looking for returns, trying the ability of management systems to maintain fishing capacity at an optimum level (Chapter 4).

Evolution of management objectives

In modern fisheries management, the set of management objectives has been broadened to reflect the more complex set of high-level principles contained in the conventional and new instruments mentioned in the introduction to this section and the broader societal expectations. The conventional objective of conservation of the target resource and associated and dependent species is extended to cover the maintenance of (or minimization of the impact on) the resources' habitat, the biodiversity and the broader ecosystem. Environmental movements have influenced the positions of governments, leading to the ban of large-scale driftnet fishing and the reduction of dolphin mortality in tuna fisheries, of turtle mortality in trawl fisheries and of seabirds mortality in longline fisheries. Efforts towards further reducing of bycatch and protecting habitats are high on the agenda. The reality of natural short-term and medium-term variability and the frightening perspective of climate change are leading to adding considerations of resilience and adaptability of both the productive ecosystems and the fishing communities.

The globalization of market-driven development and management policies lead to a need to broaden also the conventional objective of economic efficiency to cover the maintenance of present livelihoods or the provision of alternative ones, poverty reduction, food security, people's safety at work, gender and child labour considerations and equity (Chapters 1, 2, 3, 12 and 15). The consideration of resilience as an objective is one important emerging issue. Resilience is a property of complex systems' dynamics and ability to absorb shocks, self-organize, learn and adapt to change. It gains importance with the ongoing global change and the expected increased variability, higher frequency of extreme weather events, and overall reduced predictability. Ecological and social aspects of resilience are closely connected. Sustainable livelihoods are those that are resilient to stresses, can cope with crises and are capable of absorbing environmental and economic perturbations (Chapter 3).

Public goods and fisheries

Chapter 4 deals briefly with this important issue, reminding that necessary infrastructure such as roads, running water and electricity networks, and ports is often absent or in poor condition, limiting the access to fishery resources and to global markets. Conversely, the fishing capacity that can be developed in an area depends to a great extent on the public goods infrastructures available, most often developed for reasons that have little or nothing to do with fisheries but may strongly affect the potential and the outcome of fishery development and management. These are factors that will condition the success or failure of fisheries management operating as external but highly consequential drivers. Chapters 5, 6 and 10, when touching on use rights, stress the fact that such rights do not transfer property from the state to the user (the term *privatization* is sometimes incorrectly used) but represent an authorization to use such property under strict conditions. As a consequence, fishery resources remain inherently public goods and, in most cases, use rights are instruments for their stewardship (A.T. Charles personal communication).

Increasing management capacity

The increasing complexity of the task requires an increase in the capacity of the management units which are still, in many countries, extremely understaffed and inadequately

qualified. Increased capacity will be needed in particular in integrated management systems, for example in integrated coastal zone management, where the capacity of fisheries to participate and compete for allocations needs to be strengthened. Improvements are needed in data and information systems, for example to better assess the real value of fisheries and deal with uncertainty (Chapters 12 and 13); mechanisms and processes for participative assessment, advice and decision-making (Chapters 11–13); improved legislation, aligning national legislation with international and regional agreements (Chapters 5 and 6) and fleets' monitoring systems and enforcement (Chapter 14). There is also a need to develop stewardship capacity, at decentralized levels, for example, establishing user rights (Chapters 3 and 10), creating and supporting the needed institutions, educating and empowering stakeholders (Chapter 3), educating citizens about the reality of fisheries, providing credit and insurance and promoting market development.

Intrasectoral and cross-sectoral issues

The areas in which fishery managers tend to encounter most difficulty are in human behaviour and arbitration between different groups of actors (including states) competing for space and resources. Within the sector, increasing demands for fish and technological progress in locating, catching, processing and transporting fish have led to an expanding range of species being exploited and entering trade for human and animal food, aquaria, medicine, tonics, curios, bio-prospecting, etc., increasing extraction rates, volume and diversity of trade, and posing serious traceability issues (Chapter 2). Across sectors, competing activities generate conflicts and negative impacts on ecosystems such as pollution (Chapter 13). Multi-sectoral approaches are required to develop capabilities and entitlements across a broader spectrum of livelihood opportunities and provide for greater safeguards against emergencies and global change (Chapter 15). The multi-stakeholder environment complicates the participation, the process of allocation and defence of use rights and the possible arrangements for cooperative and adaptive management. In a perspective of area-based, integrated, intersectoral governance, the sector will increasingly be considered, planned and managed within a much broader governance framework such as a watershed, a coastal area or a large marine ecosystem, within which the sector will need to collaborate and compete.

A direct implication for the role of the manager is the growing need to be not only an interface between fishery stakeholders and a facilitator for self-organization of the sector but also part of the interface between fisheries and other sectors in the broader arenas of policy and integrated management.

Evolution of the legal framework

The emergence of new (systemic) concepts, approaches and techniques is slowly stretching to its limits the relevance of current fisheries legislation often enacted prior to the advent of the LOS Convention (Chapter 5). On the one hand, issues such as rights-based management, co-management and other forms of participatory management and the use of VMS (as an MCS tool) or MPAs have acquired enough maturity to be introduced in the legal framework (Chapters 3, 8, 10, 11, 14 and 15). On the other hand, issues such as the precautionary approach and decision under uncertainty continue to warrant exploration of ways to give

them practical effect and to support them formally through law (Chapter 5). Ongoing trials should be observed closely and the lessons that arise from them put to good use. The management of deep-sea fisheries of large marine ecosystems and the protection of the marine environment beyond areas of national jurisdiction as well as the use of Port State Measures (PSMs) in addition to Flag State Measures (FSMs) will remain the subject of global attention and support for the coming years and will probably generate additional binding and non-binding international instruments to the present legal arsenal (Chapter 5). States will then be expected to give effect to these new instruments in areas under their jurisdiction. In addition, the development of instruments, for example under the CBD, to manage biodiversity within and beyond national jurisdiction will certainly have impact on fishery law.

Filling the knowledge gap

The unavoidable shortage of information when implementing EAF is a problem in most fisheries, particularly small-scale fisheries. This shortage has a number of implications regarding the recognition of uncertainty and risk; the reorganization of data collection systems (by ecosystems); the identification of a suite of simple but reliable indicators of pressure, state and response for ecosystems; and the determination of optimal fishing regimes for assemblages of species with differing vulnerabilities (Chapter 13). The recognition of the need to act with imperfect knowledge leads to putting aside the concept of controlling nature (i.e. managing resources) adopting instead the idea of learning-by-doing through an adaptive approach, developing learning institutions and partnerships between managers and resource users that can learn from crises, respond to change, nurture ecological memory, monitor the environment, self-organize and manage conflicts (Chapters 3 and 11).

The fact that information will never be complete and decisions will always involve uncertainty is widely acknowledged (Chapters 3, 12 and 13). The level of difficulty faced by the manager depends on the complexity of the resource and the fishery (i.e. the number of components and their dynamics) as well as on the capacity available or affordable in such a fishery for assessment, monitoring and evaluation. In the most favourable conditions, sophisticated monitoring and analysis might be possible, using scientific surveys, indicators and complex modelling, providing well-informed policy options and scenarios and using decision-support tools such as harvest control rules (HCRs) and management strategy evaluations (MSEs). Central monitoring and enforcement might be justified and eventually funded by the industry. In the worst conditions, with little information and capacity, assessment and monitoring may need to be essentially community based, using simple indicators accessible to the community, a self-enforcement largely based on social pressure and incentives and an adaptive approach, the risks of which are jointly evaluated. Considerably greater precaution is required in that case, foregoing some potential benefits as a tax for greater uncertainty.

There is no reason, however, to use expensive research and management in high-value fisheries if simpler and cheaper approaches can be safely used, and participative approaches are advisable in all cases The use of sophisticated methods (e.g. Bayesian methods including belief networks) in complex and capacity-limited small-scale fisheries is not excluded either. Within the extremes mentioned earlier, the situation will need to be judged on a case-by-case basis, based on resources available and some cost–benefit analysis. In all cases, finding simple indicators that can faithfully track the behaviour of a complex social–ecological system represents a significant challenge.

Articulation between national and international agendas

Chapter 9 stresses the fact that debates occurring at the global level (in particular in the United Nations General Assembly and FAO) and regional levels (in RFMOs) have substantial effects on EEZ fisheries management. While the allocation of exclusive sovereign rights on fisheries in the EEZs has eased some management problems and opened the way to new solutions, the situation is still unsatisfactory. Regional fisheries are still struggling with 'lack of political will' and disregard for scientific recommendations as well as IUU fishing. At global level, agreed instruments are often not binding, and it is the task of managers to convert their guidance into enforceable national and local standards. The issue is particularly crucial for the non-fishery, environmental and other agreements, which may have numerous and important implications for fisheries, not always properly considered before adoption.

Interaction with aquaculture

The interactions between capture fisheries and aquaculture will increase in the future (Chapter 2). In capture-based aquaculture, the capture of wild larvae as well as juvenile and immature fishes has developed exponentially, for example, on high-priced carnivorous species such as tunas, groupers and shrimps. As currently practised, these activities support livelihoods but are not likely to produce large quantities of cheap protein for modest households or to reduce fishing pressure. They may instead aggravate current issues through dangerous competition with fisheries exploiting the same species as adults, aggravation of overfishing through badly recorded or unrecorded withdrawal of pre-spawning stocks or reducing food security of poor people through the transformation of cheap fish into fishmeal. The introduction of mariculture of carnivorous species should therefore be carefully analysed against broader national objectives. In culture-based fisheries, the hatchery production of small fish and their subsequent release in the aquatic system is often proposed as a method of stock enhancement or rebuilding, and the pressure to use this approach may increase with the pressure to rebuild depleted stocks. For this approach to be successful, however, it is critical to ensure that released fish survive long enough to re-establish spawning stocks or improve the fishery. This has implications for the quality of the released fingerlings as well as the release location and process but, above all, it implies, as for MPAs, that fishing capacity and fishing regimes are controlled so as to allow a sufficient number of animals to reach reproductive age. Restocking can also have negative impacts on the genetic composition and diversity of populations and any restocking programme must be carefully designed and implemented to avoid this. In any case, cost–benefit analyses are needed before undertaking such programmes and restocking should not be seen as an alternative to the needed reduction and control of fishing capacity.

Risk of extinction

The risk of extinction of key species by fisheries is a growing concern (Chapter 2). Fishing at high exploitation rates impacts the ecosystem structure and functions resulting in indirect effects on biodiversity. Fishing can threaten in particular those species that are most susceptible, such as sharks, seahorses, croakers, reef fishes, queen conchs, giant clams, corals, some sea cucumbers, orange roughy and several other small invertebrates. There is now good evidence that some species might well have been driven to local extinction and a number

of bycatch species are considered as threatened. Similarly, species belonging to the fishery resource habitats, generally disregarded by fishery management, are threatened (e.g. cold corals) and numerous target and bycatch local fish populations have been depleted to the point of disappearing from the fisheries 'radar'. The concern is reflected by the increased attention given by CITES[9] to species exploited or affected by fisheries. The possibility, in the future, to combine trade controls with management measures is a useful perspective, already being tested in some regional fishery organizations (e.g. Convention on the Conservation of Antarctic Living Marine Resources [CCAMLR] and tuna RFMOs).

Ethics

Ethical issues are just emerging.[10] The global debates taken up at the United Nations and other international fora on the need for fairer and more inclusive economic development and the protection of human rights will result in attention focusing on many small-scale fishing communities that have remained socio-economically and culturally marginalized over the last few decades (Chapter 15). The presence of numerous support groups and civil society organizations which espouse the cause of small-scale fishers and larger issues such as human rights, poverty, global hunger, indigenous people's concerns and food security will add pressures at both the national and international levels to act concretely on these matters with a greater sense of urgency. Ethical issues exist also behind the question of fishing rights and the process of exclusion. Chapter 10 refers to five 'rights' of relevance for fisheries derived from the fundamental Declaration of Human Rights: (a) the right to have healthy and nutritious fish as food; (b) the right to have access to fishery resources for livelihood; (c) the right to a healthy household, to belong to a community and to maintain one's culture; (d) the right to work and live safely in a healthy ecosystem that will support one's progeny (and future generations) and (e) the right to participate in the decisions affecting fishing as indeed provided by the Aarhus Convention. These rights are strongly connected to the question of fishery user rights and underline the need to involve people directly concerned in the decision process on who should hold those rights, how they should be managed, transferred and so on. This connecting of use rights and human rights may be increasingly important to take into account in fishery policy development, at scales from the local to the international. Ethical issues emerge also in relation to the conditions of service of crews on board of some large long-range vessels often using flags of convenience.

17.4 The future of fishery governance

The active evolution of fishery governance has taken about a century, with a strong acceleration during the last 30 years. Today, governance systems range from total neglect, arbitrary decisions and corruption (e.g. in war and poverty-ridden areas) to fairly proactive, democratic and ethical governance in a few advanced countries. In between, a majority of countries are struggling to implement the conventions and meet the commitments signed at the highest level, often with insufficient implementation capacity.

[9] The Convention on International Trade in Endangered Species of Flora and Fauna.
[10] FAO. 2005. Ethical issues in fisheries. FAO Ethics Series, 4: 30p.

The WSSD adopted in 2002, with questionable rational analysis, a series of targets implying a significant improvement of fisheries by 2015. Will these goals be met? Will the longer-term goals for sustainable and responsible fisheries be met? Predicting the future is impossible but at the cost of closing this practical guidebook on a highly theoretical note, some 'food for thought' could be offered.

The fact that fisheries are commonly a minor if not marginal economic sector and that fishery governance is part and parcel of a larger (national, regional and global) governance implies that the future of fisheries and their governance will be shaped by global and national political and economic considerations on which fisheries will have very little influence. Guessing how fishery governance will evolve in the future therefore requires strong assumptions about the evolution of the governance of the world itself. A number of scenarios for the world in the 21st century, including 'business as usual', 'best' and 'worst' cases, have been proposed (Table 17.1) and examined by Garcia and Grainger (2005) in terms of their implications for fisheries policies and governance. A brief extract of this work is given in the following section.

17.4.1 Governance of the 'Market world'

Under the most likely (*Business as usual*) scenario of the *Market world*, the ongoing globalization process generalizes and accelerates until the change is completed and a new equilibrium is reached. Under combined lobbying action by powerful financial interests and the WTO, trade barriers disappear and trade flows of resources, services and people (migrations) increase. Despite establishment of oversight institutions and privatization, the risk of depletion for natural resources with rates of growth lower than financial interest rates increases. Foreign investment grows together with export-oriented developments, private–public partnerships, industrial growth, vertical and horizontal integration and emergence of large multinational corporations. Unless the economic and strategic value of resilience is ascertained and a strong pro-resilience movement emerges, small-scale enterprises recede, and property is aggregated in fewer hands as enterprises are integrated vertically and horizontally.

The optimists suggest that under reduced demography and more success in controlling market failures triggered by public consensus (*Policy reform* sub-scenario), improved global

Table 17.1 Correspondence between the various future world scenarios.[a]

	Business as usual		Worst case		Best case	
Hammond (1998)	Market world		Fortress world		Transformed world	
Gallopin (2002)	Conventional worlds		Barbarization		Great transitions	
	Reference world	Policy reform	Fortress world	Breakdown world	Eco-communalism	New sustainability
UNEP (2003)	Market first	Policy first	Security first		Sustainability first	

[a] Source: Adapted from Garcia and Grainger (2005)

wealth and political will, exceptional governmental efforts will lead to improved sustainability through fuller implementation of international agreements, more democracy and freedom, unprecedented social and economic advances and improved resources and environment without major changes, however, in fundamental values and dominant paradigm. The pessimists consider that in totally deregulated market-driven system (*Market first* sub-scenario), the disappearance of trade barriers increases the risk of resource depletion. In a system controlled by the most powerful operators, those not able to compete are excluded, generating exclusion and tensions. In the poorest countries and communities lacking the pre-conditions to benefit from the market economy, poverty, unemployment, corruption and violence persist or increase, as does the gap between poor and rich and the disconnection between people and decision-makers. Too little is done too late to correct inequity and the wealth gap will increase as well as the demand for activities of last resort (in fisheries). Appropriation increases as close as possible to full property, and tensions rise to the point of chaos, possibly ignited by and following the structural faults of racism, or political and religious radicalism. As time goes, the situation worsens, available solutions become scarcer and the necessity for and cost of the transition to better scenarios increases. Eventually, this scenario leads to a global crisis.

17.4.2 Worst case: governance chaos

This worst case scenario is characterised by failure and collapse of democratic governance under the violent tensions generated by globalization. The system is maintained through a 'feudal' system of governance (*Fortress world* or *Security first* sub-scenarios) by a dictatorial minority owning '*islands of well-being in an ocean of chaos*' (Hammond, 1998). Also referred to as *Barbarization*, this scenario may lead to either total chaos or anarchy (*Breakdown world* sub-scenario).

This world may emerge from the *Market world* in a context in which governance is incapable of managing the change and mitigating its negative consequences on people and the environment. It emerges out of the economic divide and conflict between individuals, communities and countries about scarcer resources depleted in a policy-deficient market world. It eliminates millions of the most vulnerable livelihoods. Under this scenario, fish trade is highly protected or illegal and tariffs and non-tariff barriers increase (reversing the market tide), resources are very inequitably distributed leading to questionable legitimacy of institutions, increasing civil disobedience and criminal tendencies leading to increased IUU, destructive fishing, corruption, intolerance and radicalism. Unabated pollution affects productivity and seafood quality, life conditions, health and climate. Uncontrolled export-oriented developments threaten food security for the poorest; private alliances, priority on industrial growth and integration with emergence of large multinational corporations with private police and armies (that already exist).

Under these conditions, management of fisheries will be a low priority and, with a fictitious example, Hammond mentions specifically the implications for the sector: '*one by one, major marine fisheries collapse, victims of sustained overfishing by huge trawler fleets eager to supply the international fish market. Fish, produced almost entirely by aquaculture now, is a luxury food. Fishermen lost their jobs but more devastating was the loss of the primary source of proteins for three quarters of a billion people . . . As conditions became desperate, the voices of the disenfranchised became louder. In India a protest march by a group of fishermen became an army of more than 2 million people that converged on New Delhi*'. Less

resilient systems collapse. Aquaculture products are essentially luxury food items contributing little to food security. The poorest regions (e.g. Africa South of the Sahara and South Asia) suffer the most, hit by HIV-AIDS, climate-change-driven droughts and resulting famines. Notwithstanding increased civil unrest, because of the development of private security, this scenario is very stable and, in the absence of external interventions, requires a long phase of reorganization before a new and better pattern can emerge.

17.4.3 Best case: Transformed world

In this optimal scenario, possibly prompted by a global crisis,[11] human sense of ingenuity and compassion lead to better and more equitable life for most, and all the conceptual objectives underpinning today's ideal vision of sustainable development are achieved. Referred to also as *Sustainability first* scenario, it is also seen as a scenario of *Great transitions* with two variants: one in which sustainability is achieved through 'regression' to simpler village life with low-energy consumption (*Eco-communalism*) and the other compatible with modern urban development and technological progress (*New sustainability*). The *Back to the Future* strategy proposed by Pitcher (1996) and Pitcher and Pauly (1998) would fit under this scenario.

The keywords are decentralisation, ecosystem and human well-being, participation, collaboration, equity, communities, egalitarianism, self-sufficiency, fair trade, flexibility, adaptation, global ethics, conflict resolution and negotiation. People are environmentally conscious. Rich people modify their consumption patterns, allowing sustainable living and development, poor communities to improve food security and resources to recover. Education, leisure and spiritual pursuit are valuable incentives. Ethical codes require wise resource use. In fisheries, international agreements (e.g. for shared and straddling resources) resolve the resource allocation issues. Discards are banned and the fishery sector complies. Critical habitats are protected. Large polluting companies are made to pay for and mitigate damage and to adopt longer-term horizons for decision-making and action. Energy consumption and greenhouse gases are drastically reduced. Market forces are mitigated by consensual social and environmental goals. Income tax reductions boost the economy, allowing for a renaissance, positive welfare reforms, reduced poverty, improved health, an increased role for citizen groups and religious congregations. This evolution is boosted by an information revolution and by including globally accessible Internet development, accompanied by greening of the private sector, improved corporate ethics and deeper involvement of philanthropic foundations. It allows for the emergence of alternative livelihoods to fishing for coastal communities.

This scenario would obviously enable responsible fisheries management, helping to improve harvest quality and value, as well as revenues and profits of those fishers remaining in business. Total catches likely decrease, increasing prices and reducing accessibility to seafood for the poor unless total population declines rapidly, developed economies collapse or aquaculture focuses on low-value species . . . all rather unlikely.

A few other authors have dared to elaborate scenarios for the future of fisheries (e.g. Cochrane and Doulman, 2005) and some of these are reviewed in Garcia and Grainger

[11] Gallopin (2002) finds it difficult to conceive how the *Market world* would lead directly to a Best Case scenario, and he rather sees it as emerging from global perception of environmental stress and global risk for the ecosystem and its inhabitants, global warming with catastrophic consequences and the realization of the futility of social polarization.

(2005). All the scenarios put forward in these examples fall into one or more of the above scenarios but most fail to touch on governance or give adequate attention to the fact that the future of fisheries is largely shaped from outside the fishery sector.

The key question, when facing such scenarios, is always: what is their respective likelihood? Which one is the most probable? We are presently in a situation tending towards a Market world scenario, aiming at the Policy reform sub-scenario. This is obvious through the states' rhetoric heard at the United Nations General Assembly, FAO, and all Conferences of the Parties of environmental treaties. It is too early to tell whether the global economic crisis that has emerged since then end of 2008 will lead to any major shift in the likely dominance of this scenario. A few leading nations (perhaps led by New Zealand, Australia, Canada and some Nordic countries) seem to be making progress along the pathway to this sub-scenario. Contemporaneously, there are worrying signs of an emerging Fortress world at the global level, as well as all the gradations between these two extremes. It is likely that none of the 'pure' options described here will emerge as the global condition and that diversity will persist even though globalization may reduce the range of solutions that can globally co-exist.

Considering Gallopin's doubts about the capacity of the *Market world* (where most fisheries tend or aim) to evolve into a *Transformed world*, the key challenge is to avoid getting in a *Fortress world*. This calls for a fishery governance system that can maintain resources in a sustainable equilibrium with fishers within a global governance avoiding that market failures lead to chaos.

It is important to realize that the interest of a manager, the opportunities opened to him and hence the selected strategy will depend on the reality (from enlightened democracy to oppressive dictatorship) within which he or she is presently operating.

Sources and recommended reading

Cochrane, K.L. 2008. What should we care about when attempting to reconcile fisheries with conservation? *Proceedings of the 4th World Fisheries Congress. Vancouver, Canada, 4–7 May 2004*. American Fisheries Society, Symposium 49: 5–24.

Cochrane, K.L. and Doulman, D.J. 2005. The rising tide of fisheries instruments and the struggle to keep afloat. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences* 360: 77–94.

FAO. 1996. *Precautionary approach to capture fisheries and species introductions*. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome, FAO. 54p. The guidelines are available also at http://www.fao.org/docrep/003/w3592e/w3592e00.pdf

FAO. 1999. *Indicators for sustainable development of marine capture fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 8. Rome, FAO. 68p. The guidelines are available also at ftp://ftp.fao.org/docrep/fao/004/x3307e/x3307e

FAO. 2003. *Fisheries management. 2. The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome, FAO. 112p. The guidelines are available also at ftp://ftp.fao.org/docrep/fao/003/W3593e/W3593e00.pdf

Gallopin, G.C. 2002. Planning for resilience: Scenarios, surprises, and branch points. In: *Panarchy. Understanding Transformations in Human and Natural Systems*. Gunderson, L.H. and Holling, C.S. (eds). pp. 361–394. Island Press, Washington, Covelo, London.

Garcia, S.M. 2007. From New Atlantis to New Alliance: Science, Governance, Society and the Ecosystem Approach to Fisheries. Plenary Lecture. 2007 ICES Annual Science Conference, Helsinki, 17–21 September . http://www.ices.dk/products/CMdocs/CM-2007/CM2007.pdf

Garcia, S.M. and Charles, A.T. 2007. Fishery systems and linkages: From clockwork to soft watches. *ICES Journal of Marine Science*, 64(4): 580–587.

Garcia, S.M. and Grainger, R. 1997. Fisheries management and sustainability: A new perspective of an old problem? In: *Developing and Sustaining World Fisheries Resources. The State of Science and Management. 2nd World Fisheries Congress*. Hancock, D.A., Smith, D.C., Grant, A. and Beumer, J.P. (eds). CSIRO, Brisbane, Australia. pp.631–654.

Garcia, S.M. and Grainger, R. 2005. Gloom and doom? The future of marine capture fisheries. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences*, 360: 21–46.

Hammond, A. 1998. *Which World? Scenarios for the 21st Century: Global Destinies, Regional Choices*. Island Press, Washington, DC.

Kooiman, J., Bavink, M., Jentoft, S., Pullin, R. (eds). 2005. *Fish for Life. Interactive Governance for Fisheries. Mare Publication Series*, 3. Amsterdam University Press, Amsterdam. 427p.

Millennium Ecosystem Assessment. 2005. *Living beyond our means. Natural assets and human well-being*. Statement from the Board: 24p.

Minta, S.C. and Settle, W.H. 2003. *Conceptual Frameworks and Case-Based Knowledge Management for the Ecosystem Approach*. UN/FAO Information paper for CBD/SBSTTA, 9 November. FAO, Rome. 39p.

Pearse, P.H. 1982. *Turning the Tide. A New Policy for Canada's Pacific Fisheries*. Department of Fisheries and Oceans (DFO), Ottawa. 292p.

Pitcher, A. 1996. Reinventing Fisheries Management. NAGA. July. 15–17.

Pitcher, T. and Pauly, D. 1998. Rebuilding ecosystems, not sustainability, as the proper goal of fishery management. In: *Reinventing Fisheries Management*. Pitcher, J., Hart, P.J.B. and Pauly, D. (eds). pp.311–329. Kluwer Academic Publishers, London.

Pownall, P.C. (ed.). 1994. *Australia's Northern Prawn Fishery: The First 25 Years*. NPF25, Cleveland, Australia. 179p.

Reid, W.V., Berkes, F., Wilbanks, T.J. and Capistrano, D. 2006. *Bridging Scales and Knowledge Systems. Concepts and Applications in Ecosystem Assessment*. Island Press, Washington, DC, Covelo, California, and London, England. 351p.

Roswadowski, H.M. 2002. *The Sea Knows No Boundaries. A Century of Marine Science under ICES*. ICES and University of Washington, London and Seattle. 410p.

Shotton, R. (ed.). 2000. *Use of property rights in fisheries management. Proceedings of the FishRights99 Conference. Freemantle, Western Australia, 11–19 November 1999*. Fisheries Western Australia and Food and Agriculture Organization of the United Nations. FAO Fisheries Technical Paper No. 404/1. 342p.

UNEP. 2003. Global Environment Outlook 3. Chapter 4: outlook 2003–32. Online http://www.unep.org/geo/geo3/english/515.htm

Glossary

Compiled by Serge M. Garcia

This glossary is intended as a resource for the fisheries manager. The words that are defined are therefore not limited to those used in the book and include other fishery terms that are commonly encountered in reading and discussions on fisheries. Unless otherwise specified, the definitions below are taken directly from the FAO Glossary[1] or are a slightly modified form of those definitions.

Acceptable impact. In general, a negative or potentially negative alteration of the exploited natural system, resulting from human activities (e.g. fisheries and other impacting industries). Formally, an impact, the level and nature of which, on the basis of the available knowledge, is officially considered as representing a low enough risk to the resource, system productivity, biodiversity or society to be tolerated. The acceptability is kept under review, and the decision can be revoked on the basis of new knowledge (modified from Garcia [1996]).

Access agreement. Unilateral or multilateral agreement by which a state assigns (grants) access rights to foreign fishing vessels to catch fish inside its EEZ, usually against some form of compensation. These agreements were foreseen in the LOS Convention in the case in which coastal states did not have the capacity to harvest the full potential (at MSY qualified by economic and environmental factors), leaving a **surplus**.

Access right. The right to enter and enjoy non-subtractive (see **subtractability problem**) benefits. One of the rights in the bundle of rights that, together, constitute property (Ostrom, 2000).

Accidental catch. See **bycatch**.

Active fishing gear. A fishing gear that catches fish as a result of the movement of the gear towards the fish. The gear may be moved by a person (as in a pushnet), the wind (as in sail dredging or trolling) or an engine (as in a trawler).

Adaptability. (1) The capacity of a system to adapt to change, maintaining as much as possible of its essential functions and features. Sometimes called **adaptive capacity**, it requires the capacity to detect change, to understand its dynamic and to react to it. (2) In complex social–ecological systems, the capacity of human actors to influence **resilience** . . . to avoid

[1]These selected definitions and many others, for the same and additional terms, can be found in the FAO Glossary at http://www.fao.org/fi/glossary/default.asp.

crossing into an undesirable system regime or succeed in crossing back into a desirable one (Walker *et al*., 2004).

Adaptation. Any change in the structure or function of the fishery system (e.g. of its natural or human components) that allows the system to continue to operate more effectively in its environment. Both the process of adapting to change (e.g. of economic or environmental conditions) and the result of that process.

Adaptive management. A management process involving step-wise evolution of a flexible management system in response to feedback information actively collected to check or test its performance (in biological, social and economic terms). It may involve deliberate intervention to test the fishery system's response. Adaptive management involves: generating alternative hypotheses, assessing the value of more information, developing models for future learning and hypotheses, formulating policy options, building criteria to facilitate option comparisons and conducting option evaluation (Hilborn and Walters, 1992).

Advocacy. An action-oriented process by which one translates what one values into policies and practices that affect the well-being of individuals, families, communities and societies. It is the practice by which one attempts to influence policies and practices (FAO Glossary [2008] based on Sykes [1997]).

Algorithm. A precise rule (or set of rules) specifying how to solve some problem or to accomplish a task.

Allocation. Refers both to a share and the process of sharing. A share, a portion, of the allowable catch, effort or area attributed to a person, a community, a vessel or a company, and the process of distributing shares (rights) among selected recipients based on historical, cultural or socio-economic criteria. The beneficiaries could be contemporary (**intra-generational allocation**) or belong to successive generations (**inter-generational allocation**). Examples: splitting a total allowable catch among fishing nations or assigning coastal areas to different uses. Synonyms: **apportionment, allotment, appropriation, distribution, division** and **repartition** (FAO Glossary [2008a] adapted from Garcia and Boncoeur [2007]).

Allowable catch. The catch allowed by a management authority to be taken from a stock of a species or group of species by a fishery during a specified time period. Often defined as the **TAC**, it is often allocated explicitly amongst those having a right of access to the stock.

Artisanal fisheries. The term tends to imply a simple, individual (self-employed) or family type of enterprise (as opposed to an industrial company), most often operated by the owner (even though the vessels may sometimes belong to the fishmonger or some external investor), with the support of the household. The term has no obvious reference to size but tends to have a connotation of relatively low levels of technology but this may not always be the case. In practice, the definition varies between countries, for example from gleaning or a one-man canoe in poor developing countries to more than 20 m trawlers, seiners or long-liners in developed ones (e.g. in Europe). Artisanal fisheries can be subsistence or commercial fisheries providing for local consumption or export. See **small-scale fisheries**.

Artisanal fishermen or fishers. See **small-scale fisherman or fisher**.

Associated species. Those species that (i) prey upon the target species, (ii) are preyed on by it, (iii) compete with it for food, living space, etc. or (iv) co-occur in the same fishing area

and are exploited (or accidentally taken) in the same fishery or fisheries. These interactions can occur at any stage of the life cycle of one or other species, and the range of species concerned can therefore be very large.

Assessment. A process that connects knowledge and action regarding a problem. Review and analysis of information for the purpose of informing the decision-making process. It may not require new research and involves assembling, organizing, summarizing, interpreting and reconciling existing knowledge and communicating it to the policy-maker or other actors concerned by the problem.

Bag limits. Also called **daily bag limit**. The number and/or size of a species that a person can legally take in a day or trip. This may or may not be the same as a possession limit (Roberts *et al*., 1995).

Bayesian. A formal statistical approach in which expert knowledge or beliefs are analysed together with data. Bayesian methods make explicit use of probability for quantifying uncertainty. Bayesian methods are particularly useful for undertaking decision analyses.

Best practice. A *modus operandi* that has been successfully tested and adopted in many areas. It provides an example and guidelines to be followed elsewhere.

Bioeconomic model. A set of mathematically expressed functional relationships between biological characteristics of the resource base (e.g. a fishery resource) and the economic (and sometimes social) characteristics of its use by man. As an abstraction from reality, the validity of a bioeconomic model depends on the explicit or implicit assumptions about the biological and human processes it represents (modified from FAO [1998a]).

Biodiversity. See **biological diversity.**

Biological diversity. The variety and variability among living organisms from all sources including *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Diversity indices are measures of richness (the number of species in a system) and to some extent evenness (variances of species' local abundance). These indices are therefore indifferent to species substitutions which may, however, reflect ecosystem stresses (such as those due to high-fishing intensity). Also called **biodiversity** (FAO, 1997).

Biological overfishing. Catching such a high proportion of one or all age classes in a fishery as to reduce yields and drive stock biomass and spawning potential below safe levels. Can involve both **growth overfishing** and **recruitment overfishing**. With reference to a surplus production model, biological overfishing occurs when fishing levels are higher that those required for extracting the **maximum sustainable yield** (MSY) of a resource.

Buffer zone. In precautionary fisheries management, the area between a limit reference point and a **threshold** reference point. It corresponds to a warning that the limit is being approached. Its purpose is to reduce the probability of inadvertently driving the stock/fishery beyond the limit.

Burden of proof. The onus of proving that the defendant has committed a criminal offence generally placed upon the prosecution. Under the precautionary principle, it is suggested to 'reverse the burden of proof'. In this case, contrary to the traditional presumption of

innocence, the defendant is deemed to have committed the offence unless he or she can prove the contrary (Freestone, 1998).

Bureaucracy. The politico-administrative system which relies on hierarchical decision mechanisms, dominated by the social group of the administrators (Weber, 1923).

Buy back. Financial mechanism of a fishery management scheme, usually supported and often subsidized by governments, in which governments or any other relevant party (e.g. fishermen associations) buy vessels and fishing licences from producers in order to reduce fishing effort and capacity. Synonym: **decommissioning**.

Bycatch. Or **by-catch**. Part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. It may be retained for human use or some or all of it may be returned to the sea as discards, usually dead or dying (modified from FAO, 1998a).

Capacity-building. A process of strengthening or developing human resources, institutions, or organizations (Alcamo *et al*., 2003). The sum of efforts needed to nurture, enhance and utilize the skills and capabilities of people and institutions at all levels, towards a particular goal, for example participatory management (Berkes *et al*., 2001).

Carrying capacity. (1) The maximum population of a species that a specific ecosystem can support indefinitely without deterioration of the character and quality of the resource. It represents the point of balance between reproduction potential and environmental constraints. (2) The level of use which a natural or man-made resource can sustain over a long period of time. For example, the maximum level of recreational use, in terms of numbers of people and types of activity that can be accommodated before the ecological value of the area declines (Scialabba, 1998).

Catchability coefficient. Commonly referred to by the mathematical symbol (q), it is a measure of fishing mortality generated on a stock by one unit of effort. In fisheries models, the factor (q) relates catch per unit effort (x) to stock size (N) in the relation ($x = qN$) and relates fishing mortality (F) to fishing effort (f) in the relation ($F = qf$).

Catch management. Directly limiting the catch (or bycatch) coming out of a fishery. Managing catches may involve regulating their species composition (through prohibition and other protection measures). Examples: t**otal allowable catches (TAC), allowable biological catch** (ABC) and **bag limits** (Based on Pope, this volume).

Catch per unit of effort (CPUE). The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; for example number of fish taken per 1000 hooks per day or weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance. Also called catch per effort, fishing success, availability (modified from FAO [1998a]).

Certification. Procedure by which a third party gives written or equivalent assurance that a product, process or service conforms to specified requirements. Certification may be based on a range of inspection activities which may include continuous inspection in the production chain (FAO, 2005a).

Chain of custody. The set of measures which is designed to guarantee that the product put on the market and bearing the certification is really a product coming from the certified

fishery concerned. These measures should thus cover both the tracking/traceability of the product all along the processing, distribution and marketing chain, as well as the proper tracking of the documentation and control of the quantity concerned (FAO, 2005a).

Ciguatera. Poisoning from consumption of some tropical fish which have accumulated a toxin (poison) produced by their food (coral, algae). Provokes disruptions of the nervous and muscular system and may result in death.

Civil society. A voluntary and informal grouping of people around shared interests, purposes and values. In theory, its institutional forms are distinct from those of the state, family and market; though in practice, the boundaries between state, civil society, family and market are often complex, blurred and negotiated. Civil society commonly embraces a diversity of spaces, actors and institutional forms, varying in their degree of formality, autonomy and power. Civil societies are often populated by organizations such as registered charities, development non-governmental organizations, community groups, women's organizations, faith-based organizations, professional associations, trade unions, self-help groups, social movements, business associations, coalitions and advocacy groups (slightly adapted from The London School of Economics Centre for Civil Society. http://www.lse.ac.uk/collections/CCS/).

CITES. Convention on International Trade in Endangered Species of Flora and Fauna (www.cites.org).

Climate change. Variation in the Earth's global climate or in regional climates over time. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years. These changes can be caused by dynamic process on Earth, external forces including variations in sunlight intensity and more recently by human activities.

Co-management. A process of management in which government shares power with resource users, with each given specific rights and responsibilities relating to information and decision-making (OECD, 1996). A partnership arrangement in which government, the community of local resource users (fishers), external agents (non-governmental organizations, research institutions), and sometimes other fisheries and coastal resource stakeholders (boat owners, fish traders, credit agencies or money lenders, tourism industry, etc.) share the responsibility and authority for decision-making over the management of a fishery (Berkes *et al*., 2001).

Collapse. Reduction of a stock abundance by fishing and/or other causes to levels at which the production is negligible compared to historical levels. The word is normally used when the decline is sudden compared with the likely timescale of recovery, if any, but is sometimes used melodramatically for any case of overfishing (Cooke, 1984).

Command-and-Control. In relation to policy and management, command-and-control instruments (e.g. mechanisms, laws, measures) rely on prescribing rules and standards and using sanctions to enforce compliance with them (modified from Scialabba [1998]).

Commons. See **common pool resources.**

Common pool resources (or commons). A class of resources systems in which (i) **exclusion** of beneficiaries through physical or institutional means is especially costly if not impossible, even if they do not contribute to its management and undermine the capacity for others to do so and (ii) exploitation by one user reduces resource availability for others

(**subtractability problem**). While a common pool resource system (a fishing ground) can be jointly appropriated (e.g. under a common property regime), the resource units withdrawn from it, for example the catch, are private (combined from Berkes [1989]; Ostrom [1990] and Ostrom *et al*. [1999]).

Common property resources. Resources owned and managed collectively by a community or a group within a community, owned and managed in common (e.g. under a **common property regime**) for the benefit of the community or that particular group. Exclude individual rights. A common property represents *de facto* a **private property** for the co-owners who can exclude all other potential users from use and decision-making (Bromley, 1991) but cannot exclude any of the members of the community. A common property resource is a 'common' for the insiders (which cannot be excluded) while it is a 'property' for the outsiders that are excluded from its use. Also referred to as **communal property resources**.

Communal property resources. See **common property resources.**

Common property regime. A system of established rights, duties, controls and punishments for violations agreed by the user group to ensure equity and avoid overexploitation of a common property resource (modified from Choudhury and Jansen [1999]).

Community. A social group of organisms sharing an environment, normally with shared interests. In human communities, a social group possessing shared beliefs and values, stable membership and the expectation of continued interaction. It can be bounded geographically by political or resource boundaries or socially as a community of individuals with common interests (Berkes *et al*., 2001).

Community quota. A harvest right (portion of a TAC) assigned to a community in a co-management arrangement, so fishers within the community have a major role (perhaps with broader community involvement) in establishing fishery management plans, in allocating the quota to suit the local situation as well as community values and objectives and in regulating their fishing activity. Community quotas defined on a geographical basis, in particular, have the potential to build on local stewardship interests (Charles, this volume).

Confidence interval. The probability, based on statistics, that a number will be between an upper and lower limit (Roberts *et al*., 1995).

Conservation. The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations. Conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment (IUCN/UNEP/WWY, 1980).

Conventional management. The type of management conceived and implemented for large-scale fisheries in the North Sea in the second half of the 20th century. Also called **target resources oriented management** (TROM). Distinguished from **traditional management.**

Criterion. A condition or a fact used as a standard by which something can be judged or considered (http://dictionary.cambridge.org). Elements of the sustainable development reference system (SDRS), the behaviour of which can be described via indicators, proxy-indicators and reference points (FAO, 1999). For example, fishing capacity is a criterion, in the technological dimension, related to fishing pressure. Spawning biomass is a criterion, in the biological

dimension, related to the well-being of the stock. Total income (in cash and in kind) is a criterion, in the economic dimension, related to the well-being of humans in the fishery.

Critical habitat. Specific areas within the geographical range occupied by the species that contain physical or biological features crucial to the survival of the species and hence essential to its conservation and may require special management considerations or protection to maintain such features.

Culture-based fisheries. Fisheries on resources for which the recruitment originates or is supplemented from cultured stocks (the process is called stocking) raising total production beyond the level sustainable through natural processes. Culture-based fisheries may therefore involve the introduction of new species or strains, altering species composition or genetic pools.

Customary marine tenure (CMT). Traditional institutions through which access to inshore marine resources is generally controlled by social units including individuals, families, clans or other kinship-based institutions and villages. These tenure institutions may apply to relatively simple communally owned marine areas from which outsiders are excluded, as well as complex and overlapping systems of individual and family rights to space, species, gear and even specific gears and practices (Cinner, 2005). See also **territorial use rights in fisheries (TURFs).**

Customary rights. Rights of individuals or groups founded upon customary, long continued practices and usage (CIFOR, 1999).

Data-less management. A type of **traditional management** used in data-poor fisheries, the importance of supplementing traditional knowledge with the use of studies on similar fisheries in other locations, including the use of marine protected areas (Johannes, 1998).

Demersal. Living in close relation with the bottom and depending on it. Example: cods, groupers and lobsters are demersal resources. The term 'demersal fish' usually refers to the living mode of the adult.

Deep-sea fisheries. Fisheries carried out in waters deeper than about 400 m are generally considered to be deep-sea fisheries (http://www.ices.dk/marineworld/deepseafish.asp, ICES, 2008). **Deep-sea fisheries in the high seas** are tentatively defined as: Fisheries that (i) occur in areas beyond the limits of national jurisdiction; (ii) take a catch (intended as everything brought up by the gear) that includes species that can only sustain low exploitation rates and (iii) use fishing gear that is likely to contact the seafloor during the normal course of fishing operations (FAO, 2008c).

Decentralization. The dispersion, distribution, delegation of functions and powers from a central authority to regional and local authorities (not nominated by the central authority) (Merriam Webster online dictionary). See also **devolution.**

Decision analysis. A formal analysis to aid decision-making in the face of uncertainty. A decision analysis usually evaluates the expected outcomes (e.g. average catch, constancy of catch and probability of rebuilding to a given biomass target) of alternative management controls. A decision analysis can also address management consequences under different plausible assumptions about the status of the stock (Kim, 1992).

Decommissioning. The formal process to remove a fishing vessel from operational status to terminate its career. See **buy-back.**

Density dependence. The dependence of a factor influencing population dynamics (such as survival rate or reproductive success) on population density. The effect is usually in the direction that contributes to the regulative capacity of a stock (Cooke, 1984).

Development. In the context of ecologically sustainable development, progress towards desirable results rather than growth itself (Australian Government Publishing Service, 1991). See **fishery development.**

Devolution. Transference (as of rights, powers, property or responsibility) to another especially the surrender of powers to local authorities by a central government (Merriam Webster online dictionary). See also **decentralization**.

Dimension. The dimensions of a fishery system are 'the classes used to describe a system and cluster its components' (modified from FAO [1999]). The sustainable development framework, for example, has biological, ecological, technological, economic, social and institutional/legal dimensions. These might be grouped into the two main dimensions of sustainable development: human and environmental, also referred to as subsystems. The Pressure-State-Response framework developed and proposed by the United Nations has three explicit dimensions.

Discards. To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Discounting. Determining the present value (net worth) of assets by applying a discount rate to the expected net benefits from future uses of those assets. The discount rate reflects the social preferences for current (as compared with future) uses (United Nations, 1997).

Ecologically sustainable development (ESD). Using and conserving the community's resources so that the ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased. See also **sustainable development**.

Economic efficiency. A measure of how well economic inputs (capital, labour, etc.) are combined to produce a given output. Economic efficiency is maximized when inputs are combined so as to produce the required output at minimum cost (Australian Government Publishing Service, 1991). See **efficiency.**

Economic exclusion. Leaving individuals out of a particular economic activity, for example fishing activity, because of their economic or financial inability to access the capital, the factor of production necessary to enter and/or operate this activity (Bene, 2003, p. 960).

Economic overfishing. Occurs when a fishery is generating no economic rent, primarily because an excessive level of fishing effort is applied in the fishery. Economic overfishing does not always imply biological overfishing.

Ecotourism. Travel undertaken to witness the unique natural or ecological quality of particular sites or regions, including the provision of services to facilitate such travel (United Nations, 1997).

Ecosystem. A spatio-temporal system of the biosphere, including its living components (plants, animals, micro-organisms) and the non-living components of their environment, with their relationships, as determined by past and present environmental forcing functions and interactions amongst biota.

Ecosystem approach to fisheries (EAF). An approach to fisheries management and development that strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. The purpose of EAF is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems (FAO, 2003).

Ecosystem goods and services. Material (goods) and non-material (services) commodities produced by the ecosystem that yield positive utility. Examples include food and revenues as goods and storm protection or aesthetic landscapes as services (modified from Sutinen [2000]). The nature of these goods and services may be related to **economics** (e.g. fish catch and revenues), **food security** (e.g. subsistence, barter trade), **recreation** (e.g. sport fishing, snorkelling), **aesthetics** (e.g. watersheds, coastal or underwater landscapes, aquarium resources), **natural protection** (from storms, tsunamis) or cultural (traditions, taboos and livelihoods), and **conservation** (of species or genetic pools).

Ecosystem overfishing. Occurs when the historical species balance (composition and dominance) is significantly modified by fishing (e.g. with reductions of large, long-lived, demersal predators and increase of small, short-lived species at lower trophic levels). The process by which fishing is so intense as to alter the balance of species on the fishing grounds, with some species increasing but failing to replace the depleted ones (Pauly, 1998).

Effective fishing effort (F/q). Fishing effort adjusted, when necessary, so that each increase in the adjusted unit causes a proportional increase in instantaneous rate of fishing (Ricker, 1975). Measures of fishing effort such as hooks per day of fishing that have been standardized so that the measure is proportional to the fishing mortality rate that the gear(s) impose on the stock of fish. Controls purported to limit effective effort imply that the fishing mortality rate will thereby be limited (Restrepo, 1999).

Efficiency. When facing multiple objectives or conflicting interests, a decision or policy is considered 'efficient' or 'Pareto optimal' when no alternatives exist that could improve the degree of fulfilment of an objective or the satisfaction of an interest without compromising the others. Efficiency is a condition of optimality but should not be confused with it (Garcia and Boncoeur, 2007). See **economic efficiency**.

Empirical knowledge. Knowledge derived from experiment and observation rather than theory. See **traditional ecological knowledge; local ecological knowledge.**

Empowerment. The process of enhancing an individual's or group's capacity to make purposive choices and to transform those choices into desired actions and outcomes. Effective participation, after appropriate capacity-building, can bring about empowerment. Antonym: **disempowerment**. The term is commonly used to indicate both *an outcome*, in which a person or group enjoys a state of empowerment, and *a process*, an action that moves a group or person from a lower to a higher state of empowerment. (Alsop, Bertelsen and Holland 2006)

Enforcement. The act of enforcing; ensuring observance of or obedience to laws, rules and norms.

Equilibrium. A situation which exists after the specified conditions (e.g. fishing pressure, environmental conditions and population parameters such as growth, mortality and recruitment)

have been in effect long enough to affect all ages for the whole exploited life and the system, while probably varying in the short-term, will therefore remain essentially unchanged with time. Also referred to as **steady state.**

Eutrophication. Generally, the natural or man-induced process by which a body of water becomes enriched in dissolved mineral nutrients (particularly phosphorus and nitrogen) that stimulate the growth of aquatic plants and enhance organic production of the water body. Excessive enrichment may result in the depletion of dissolved oxygen and eventually to species mortality and replacements.

Equity. A principle of stewardship. In fisheries and environmental management, equity relates to fairness, justice, impartiality and freedom from bias or favouritism (e.g. in the allocation of rights or determination of claims). It requires that similar options be available to all parties. It is an important factor of compliance. See **inter-generational equity** (Garcia and Boncoeur, 2007).

Exclusion. The ability to exclude people other than the members of a defined group (Berkes, 2006). Exclusion may be intended (e.g. in a limited entry or ITQ programme or in a no-take zone) or unintended (e.g. as a result of poverty).

Exclusive economic zone (EEZ). Area adjacent to a coastal state which encompasses all waters between (a) the seaward boundary of that state, (b) a line on which each point is 200 nautical miles (370.40 km) from the baseline from which the territorial sea of the coastal state is measured (except when other international boundaries need to be accommodated) and (c) the maritime boundaries agreed between that state and the neighbouring states.

Externality. Unintended harmful or beneficial effects incurred by a party that is not directly involved with production or consumption of the commodity in question (Sutinen, 2000).

Extinction. The total disappearance of a species. In addition to the presence of an external threat (e.g. fishing) the risk of extinction of a species depends on its population demographics, biological characteristics, such as body size, trophic level, life cycle, breeding structure or social structure requirements for successful reproduction, vulnerability due to aggregating habits, natural fluctuations in population size (dimensions of time and magnitude) and residency/migratory patterns.

Fecundity. In general, the potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity usually increases with age and size. The information is used to compute stock or population spawning potential.

Fishers. A word commonly used to describe any male or female engaged in any aspect of the fishing activity.

Fishery-independent survey. Sampling, collecting, observing, or surveying the fish or fishery resources undertaken without the use of commercial fishery vessels or data. They are usually undertaken on board of scientific research vessels, to increase scientific knowledge of the fishery resources or their environment, or to test a hypothesis as part of a planned, directed investigation or study conducted according to methodologies generally accepted as appropriate for scientific research (modified from US Department of Commerce, 1996). Also called **scientific survey.**

Fishery laws. The set of laws that affect the administration and set the rules for the fishery sector. They can be specific to the sector or not. **Fishery-specific laws** constitute the legislation of direct application to fisheries. Usually organized in a Fisheries Act or Code, they are the principal identifiable and overarching national instrument governing fishery matters. They are usually implemented through **subsidiary legislation** such as regulations, decrees, by-laws and administrative orders. **Non-fishery-specific laws** such as the national Constitution, local government laws, veterinary, environmental or health legislation impact fisheries indirectly (based on Kuemlangan, this volume).

Fishery development. Increasing welfare of fishing communities, fishworkers and society at large through (a) higher productivity in the harvesting, processing, distribution and marketing of fish through technological improvements and more efficient institutional and organizational arrangements; (b) higher productivity of human resources through better education, health services and social amenities and (c) more secure lives through better insurance and protection from economic shocks, accidents, and man-made and natural catastrophes and disasters.

Fishery management. The integrated process of information gathering, analysis, planning, decision-making, allocation of resources and formulation and enforcement of fishery regulations by which the fishery management authority controls the present and future behaviour of interested parties in the fisheries, in order to ensure the continued productivity of the living resources (FAO, 1995).

Fishery management plan. See **management plan**.

Fishery manager. The executive head of the entity charged with the responsibility of general fisheries management. The head of a division or section charged with managing a specific fishery. In modern, participative management systems, the 'manager' is often, in practice, a team, working in close collaboration.

Fishing capacity. (1) The potential fishing effort that could be exerted in a fishery, over a period of time (year, season) if all fishers are participating and all vessels and gear are fully used. (2) The maximum amount of fish that could be taken in a fishery or by a single fishing unit (e.g. a fisher, community, vessel or fleet) over a period of time (season, year), given the biomass and age structure of the fish stock and the present state of the technology, in the absence of any regulated catch limitations and if the means available are fully used (adapted from FAO [1998b]).

Fishing effort. The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time, for example hours trawled per day, number of hooks set per day or number of hauls of a beach seine per day. When two or more kinds of gear are used, the respective efforts must be adjusted to some standard type before being added (FAO, 1997).

Fishing mortality (F). A mathematical expression of the part of the total rate of deaths of fish due to fishing. Fishing mortality is often expressed as a rate that indicates the percentage of the population caught in a year (modified from Commonwealth of Australia [1997]).

Food security. A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Antonym: **food insecurity.**

Food insecurity. Situation characterized by the fact that people do not have access to a sufficient amount of safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food insecurity may stem from insufficiency in food availability and/or buying power or problems of food distribution. It can be chronic, seasonal or temporary.

Free rider. Someone who enjoys benefits of a common resource, or of other people's effort, without sharing the costs reducing the benefits of legitimate users. Examples: a foreign vessel exploiting the resources of an EEZ resource without payment to the state. A vessel fishing in an area under control by an RFMO without complying with the legal management regulations.

Generation length. Generation length is the average age of parents of the current cohort (i.e. newborn individuals in the population). Generation length therefore reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual, except in taxa that breed only once. Where generation length varies under threat, the more natural, that is predisturbance, generation length should be used as the standard index (IUCN, http://www.iucnredlist.org/info/categories_criteria2001#definitions).

Ghost fishing. The capture of aquatic organisms by lost or abandoned gear (Bjordal, this volume).

Globalization. Often understood as a movement toward greater economic, political and cultural integration across nations. Commonly associated with 'space-time' compression (Leichenko and O'Brien, 2008). To be distinguished from **internationalization** (e.g. of a business operating worldwide) that recognizes the existence of different peoples, cultures, languages, nations, borders, economies and ecosystems (compiled from different sources. FAO Glossary [2008a]).

Goal. An aim or desired result. The end toward which effort is directed (Compact Oxford English Dictionary; Merriam Webster online dictionary). Synonyms: **aim**.

Good governance. Governance that is participatory, transparent and accountable. Here transparency refers to openness, the free availability of information, decisions and plans and the use of language that stakeholders can understand. Accountability means that people who make the decisions should be available to answer to the people who are affected by the decisions (United Nations, 2008).

Governance. Many definitions are available in the FAO Glossary, 2008a. For example:

1. The whole of public and private interactions taken to solve problems and societal opportunities. It includes the formulation and application of principles guiding those interactions and care for institutions that enable them. (Kooiman *et al*., 2005).
2. The formal and informal arrangements, institutions, and mores which determine how resources or an environment are utilized, how problems and opportunities are evaluated and analysed, what behaviour is deemed acceptable or forbidden, and what rules and sanctions are applied to affect the pattern of resource and environmental use. (Sutinen, 2000).

Growth overfishing. Occurs when too many small fish are being harvested too early, through excessive fishing effort and poor selectivity (e.g. too small mesh sizes) and the fish

are not given enough time to grow to the size at which the maximum yield-per-recruit from the stock would be obtained. A reduction of fishing mortality on juveniles, or their outright protection, would lead to an increase in yield from the fishery.

Harvest control rule (HCR). A rule that describes how harvest is intended to be controlled by management in relation to the state of some indicator of stock status. For example, a harvest control rule can describe the various values of fishing mortality which will be aimed at for various values of the stock abundance. It formalizes and summarizes a management strategy. Constant catch and constant fishing mortality are two types of simple harvest control rules (Restrepo, 1999). Also referred to sometimes as a **harvest strategy** or **harvest control law**.

High grading. The discarding of a portion of a vessel's legal catch that could have been sold, so that a higher or larger grade of fish can be subsequently caught that brings higher prices. This may occur in any fishery, but the incentive to do so is particularly great with catch limitations for example individual catch quotas (adapted from Gough and Kenchington [1995]).

High seas. Waters beyond the areas of national jurisdiction (which can be 200 miles or less).

Hydrothermal vents. A fissure in the earth's surface from which geothermally heated water issues. Hydrothermal vents are commonly found near volcanically active places, areas where tectonic plates are moving apart, ocean basins and hotspots. Relative to the majority of the deep sea, the areas around submarine hydrothermal vents are biologically more productive, often hosting complex communities fuelled by the chemicals dissolved in the vent fluids (including giant tube worms, clams and shrimp) (Wikipedia, 2008).

Hyperstability. A phenomenon whereby the continued re-aggregation of fish as abundance decreases maintains high catch rates and therefore can obscure the decline in the population as a whole until its abundance is very low and the risk of collapse high.

Incentives. Something which encourages a person to do something. In economics, any factor (financial or non-financial) that provides a motive for a particular course of action or counts as a reason for preferring one choice to the alternatives. Depending on the different ways in which they motivate agents to take a particular course of action, incentives may be classified as remunerative (or financial), moral or coercive (based on Wikipedia [2008]).

Incidental catch. See **bycatch.**

Indicator. A signal of processes, inputs, outputs, effects, results, outcomes, impacts, etc. that enable such phenomena to be judged or measured (Choudhury and Jansen, 1999). It is a variable, pointer or index. Its fluctuations reveal the variations in key elements of a system. Its position and trend in relation to reference points or values indicates the present state and dynamics of the system components (FAO, 1999). The selection of indicators is strongly dependent on management objectives.

Individual transferable quota (ITQ). A right to harvest a particular amount of resources that can be transferred, for example by sale, lease or will. A type of quota (a part of a total allowable catch) allocated to individual fishermen or vessel owners and which can be sold to others (NRC, 1999).

Illegal fishing. Refers to activities (i) conducted by national or foreign vessels in waters under the jurisdiction of a state, without the permission of that state or in contravention of

its laws and regulations; (ii) conducted by vessels flying the flag of states that are parties to a relevant regional fisheries management organization but operate in contravention of the conservation and management measures adopted by that organization and by which the states are bound, or relevant provisions of the applicable international law or (iii) in violation of national laws or international obligations, including those undertaken by cooperating states to a relevant regional fisheries management organization. See also **unreported fishing; unregulated fishing; IUU.**

Input controls. Management instruments used to control the time and place as well as type and/or amount of fishing with the view to limit yields and fishing mortality; for example restrictions on type and quantity of gear, effort and capacity; closed seasons.

Institution. Socially constructed codes of conduct (rules and norms) that define practices, assign roles and guide interactions. This definition of institutions, as the set of rules actually used, is different from the common use of the term generally to mean agencies (Berkes, this volume).

Institutional framework. The range of institutions that together form the decision-making environment, so helping to shape broad policies and specific instruments for governing fisheries. It includes particular organizations and the system of beliefs, law, science and social organization that legitimize, inform and uphold the fishery, as well as the outputs in the form of rights, responsibilities and regulations (Symes, 2007). They are in effect social constructs that give structure, order and predictability to human relations and interactions (Jentoft, 2005).

Interest group. A group of persons having a common identifying interest that often provides a basis for action (Merriam Webster online dictionary).

Inter-generational equity. Requires that future generations be given the same opportunity as the present ones to decide on how to use the resources. It can be sought through avoidance of actions that are not potentially reversible on some agreed timescale (e.g. a human generation), consideration of long-term consequences in decision-making and rehabilitation of degraded physical and biological environments (Garcia and Boncoeur, 2007).

ITQ. See **individual transferable quota**.

IUU. Illegal, unreported and unregulated fishing. See **illegal fishing, unreported fishing,** and **unregulated fishing.**

Keystone species. A strongly interacting species whose top-down effect on species diversity and competition is large relative to its biomass dominance within a functional group. This operational definition links the community importance of keystone species to a specific ecosystem process, for example their role in regulation of species diversity at lower trophic levels that are structured by competition for a limited resource (Davic, 2003).

Kinship. State of relatedness or connection by blood, marriage or adoption. A term used to designate entities of common genealogical origin, whether biological, cultural or historical descent. Kinship is one of the most basic principles for organizing individuals into social groups, roles and categories. The kinship system includes people related both by descent and marriage.

Limited entry. Fishery where the number of operators (and size of boats) is restricted through license limitation or quota systems to control the amount of fishing effort. It frequently involves controls on the number and size of vessels and conditions relating to the

transfer of fishing rights or the replacement of vessels (modified from Commonwealth of Australia [1997]).

Livelihood. Individuals, households or groups making a living, attempting to meet their various economic necessities, coping with uncertainties and responding to new opportunities. (de Haan and Zoomers, 2005). A means of securing the necessities of life. A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future while not undermining the natural resource base (adapted from Chambers and Conway [1992]).

Local ecological knowledge (LEK). A form of fisher's ecological knowledge that does not have the same historical and multigenerational character as **traditional ecological knowledge** (Berkes, this volume).

Malthusian overfishing. Is what occurs when poor fishermen faced with declining catches and lacking other alternative sources of livelihood overfish the resources, potentially to the point of collapse, in their effort to maintain their incomes (Pauly, 1988).

Management constituency. The group of people, bound by shared structures, interests and goals, from whom the fishery management authority hopes to attract consensus, support and collaboration (Constructed from a generic Wikipedia definition).

Management measures. The measures designed to achieve particular management goals include **technical measures, input–output controls** and **socio-economic incentives.**

Management plan. An explicit arrangement (contract) between the interested parties and the fisheries management authority which makes explicit the objectives and means of management, the nature of the management authority, its powers and responsibilities, its working and consultation procedures, as well as the rights and responsibilities of the interested parties in the fishery (FAO, 1995).

Management procedure (MP). The combination of pre-defined data, together with an algorithm to which such data are input, to provide a value for a TAC or effort control measure; this combination should have been demonstrated, through simulation trials, to show robust performance in the presence of uncertainties. Additional rules may be included, for example to spread a TAC spatially to cater for uncertainty about stock structure (Radmeyer, Plagànyi, and Butterworth, 2007). See also **operational management procedure (OMP).**

Management strategy. The strategy adopted by the management authority to reach established management goals. In addition to the objectives, it includes choices regarding all or some of the following: access rights and allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing) and fishing operations (e.g. calendar, closed areas and seasons).

Manager. See **fishery manager.**

Marginalization. Exclusion from meaningful participation in society, community or fishery and their benefits. Factors of marginalization may include deficiencies in the labour market; poverty; educational, gender or physical handicap; racism and sexual behaviour (Wikipedia, 2008). See **social marginalization**.

Mariculture. Cultivation, management and harvesting of marine or amphidromus organisms in the sea in specially constructed rearing facilities for example cages, pens and long-lines.

For the purpose of FAO statistics, mariculture refers to cultivation of the end product in seawater even though earlier stages in the life cycle of the concerned aquatic organisms may be cultured in brackish or freshwater or captured from the wild. This definition includes farmed fish released in the marine environment for mariculture-based capture fisheries and the weight increments gained by the wild-caught organisms through capture-based aquaculture activities (FAO Glossary of Aquaculture, 2008a).

Marine protected area (MPA). Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment (Kelleher and Kenchington, 1992; IUCN, 1994).

Marine reserve. Also referred to as **no-take area**. Marine areas in which all extractive activities are prohibited. The purpose is usually conservation of the area with its biodiversity.

Market failure. The inability of the market to allocate resources efficiently (see **efficiency**). The major causes of market failure include (1) imperfect competition (monopoly), (2) imperfect information, (3) public goods, (4) inappropriate government intervention and (5) externalities (Sutinen, 2000). The term was first used by Bator (1958). Market failure can be viewed as a scenario in which individual's pursuit of self-interest leads to bad results for society as a whole (Wikipedia, 2008).

Maximum economic yield (MEY). When relating total revenues from fishing to total fishing effort in a surplus production model, the value of the largest positive difference between total revenues and total costs of fishing (including the coast of labour and capital) with all inputs valued at their opportunity costs.

Maximum sustainable yield (MSY). The highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process. Also referred to sometimes as **potential yield.**

Monitoring, control and surveillance (MCS). An integrated set of functions of a technical (data collection), legislative (enacting of instruments) and policing (enforcement) nature, essential for the effective implementation of fishery development and management plans. **Monitoring** includes the collection, measurement and analysis of fishing activity including, but not limited to, catch, species composition, fishing effort, bycatch, discards, area of operations, etc. **Control** involves the specification of the terms and conditions under which resources can be harvested. These specifications are normally contained in national fisheries legislation and other arrangements that might be nationally, sub-regionally or regionally agreed. **Surveillance** involves the regulation and supervision of fishing activity to ensure that national legislation and terms, conditions of access and management measures are observed (Flewwelling *et al.*, 2003).

Moratorium. A mandatory cessation of fishing activities on a species (e.g. the blue whale), in an area (e.g. a sanctuary), with a particular gear (e.g. large scale driftnets) and for a specified period of time (temporary, definitive, seasonal or related to re-opening criteria).

Multistakeholder process. A process of consultation, assessment or decision-making that brings stakeholders (including government agencies) together. A tool for public participation in fisheries administration which may or may not involve delegation of decisional power

(**empowerment**). **Co-management** is a multistakeholder process but one that involves the sharing of decision-making power and responsibilities (based on Berkes, this volume).

No-take MPA. A type of marine protected area in which any extractive activity is strictly prohibited. Equivalent to a **marine reserve**.

Natural mortality (M). Deaths of fish from all causes except fishing (e.g. ageing, predation, cannibalism, disease and perhaps increasingly pollution). It is often expressed as a rate that indicates the percentage of fish dying in a year; for example, a natural mortality rate of 0.2 implies that approximately 20% of the population will die in a year from causes other than fishing.

Net present value (NPV). The value of an investment calculated by adding the present value of expected future cash flows to the initial cost of the investment; the difference between the cost of an investment and the discounted present value of all future earnings from that investment. If the net present value is positive, the investment should be made (unless an even better investment exists) otherwise it should not (Webster's New Millennium Dictionary of English, 2008).

Nursery habitat or area. Habitat used by the juveniles of a particular species that contributes a greater than average number of individuals and large numbers of juveniles to the adult population on a per-unit-area basis as compared to other habitats used by juveniles.

Open access. A condition of a fishery in which anyone who wishes to fish may do so. The access to the resource is free to all because there is no ownership of the resource. This condition should not be confused with '**common property**', a form of communal ownership of the resource and control of the access to it (Charles, this volume).

Operational management procedure (OMP). A management procedure (MP) that has been implemented in contrast to the ones that are conceptual only (Radmeyer, Plagànyi, and Butterworth, 2007).

Opportunity cost. The benefit foregone by using a scarce resource for one purpose instead of its next best alternative. Typically applied to capital and labour inputs to reflect their real costs to society as against their costs to a private entrepreneur which may be lower or higher because of subsidies, taxes and various kinds of market distortions (Gittinger, 1992). An amount a fisherman could earn for his time and investment in another business or occupation (Roberts, 1995).

Optimum sustainable yield (OSY). The amount of sustainable yield corresponding to the greatest overall long-term benefits to the nation in environmental, biological, social and economic terms. Its value depends on the relative weights attached to the sometimes conflicting objectives concerning food, revenues, employment, recreation, etc., and to the bio-ecological conservation constraints (e.g. spawning stock size, environmental impact). It also depends on discount rates. In relation to LOSC, it corresponds to the concept of 'MSY' as modified by any relevant economic, social or ecological factor'. See **optimum yield.**

Optimum yield (OY). A deliberate melding of biological, economic, social, and political values designed to produce the maximum benefit to society from a stock of fish (Roedel, 1975).

Output controls. Management instruments aimed at controlling the characteristics of the catch and landings. This is achieved by (i) limiting catch or landings through total allowable catch (TAC) and quotas; (ii) prohibiting the landing of protected species, certain sizes,

a given sex, or animals at a particular stage of the breeding cycle; (iii) regulating discards and/or (iv) establishing limits for the daily bag and possession. See also **harvest control rules, catch quotas.**

Overexploitation. See **overfishing**

Overfishing. A generic term used to refer to the state of a stock subject to a level of fishing effort or fishing mortality such that a reduction of effort would, in the medium term, lead to an increase in the total catch. Often referred to as **overexploitation** and equated to **biological overfishing**, it results from a combination of **growth overfishing** and **recruitment overfishing** and occurs often together with **ecosystem overfishing** and **economic overfishing.**

Ownership. See **property.**

Parties. The states parties to an agreement are those states which have consented to be bound by this agreement and for which the agreement is in force (1995 UN Fish Stock Agreement, Article 1.2).

Participatory management. Any form of management involving a degree of stakeholder participation. Co-management is a specific form of participatory management in which there is a sharing of decision-making power between the state and the stakeholders.

Partnership management. A form of participatory management undertaken in common between the state and the fishers (hence with some transfer of power to fishers) under some form of contractual arrangement. **Co-management** is a form of partnership management. See also **participatory management.**

Passive fishing gear. A fishing gear that catches fish as a result of the movement of the fish towards the gear (e.g. a gillnet, pot or trap). The gear is stationary. However, drift nets are considered as passive gears as the capture results essentially from the movement of the fish.

Pelagic fish. Fish that spend most of their life swimming in the water column with little contact with or dependency on the bottom. Usually refers to the adult stage of a species.

Personal right. A right that is attached to a person (e.g. a fisher) rather than on a thing (e.g. a fish resource). This right is based on one's status as an individual and does not derive from property (Merriam Webster Dictionary of Law, 1996). The personal right (e.g. a use right, a quota) is one that is exercised upon something (e.g. the resource) through a personal obligation exercised on a third party (the state) who stands between the holder of the right (e.g. the fisher) and the property. The purpose of personal rights is not alienation of the property but rather an authorization to use it under certain conditions. *The effective purpose of a personal right is obligation, whether deriving from a contract, a quasi-contract, an offence, a quasi-offence or from the law* (translated from Demolombe [1850]).

Policy. The definite course or method of action, selected from among alternatives, by a government or its mandated fisheries authority, in light of given conditions including legal and constitutional constraints to guide and determine present and future development and management actions towards satisfaction of agreed objectives (adapted from Merriam Webster Dictionary).

Port states. States to which fishing ports and landing places belong. These states have duties and responsibilities in the control of fishing vessels landing in their ports. A port state has the right and the duty to take measures to promote the effectiveness of conservation and

management. It may, *inter alia*, inspect documents, fishing gear and catch on board fishing vessels, when such vessels are voluntarily in its ports or at its offshore terminals. It may adopt regulations empowering the relevant national authorities to prohibit landings and transhipments where it has been established that the catch has been taken in a manner which undermines the effectiveness of conservation and management measures on the high seas (1995 UN Fish Stock Agreement, Article 23).

Positivism. A philosophy that states that the only authentic knowledge is scientific knowledge and that such knowledge can only come from positive affirmation of theories through strict scientific method. It was developed by Auguste Comte (widely regarded as the first sociologist) in the middle of the 19th century (Wikipedia, 2008).

Private property. A situation in which an individual or a corporation has the right to exclude others and to regulate the use of the resource.

Privatization. A wide variety of activities by which some public entity conveys property rights to one or several private entities – everything from outright giveaways or sales of public resources to licences or concessions. Privatization can but need not be total (Cole, 2000).

Precautionary approach to fisheries (PAF). The precautionary approach involves the application of prudent foresight, taking account of the uncertainties in fisheries systems and the need to take action with incomplete knowledge. It requires, *inter alia* (i) consideration of the needs of future generations and avoidance of changes that are not potentially reversible; (ii) prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly; (iii) that any necessary corrective measures are initiated without delay, and that they should achieve their purpose promptly, on a timescale not exceeding two or three decades; (iv) that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource; (v) that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource and that increases in capacity should be further contained when resource productivity is highly uncertain; (vi) all fishing activities must have prior management authorization and be subject to periodic review; (viii) an established legal and institutional framework for fishery management, within which management plans that implement the above points are instituted for each fishery and (ix) appropriate placement of the burden of proof by adhering to the requirements above (FAO, 1996, para 6).

Precautionary principle. In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (United Nations, 1992).

Productivity. For a fish stock, relates to the birth, growth and death rates of a stock. A highly productive stock is characterized by high birth, growth and mortality rates, and as a consequence, a high turn-over and production to biomass ratio (P/B). Such stocks can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive stocks.

Property. Refers both to the physical object to which various legal rights, privileges, etc., are attached and to the legal interest (or aggregate of legal relations) appertaining to such a physical object (Honoré, 1961).

Property right.

1. A type of resource **ownership** by an individual, a group (communal rights and common property) or the state (state property and public property). Property refers to a 'bundle' of rights including (1) access – the right to enter and enjoy non-subtractive benefits; (2) withdrawal – the right to harvest and subtract; (3) management – the right to regulate; (4) exclusion – the right to defend the property and (5) alienation – the right to transfer, lease, sell all or part of this bundle of rights. Some of these rights may be further subdivided. The granting or acquisition of all five main rights characterizes full property or **ownership** (Ostrom, 2000).
2. In Roman Law, property rights compound the right to use a tangible or intangible asset (*usus*), the right to harvest and appropriate the returns from the asset (*fructus*) and the right to give, sell and destroy the asset or its returns (*abusus*). The last of these is the foundation of complete ownership. Since these rights are opposable to anyone, they are absolute property rights. Any one or more of the first three rights (access, management and exclusion or *usus*, *fructus* and *abusus*) may be transferred. The concept of usufruct (*usufructus*) defined as the right of using the returns of someone else's asset is also potentially useful in fisheries. Full ownership will only be transferred if all four absolute rights are transferred together (Kerrest, 2002).

Property rights regime. There are four distinct types of property regimes: private (*Res privatae*), common (*Res communis*), State (*Res publicae*) and non-property regimes (*Res nullius*, open access). Property rights regimes in real life often combine features from these four ideal types (Bromley, 1991).

Public goods. Or **public resources.** Resources that can be simultaneously utilized by many users without reduction of their availability to others (non-subtractive, non-competitive and non-rival use). Examples: a maritime landscape; Internet. A public good cannot, in principle, be appropriated although its use could lead to saturation. Attempts to appropriate it often lead to conflict. Whether a resource is public or common depends on the type of use. A coastal area may be considered a public resource system for a set of 'non-consumptive' uses (e.g. conservation, diving, bathing, scientific observations) and a common resource for other uses (e.g. fisheries and aquaculture) (Garcia and Boncoeur, 2007). Antonym: **private goods.**

Public ownership. A situation in which the property (and the mandate for management of a common resource) is vested in the state.

Quota. A share of the total allowable catch (TAC) allocated to an operating unit such as a country, a vessel, a company or an individual fisherman (individual quota) depending on the system of allocation. Quotas may or may not be transferable, inheritable and tradable. While generally used to allocate total allowable catch, quotas could be used also to allocate fishing effort or biomass.

Real right. A right that is attached to a thing (e.g. a property) rather than a person (e.g. the farmer) (derived from Merriam Webster Dictionary of Law, 1996). A right that the owner can exert directly upon the property, making use of it. Different from **personal right.**

Recruitment. The number of fish added to the exploitable stock, in the fishing area, each year, through a process of growth (i.e. the fish grows to a size where it becomes catchable) or migration (i.e. the fish moves into the fishing area).

Recruitment effect. In a marine protected area, the net export of eggs/larvae from inside the MPA to outside it.

Recruitment overfishing. A situation in which the rate of fishing is (or has been) such that annual recruitment to the exploitable stock has become significantly reduced. The situation is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year. If prolonged, recruitment overfishing can lead to stock collapse, particularly under unfavourable environmental conditions (Restrepo, 1999).

Reductionism. (1) An approach to understanding the nature of complex things by reducing them to the interactions of their parts or to simpler or more fundamental things. (2) A philosophical position that a complex system is nothing but the sum of its parts and that an account of it can be reduced to accounts of individual constituents. The term may be applied to objects, phenomena, explanations, theories and meanings (Wikipedia, 2008).

Reference direction. A particular trend (qualitative change) of a fishery indicator that corresponds to a change considered as desirable (i.e. aiming in the right direction) and can be used as a guide for fisheries management. Example: aim to increase biomass at 2% per year.

Reference point. Also referred to as **reference value.** (1) A particular state (value) of a fishery indicator corresponding to a situation considered as desirable (target reference point [TRP]), dangerous (threshold reference point [ThRP]) or undesirable (limit reference point [LRP]). Both ThRPs and LRPs require immediate action and differ in the degree of urgency. (2) An estimated value derived from an agreed scientific procedure and/or model, which corresponds to a specific state of the resource and of the fishery and that can be used as a guide for fisheries management. Reference points may be general (applicable to many stocks) or stock specific (Garcia, 1997).

Regime shift. In complex system dynamics, a rather rapid and durable (medium to long term) change in the parameters characterizing a state and properties of the system (structure, functions and relations). In fisheries, the term is most often used in reference to a medium- to long-term modification in environmental conditions that impacts the productivity of a stock, several stocks or an ecosystem.

Rent. In a fishery, the difference between the total revenues obtained from the fishery resource and the total costs of production, that is capital and labour valued at their opportunity costs (see **opportunity costs**). The total costs of production include a reasonable profit and the rent is often considered as a 'surplus' profit, over and above what would be considered a 'normal' rate of return. For this reason, the decision as to who gets the rent (e.g. the society, the management authority or the fishermen) remains a key policy issue.

Rent seeking. The use of resources in an attempt to gain control over artificially created monopoly situations.

Res communis. A thing which belongs to a group of persons, may be used by every member of the group, but cannot be appropriated by anyone. Should not be confused with non-property (or res nullius) in which resources have no owner until they have been captured. (Kerrest, 2002). Sometimes referred to as **Res communes**. See also **common property.**

Resilience. The capacity of a system to absorb disturbance and reorganize while undergoing change so as still to retain essentially the same function, structure, identity and feedbacks (Holling, 1973; Walker *et al*., 2004).

Res nullius. A thing which does not belong to anybody and may be appropriated by anybody. See **commons; common property resources.**

Resource. A natural good turned into a commodity. Example: fishery resource. The meaning may be updated to include ecosystem services and human well-being (MA, 2005; Berkes this volume).

Restocking. The release of cultured or wild caught aquatic species (usually juveniles) into the wild to restore the spawning biomass of severely overfished stocks to levels at which they can once again provide sustainable yields (FAO Aquaculture Glossary, 2008b). See **stocking.**

Restrictive licensing. Also called **limited entry**. Effort management consisting of some form of restriction of access to the fish that limits the total number (or tonnage) of vessels as well as their fishing power. Range from basic registration and payment of administrative registration fees to effective limitation of the number of fishers, vessels or total fleet capacity.

Right. The ability of the claimant to call upon others without such claims to acknowledge their duty to honour the claim with any violation of such duty sanctioned by the state or an authority. It is a capacity (of the right holder) to control, with the assent and assistance of the state, the action of the others (from Kuemlangan, this volume). See **property right.**

Risk. A term used with many different meanings: (1) the magnitude of a hazard and the probability of its occurrence (Nash and Nash, 1995 in Choudhury and Jansen, 1999), (2) a measure of the probability that damage to life, health and property, and/or the environment will occur as a result of a given hazard, and the magnitude of the consequences of the effect occurring (ISO, 1996 according to Choudhury and Jansen 1999).

Robustness. (1) For a fish population, the capacity to persist in the presence of fishing or other negative impact. This depends on the existence of compensatory mechanisms (Cooke, 1984). (2) For a statistical procedure or mathematical model, the property of being relatively insensitive to errors in model formulation or parameters estimates.

Seamount. A large isolated elevation characteristically of conical form. Seamounts are undersea mountains whose summits lie beneath the ocean waves. They are usually volcanic in origin and are generally defined as having an elevation of greater than 1000 m from the seabed.

Scenario. A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technology change, prices) and relationships. Scenarios are neither predictions nor projections and sometimes may be based on a 'narrative storyline.' Scenarios may be derived from projections but are often based on additional information from other sources (Alcamo *et al*., 2003).

Selectivity. Ability to target and capture fish by size and species during harvesting operations, allowing juvenile fish and non-target species to escape unharmed. In stock assessment, conventionally expressed as a relationship between retention and size (or age) with no reference to survival after escapement.

Self-organization. In complex adaptive systems, the spontaneous emergence of organized structure. In adaptive co-management, self-organization involves the emergence of actors working in a collaborative and creative process, often drawing on a range of knowledge sources and ideas, to resolve issues and move forward in response to disturbance (Armitage *et al*., 2007).

Self-regulation. The ability of a defined group of players (fishers; fish processing companies and so on) to make and enforce their own rules and norms among themselves.

Small-scale fisheries. It tends to imply the use of a relatively small size gear and vessel. The term has sometimes the added connotation of low levels of technology and capital investment per fisher, although that may not always be the case. See **artisanal fisheries.**

Small-scale fisherman or fisher. In developing countries, a fisher or fisherman who: (a) generally fishes inshore and close to his home community and relies on local resources; (b) has limited opportunities for alternative employment; (c) uses small craft and simple gear (though not necessarily simple techniques) and (d) is usually bound by traditional community mores and customs. Also called artisanal fisherman (Christy, 1986). Synonym: **artisanal fishermen.**

Social discount rate. The discount rate used to estimate the social value (or value to the community as a whole) of an enterprise. It is sometimes held that, to reflect social values, the social discount rate should be lower than the discount rate used in the private sector (Smith, 2001).

Social–ecological system. A term used to emphasize the point that social and ecological systems are in fact linked, and that the delineation between social and ecological (and between nature and culture) is artificial and arbitrary. The integrated concept of humans-in-nature (Berkes *et al*., 2001).

Social learning. The collaborative and mutual development and sharing of knowledge by multiple stakeholders through learning-by-doing (Armitage *et al*. 2007).

Social marginalization. Process which leads to the denial of the command over a resource, service or commodities for certain actors based on social criteria such as caste, gender or ethnic origins (Bene, 2003: 961).

Sovereign rights. The rights of independent sovereign states to legislate, manage, exploit and control access to the natural resources under their jurisdiction. They include the right to determine property regimes applicable to those resources. Sovereign rights imply independence and exclusivity. They may be subject to binding conditions, as in the LOSC, where sovereign rights over natural resources are coupled with management and conservation responsibilities. Sovereign rights are not property rights, but they imply the right to establish property regimes. As a consequence, while the LOS Convention does not refer to property rights and has not explicitly required their establishment, it has explicitly given to the states the right to do so (Garcia and Boncoeur, 2007).

Spawning stock biomass per recruit (SSB/R). The expected lifetime contribution to the spawning stock biomass for the average recruit to the fishery. For a given exploitation pattern, rate of growth, maturity schedule and natural mortality, an equilibrium value of SSB/R can be calculated for any level of F. SSB/R decreases monotonically with increasing fishing mortality, F (Restrepo, 1999).

Spawning stock. Mature part of a stock responsible for the reproduction. Strictly speaking, the portion of an overall stock having reached sexual maturity and able to spawn. Often conventionally defined as the number or biomass of all individuals beyond 'age at first maturity' or 'size at first maturity', that is beyond the age or size class in which 50% of the individuals are mature.

Species diversity. The variety of species in a community, which can be expressed quantitatively in ways which reflect both the total number of species present and the extent to which the system is dominated by a small number of species (Australian Government Publishing Service, 1991).

Spill-over effect. In a marine protected area, the net export of adults from inside an MPA to outside it.

Stakeholder. An individual or group of individuals (including fishing communities, commercial fishing entities, governmental and non-governmental institutions, traditional communities, universities, research institutions, development agencies and banks and donors) with an interest or claim (whether stated or implied) who could potentially be impacted by or have an impact on a given project and its objectives (e.g. a fishery management strategy or plan). Stakeholder groups that have a direct or indirect 'stake' can be at the household, community, local, regional, national or international level (adapted from FAO, 1997).

Stakeholder analysis. A process that seeks to identify all of the stakeholders in a fishery and describe their interests. It is considered to be a necessary stage to carry out in establishment and review of participatory management (from Berkes *et al*., 2001).

Standard. A criterion (or indicator, or reference point) that has been formally established and is enforced by an authority, and on the basis of which constraining action can be taken (modified from Garcia 1997). The MSY has been established as a standard by UNCLOS but has since been abundantly criticized if used as a target reference point, by scientists and practitioners. It is, however, still considered as a minimum standard for stock rebuilding, and its nature has been changed from being a target reference point (TRP) to a limit reference point (LRP) through the adoption of the UN Fish Stocks Agreement (UNFSA) and of the Code of Conduct for Responsible Fisheries (CCRF) in 1995. See **indicator.**

Standard of proof. The level of proof that is required. In general, a criminal case must be proved 'beyond all reasonable doubt' (Freestone, 1998).

State property. Exists when the rights to control access, use and regulation are vested exclusively in governments. It is sometimes considered as a form of **common property,** different from the usual one in that it is owned by a very large group of co-owners most of which are located far away from the resource (Ostrom, 1990).

Stochastic. A system that has components affected by random variability. For example, when fishery stock projections are elaborated, future recruitments are projected with a stochastic component (i.e. the values introduced in the projection randomly vary from year to year, within defined limits) (Restrepo, 1999).

Stochastic model. A stochastic model is a model whose behaviour is not fully specified by its form and parameters, but which contains an allowance for unexplained effects which are represented by random variables (Cooke, 1984).

Stock. (1) The part of a fish population which is under consideration from the point of view of actual or potential utilization (Ricker, 1975). (2) A group of individuals in a species occupying a well defined spatial range independent of and more or less genetically isolated from other stocks of the same species. Random dispersal and directed migrations due to seasonal or reproductive activity can occur. Such a group can be regarded as an entity for management

or assessment purposes. Some species form a single stock (e.g. southern bluefin tuna) while others are composed of several stocks (e.g. albacore tuna in the Pacific Ocean comprises separate Northern and Southern stocks). The impact of fishing on a species cannot be reliably determined without knowledge of this stock structure.

Stocking. The practice of putting artificially reared young fish into a sea, lake or river. These are subsequently caught, preferably at a larger size (Cooke, 1994).

Subsidiarity principle. As related to levels of governance, suggests that authority belongs at the lowest level capable of effective action (Sutinen, 2000). The principle is incorporated in the Maastricht Treaty that lays out the framework for establishing the European Community: 'decisions [should be] taken as closely as possible to the citizen'.

Subtractability problem. In a commons system, such as a group of fishers exploiting the same fish stock, each user is potentially capable of subtracting from the welfare of all other users. Hence, the solution to the subtractability problem depends on the ability of social groups to design a variety of mechanisms to regulate resource use among their members (Ostrom, 1990; Berkes, 2006).

Surplus. The difference between the allowable catch in an EEZ and the quantity that the coastal state has the capacity to harvest. According to Article 62.2 of the Law of the Sea Convention, the coastal state must give to other states access to such surplus, selecting them on the basis of criteria given in Paragraph 62.3. (UN LOSC, 1982).

Surplus production model. Mathematical representation of the way a stock of fish responds to the removal of its individuals (e.g. by fishing). In fisheries, usually represented by a relationship between yield and/or catch per unit of effort, and fishing effort or fishing mortality. Examples: the Schaefer and Fox models.

Sustainability. Ability to persist in the long term. Often used as a 'short hand' for sustainable development. Characteristic of resources that are managed so that the natural capital stock is non-declining through time, while production opportunities are maintained for the future (Sutinen, 2000).

Sustainable development. Management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Such sustainable development conserves (land) water, plants and (animal) genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable (FAO, 1989). Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987).

Sustainable development reference systems (SDRS). Graphical summary representations of the conditions of a fishery or a fishing sector in terms of sustainability. It comprises indicators and reference values selected on the basis of the objectives (targets) retained for the system, the constraints within which the system operates, and the limits imposed by nature or society. The sustainability barometer (Prescott-Allen, 1996) as well as amoeba, star and kite diagrams are examples of SDRS. The surplus production model has been used for 50 years as an implicit SDRS, using yield (production or revenues), effort (as a proxy for fishing mortality), CPUE (as a proxy for biomass) and costs as indicators, and MSY, MEY, BMSY, etc., as reference values.

Sustainable fishing. Fishing is sustainable when it can be conducted over the long term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations (Anonymous, 1998).

Sustainable livelihoods. A livelihood that can cope with and recover from stresses and shocks, maintain or enhance its capabilities, assets and entitlements, while not undermining the natural resource base (Chambers and Conway, 1992).

Target resources oriented management (TROM). See **conventional management.**

Target species. Those species that are primarily sought by the fishermen in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species.

Technical measures. Contain two categories of measures for regulating fisheries: **prohibitions** which are used in case of high risk and **regulated measures**. Use of toxic substances, dynamite and other destructive methods will usually be prohibited. Authorized uses are regulated through regulations, decrees, by laws and administrative orders. Area and time restrictions are technical measures. Technical measures, as opposed to effort or catch quotas or property rights, are often assumed (often wrongly) to have no distributional effect.

Tenure. Socially defined agreements held by individuals or groups (either recognized by law or customary norms) on the rights of access and the rules for use of either a land area or associated resources, such as individual trees, plant species, water or animals (CIFOR, 1999).

Territorial use rights in fisheries (TURF). A traditional form of ownership attached to a relatively small and clearly distinguishable territory to which value is associated. It includes the rights of: (i) exclusion; (ii) determination of the kind and amount of use and (iii) extraction of benefits, present and future. The territory governed by a TURF can relate to the surface, the bottom or the entire water column within a specific area. The tenure may or may not be in perpetuity. The owner can be a private individual, an enterprise, a cooperative, an association or community, a town or province, a national government (the EEZ is a form of TURF). The size of the territory will vary with the use, the resource being harvested and the geographical characteristics. A TURF may have significantly greater importance to the welfare of the community that can be measured in economic terms (Compiled from Christy, 1982).

Threatened species. The IUCN Red List of Threatened Species defines a number of categories of threat based on the risk of extinction in the wild, for example critically endangered (extremely high risk); endangered (very high risk); vulnerable (high risk); near-threatened (if management measures are not introduced); least concern (no imminent risk); data deficient (impossible to assess); and not evaluated. The vulnerability of a species to threats of extinction depends on its population demographics, biological characteristics such as body size, trophic level, life cycle, breeding structure or social structure requirements for successful reproduction and vulnerability due to aggregating habits, natural fluctuations in population size (dimensions of time and magnitude) and residency/migratory patterns (IUCN; FAO Glossary, 2008a).

Threshold. The critical boundary (e.g. spatial, temporal) where the attraction of a system to a new equilibrium or configuration supersedes the system's attraction to its current state (Armitage *et al.*, 2007). For example, in a stock that requires a certain population density

for successful reproduction, collapse may occur suddenly when the population density at spawning falls below a critical density in a given year.

Total allowable catch (TAC). The total catch allowed to be taken from a resource in a specified period (usually a year), as defined in the management plan. The TAC may be allocated to the stakeholders in the form of quotas as specific quantities or proportions (Australian Government Publishing Service, 1991).

Traditional. Pertaining to time-honoured orthodox doctrines. Consisting of or derived from tradition. It consists of the beliefs or customs taught by one generation to the next, often orally. It is also a set of customs or practices. More importantly, it can be seen as information or composed of communicable information brought into the present from the past, in a particular societal context.

Traditional ecological knowledge (TEK). A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission about the relationships of living beings (including humans) with one another and with their environment (Berkes, 2008).

Traditional management. Locally designed and often self-regulated management practiced for multiple generations in fishing communities, often based on norms of appropriate conduct, access rules, regulation of fishing gears and practices, seasonal restrictions, protected area and species taboos, and rituals (Johannes, 2002).

Tragedy of the commons. A misnomer. An expression coined by Hardin (1968) describing the tragedy (negative consequences) of open access, erroneously referring to it as common property. Reformulated by the author as the **Tragedy of unmanaged commons** (Hardin 1998). The concept was indeed already elaborated by Aristotle (4th century BC) who stated that *that which is common to the greatest number has the least care bestowed on it* (Cole 2000). Closer to us, Graham (1935) in his Modern Theory of Exploiting a Fishery and its Application to the North Sea Trawling, predicted that all non-limited fisheries will decline.

Transferability. Refers to the quality of a use right in terms of the sort and extent of restrictions placed on the transfer from one user to another through trade, will or any other means.

Trophic cascade. Trophic cascades occur when predators in a food chain suppress the abundance of their prey, thereby releasing the next lower trophic level from predation. For example, if the abundance of large piscivorous fish is increased in a lake, the abundance of their prey, zooplanktivorous fish, should decrease, large zooplankton abundance should increase. Trophic cascades may also be important for understanding the effects of removing top predators from food webs, as humans have done in many places through hunting and fishing activities. http://en.wikipedia.org/wiki/Trophic_cascade.

TURF. See **territorial use rights in fisheries; customary marine tenure (CMT)**

Ultra vires. From Latin: Beyond the powers. The doctrine in the law of corporations that holds that if a corporation enters into a contract that is beyond the scope of its corporate powers, the contract is illegal. http://legal-dictionary.thefreedictionary.com/ultra+vires.

Unaccounted fishing mortality. The mortality due to fishing that remains unrecorded. This can include the mortality of aquatic organisms entering into contact with but not retained by

the fishing gear as a result of injuries caused by this contact (e.g. death from loss of scales during escapement from a gillnet or a trawl or because of shells severely damaged by the passage of a dredge). It may also include the mortality of discarded animals if they are not accounted as catch.

Uncertainty. The degree to which a future condition (e.g. of an ecosystem) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined terminology or uncertain projections of human behaviour (Alcamo *et al*., 2003). In adaptive co-management, uncertainty refers to the extent to which actors are unable to understand, predict or control how system components, relationships and processes will interact, and what outcomes will result (Armitage *et al*., 2007). In statistics and risk analysis, the estimated amount (or percentage) by which an observed or calculated value may differ from the true value (FAO, 1995).

United Nations General Assembly (UNGA). Established in 1945 under the Charter of the United Nations, the General Assembly occupies a central position as the chief deliberative, policy-making and representative organ of the United Nations. Comprising all 192 Members of the United Nations, it provides a forum for multilateral discussion of the full spectrum of international issues covered by the Charter. It also plays a significant role in the process of standard-setting and the codification of international law (including in fisheries).

Unregulated fishing. Refers to fishing activities: (i) in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization or (ii) in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with state responsibilities for the conservation of living marine resources under international law. See also **illegal fishing; unreported fishing.**

Unreported fishing. Refers to fishing activities: (i) which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations or (ii) undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization. See also **unregulated fishing; illegal fishing.**

Use rights. The rights held by individual fishers, fishing groups, fishing communities or companies to use the fishery resources. These may be in the form of rights to an amount of fishing effort (effort rights) or catch that can be taken in the fishery (harvest rights or harvest quotas). They can be defined by local custom, mutual agreements or prescribed by other entities holding access rights. They may restrict the use of particular harvesting techniques

Utilitarianism. A creed that accepts utility or the greatest happiness as the foundation of morals and holds that actions are right in proportion as they tend to promote happiness (Alcamo *et al*., 2003).

Variable. A quantity affected by variations in time and/or space. If it is explicitly connected to objectives and associated with a reference value, a variable becomes an indicator.

Vessel monitoring system (VMS). As part of modern monitoring, control and surveillance systems (MCS), the VMS is a vessel tracking system (usually satellite based) which provides

management authorities with accurate information on fishing vessels position, course and speed at time intervals. Detail of VMS approved equipment and operational use will vary with the requirements of the nation of the vessel's registry, and the regional or national water in which the vessel is operating.

Vulnerable ecosystems. Areas that are easily disturbed by human activities, and are slow to recover or which will never recover. Marine ecosystems may be easily disturbed if: (1) they are characterised by low levels of natural disturbance and/or low levels of natural mortality; (2) component species are fragile and are easily, killed, damaged or structurally or biologically altered by human impacts, in this case mechanical disturbance by fishing gear; (3) distribution is spatially fragmented with patches of suitable habitat that are small in area and 'rare' in comparison to the overall area of seabed or (4) important ecosystem functions are disrupted or degraded. Alex D. Rogers, Malcolm R. Clark, Jason M. Hall-Spencer, Kristina M. Gjerde (2008). The Science behind the Guidelines: A Scientific Guide to the FAO Draft International Guidelines (December 2007), For the Management of Deep-Sea Fisheries in the High Seas and Examples of How the Guidelines May Be Practically Implemented. IUCN, Switzerland, 2008.

Vulnerable species. Taxa of various types, including (a) taxa believed likely to move into the 'endangered' category in the near future if the relevant causal factors continue to operate. These factors may include overexploitation, extensive destruction of habitat and other environmental disturbances; (b) taxa with populations that have been seriously depleted and whose ultimate security has not yet been assured and (c) taxa with populations that are still abundant but are under threat from severe adverse factors throughout their range (United Nations, 1997).

Vulnerability. The degree to which a system is likely to experience harm due to exposure to a hazard, either a perturbation (disturbance or shock) or a stress. Vulnerability is registered not by exposure to hazards alone; it also resides in the resilience of the system experiencing the hazard (Turner *et al*., 2003). A condition arising from the interaction of three factors, namely: (i) risk exposure, or the nature and degree to which a household (or community) is exposed to a certain risk such as a natural disaster, conflicts, macro-economic changes, etc.; (ii) sensitivity to this risk, measured for instance through the dependence of the household (or community) on fishing activity for food security or income generation and (iii) adaptive capacity of the household (or community) to deal with risk – that is its ability to cope with changes (FAO, 2005b).

Yield-per-recruit analysis. Analysis of how growth, natural mortality and fishing interact to determine the best size of animals at which to start fishing them, and the most appropriate level of fishing mortality. The standard yield-per-recruit models do not consider the possibility of changes in recruitment (and reproductive capacity) due to change in stock size or with environmental impacts but can be modified to take these factors into account.

Sources and recommended reading

Alcamo, J., Ash, N.J., Butler, C.D. *et al*. 2003. *Ecosystem and Human Well-being. A Framework for Assessment. Millennium Ecosystem Assessment*. Island Press, Washington, DC, U.S.A. 245p.

Alsop, R., Bertelsen, M.F. and Holland, J. 2006. *Empowerment in practice. From analysis to implementation*. The World Bank. Directions in Development. Washington: 356 p-1

Anonymous. 1998. Sustaining Marine Fisheries. *A Report of the Committee on Ecosystem Management for Sustainable Fisheries; Ocean Studies Board; Commission on Geosciences, Environment, and Resources; National Research Council*. National Academy Press, Washington, DC, U.S.A.

Armitage, D., Berkes, F. and Doubleday, N. (eds). 2008. *Adaptive Co-Management: Collaboration, Learning, and Multi-Level Governance*. University of British Columbia Press, Vancouver.

Australian Government Publishing Service. 1991. *Ecologically Sustainable Development Working Groups. Final Report – Fisheries*. Australian Government Publishing Service, Canberra, Australia. 202p.

Bator, F.M. 1958. The anatomy of market failure. *The Quarterly Journal of Economics*, 72(3): 351–379.

Berkes, F. 2006. From community-based resource management to complex systems: The scale issue and marine commons. *Ecology and Society*, 11(1): 45. Online http://www.ecologyandsociety.org/vol11/iss1/art45/

Berkes, F. 2008. *Sacred Ecology,* 2nd edition. Routledge, New York.

Berkes, F., Feeny, F., McCay, B.J. and Acheson, J.M. 1989. The benefits of the commons. *Nature*, 340: 91–93.

Berkes, F., Mahon, R., McConney, P., Pollnac, R.C. and Pomeroy, R.S. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods*. International Development Research Centre, Ottawa. Online http://www.idrc.ca/books/

Bromley, D. 1991. *Environment and Economy Property Rights and Public Policy*. Blackwell, Oxford.

Chambers, R. and Conway, G. 1992. Sustainable rural livelihoods: Practical concepts for the 21st century. IDS Discussion Paper 296. Brighton, IDS.

Chesson, J. and Clayton, H. 1998. *A Framework for Assessing Fisheries with Respect to Ecologically Sustainable Development*. Bureau of Rural Sciences, Canberra, Australia. 60p.

Choudhury, K. and Jansen, L.J.M. 1999. *Terminology for Integrated Resources Planning and Management*. FAO, Rome. 69p.

Christy, F. 1982. Territorial use rights in marine fisheries: Definitions and conditions. FAO Fisheries Technical Paper No. 227. Rome, FAO. 10p.

CIFOR. 1999. *The CIFOR Criteria and Indicators Generic Template*. Center for International Forestry Research (CIFOR), Jakarta, Indonesia. 53p.

Cinner, J. 2005. Socioeconomic factors influencing customary marine tenure in the Indo-Pacific. *Ecology and Society* 10(1): 36. Online http://www.ecologyandsociety.org/vol10/iss1/art36/

Cole, D. 2000. New forms of private property: Property rights in environmental goods. In: *Enclyclopedia of Law and Economics, Volume II. Civil Law and Economics*. Bouckaert, B. and De Geest, G. (eds). pp. 274–314. Edward Elgar, Cheltenham, Gloucestershire, U.K.

Compte, A. 1851. *Système de Politique Positive*. Librairie scientifique-industrielle de L. Mathias Paris.

Cooke, J.G. 1984. Glossary of technical terms. In: *Exploitation of Marine Communities*. May, R.M. (ed.). Springer-Verlag, Berlin.

Davic, R.D. 2003. Linking keystone species and functional groups: A new operational definition of the keystone species concept. *Conservation Ecology*, 7(1): r11. Online http://www.consecol.org/vol7/iss1/resp11/

Demolombe, C. 1850. *Cours de droit civil*. Editions Auguste Durand.

FAO. 1989. *Sustainable development and natural resources management. Conference*. Food and Agriculture Organization of the United Nations, Rome. C 89/2 – Suppl. 2. August. 54p.

FAO. 1993. *Guidelines for land-use planning*. FAO Development Series, 1. Rome, FAO.

FAO. 1995. Guidelines for responsible management of fisheries. In: *Report of the Expert Consultation on Guidelines for Responsible Fisheries Management, Wellington, New Zealand, 23–27 January*. FAO Fisheries Report No. 519. Rome, FAO.

FAO. 1996. Precautionary approach to capture fisheries and species introductions. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome, FAO. 54p.

FAO. 1997. Fisheries management. FAO Technical Guidelines for Responsible Fisheries No. 4. Rome, FAO. 82p.

FAO. 1998a. Guidelines for the routine collection of capture fishery data. FAO Fisheries Technical Paper No. 382. Rome, FAO. 113p.

FAO. 1998b. Report of the FAO technical working group on the management of fishing capacity. FAO Fisheries Report No. 586. Rome, FAO.

FAO. 2003. The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries No. 4 (Suppl. 2). Rome, FAO. 112p.

FAO. 2005a. Guidelines for the ecolabeling of fish and fishery products from marine capture fisheries. Rome, FAO. 90p. (Trilingual). (Based on ISO Guide 2, 15.1.2 and Principles for Food Import and Export Certification and Inspection, CAC/GL 20.)

FAO. 2005b. Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Technical Guidelines for Responsible Fiseries No. 10. Rome, FAO. 79p.

FAO. 2008a. Fisheries glossary. Online http://www.fao.org/fi/glossary/default.asp

FAO. 2008b. Glossary of aquaculture. Online: http://www.fao.org/fi/glossary/aquaculture/

FAO. 2008c. Draft international guidelines for the management of deep-sea fisheries in the high seas. FAO meeting document TC/DSF/2008.2. *Document presented at the FAO Technical Consultation on the International Guidelines for the Management of Deep-Sea Fisheries in the High Seas, Rome, 4–8 February*.

Ferrer, E.M. 1991. Territorial use rights in fisheries and the management of artificial reefs in the Philippines. *ICLARM conference proceedings, Manila*.

Flewwelling, P., Cullinan, C., Balton, D., Sautter, R.P. and Reynolds, J.E. 2003. Recent trends in monitoring, control and surveillance systems for capture fisheries. FAO Fisheries Technical Paper No. 415. Rome, FAO.

Freestone, D. 1998. The burden of proof in natural resources legislation. Some critical issues for fisheries law. FAO Legislative Study No. 63. Rome, FAO. 25p.

Garaway, C.J. and Arthur, R.I. 2004. *Adaptive Learning: A Practical Framework for the Implementation of Adaptive Co-management – Lessons from Selected Experiences in South and Southeast Asia*. MRAG Ltd, London.

Garcia, S.M. 1996. The precautionary approach to fisheries and its implications for fishery research, technology and management: An updated review. FAO Fisheries Technical Paper No. 350.2. Rome, FAO.

Garcia, S.M. 1997. Indicators for sustainable development in fisheries. In: FAO (1997). Land Quality indicators and their use in sustainable agriculture and rural development, 131–162.

Garcia, S.M. and Boncoeur, J. 2007. Allocation and conservation of ocean fishery resources: Connecting rights and responsibilities. *American Fisheries Society Symposium*. American Fisheries Society, Bethesda, Maryland, U.S.A. 28 p.

Gittinger, J.P. 1992. *Economic Analysis of Agricultural Projects*. 2nd edition. *The Economic Development Institute of the World Bank*. The John Hopkins University Press, Baltimore and London. 505p.

Gough, J. and Kenchington, T. 1995. *A Glossary of Fisheries Science*. Communications Branch, DFO, Nova Scotia, Canada.

Haas, P.M. 1990. *Saving the Mediterranean: The Politics of International Environmental Cooperation*. Columbia University Press, New York.

Hardin, G. 1998. Extensions of the 'Tragedy of the commons'. *Science. Essays on Science and Society*, 280(5364): 682–683.

Hilborn, R. and Walters, C. 1992. *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*. Chapman and Hall, New York.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4: 1–23.

Honoré, A.M. 1961. Ownership. In: *Oxford Essays in Jurisprudence*. Guest A.D. (ed.). pp. 107–147. Oxford University press, Oxford, U.K.

IUCN. 1994. *Resolution 19.46 of the 19th Session of the General Assembly of the World Conservation Union (IUCN), Buenos Aires, Argentina*. IUCN, Gland, Switzerland.

IUCN/UNEP/WWF. 1980. *World Conservation Strategy: Living Resource Conservation for Sustainable Development*. International Union for the Conservation of Nature, Gland, Switzerland.

Jentoft, S. 2005. Institutions for fisheries governance: introduction. In: *Fish for Life: Interactive Governance for Fisheries*. Kooiman, J., Bavink, M., Jentoft, J. and Pullin, R. (eds). pp. 147–151. Amstaerdam University Press, Amsterdam.

Johannes, R.E. 1998. The case for data-less marine resource management: Examples from tropical nearshore fisheries. *Trends in Ecology and Evolution*, 13: 243–246.

Kelleher, G. and Kenchington, R. 1992. *Guidelines for Establishing Marine Protected Areas*. IUCN, Gland, Switzerland.

Kerrest, A. 2002. Outer space: res communis, common heritage or common province of mankind? *Proceedings of the Nice ECSL courses ESA-ECSL. European Centres for Space Law, Paris*. IUCN, Gland, Switzerland.

Kim, S.H. 1992. *Statistics and Decisions*. Van Nostrand Reinhold, New York. 336p.

Kooiman, J., Bavinck, M., Jentoft, S. and Pulin, R. (eds). 2005. *Fish for Life: Interactive Governance for Fisheries*. Amsterdam University Press, Amsterdam.

Leichenko, R.M. and O'Brien, K.L. 2008. *Double Exposure: Global Environmental Change in an Era of Globalization*. Oxford University Press, New York.

MA. 2005. *Ecosystems and Human Well-Being: Synthesis. Millennium Ecosystem Assessment*. Island Press, Washington DC.

Munro, G. 2003. On the management of shared fish stocks. *Papers presented at the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks. Bergen, Norway. 7–10 October 2002*. FAO Fisheries Report No. 695. Rome, FAO. 246p.

NRC. 1999. *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas*. US National Research Council. National Academy Press, Washington. 422p.

NU LOSC. 1982. http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm

OECD. 1996. *Synthesis Report for the Study on the Economic Aspects of the Management of Marine Living Resources*. AGR/FI(96)12.

OECD. 1997. *Towards Sustainable Fisheries: Issue Papers*. Report OECD/GD(97)54.

Ostrom, E. 1990. *Governing the Commons. The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge, UK.

Ostrom, E. 2000. Private and common-property rights. II. Civil law and economics. In: *Encyclopedia of Law and Economics*. Bouchaert, B. and De Geest, G. (eds). pp. 332–379. Edward Elgar Publisher, Cheltenham, England.

Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B. and Policansky, D. 1999. Revisiting the commons: Local lessons, global challenges. *Science*, 284: 278–282.

Pauly, D. 1988. Some definitions of overfishing relevant to coastal zone management in Southeast Asia. *Tropical coastal area management*, 3(1): 14–15.

Plummer, R. and Armitage, D.R. 2007. Charting the new territory of adaptive co-management: A Delphi study. *Ecology and Society*, 12(2): 10. Online http://www.ecologyandsociety.org/vol12/iss2/art10/

Radmeyer, R.A. Plagànyi, E. and Butterworth, D. 2007. Tips and tricks in designing management procedures. *ICES Journal of Marine Science*, 64(4): 618–625.

Restrepo, V. 1999. *Annotated Glossary of Terms in Executive Summary Reports of the International Commission for the Conservation of Atlantic Tunas' Standing Committee on Research and Statistics (SCRS)*. ICCAT, Madrid, Spain.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, 191: 2–6.

Roberts, K.J., Horst, J.W., Roussel, J.E. and Shephard, J.A. 1995. *Defining Fisheries: A User's Glossary*. Louisiana State University, Louisiana, U.S.A., 22 p. (Rev.). Online http://www.ncfisheries.net/stocks/glossary.htm

Roedel, P.M. (ed.). 1975. *Optimum Sustainable Yield as a Concept in Fisheries Management*. American Fisheries Society, *Special publication*, 9: 89p.

Scialabba, N. (ed.). 1998. *Integrated Coastal Area Management and Agriculture, Forestry and Fisheries*. FAO Guidelines, 256p.

Smith, L.D. 2001. *Reform and Decentralization of Agricultural Services: A Policy Framework*. FAO Agricultural Policy and Economic Development Series, 7.

Sutinen, J.G. (ed.). 2000. *A Framework for Monitoring and Assessing Socioeconomics and Governance of Large Marine Ecosystems*. NOAA Technical Memorandum NMFS-NE-158: 32 pp.

Sykes, J.T. 1997. Advocacy: bringing science to policy and practice. *1997 World Congress on Gerontology. Institute on Aging, University of Visconsin, USA*.

Symes, D. 2007. Fisheries management and institutional reform: AEuropean perspective. *ICES J. Marine Science*, 64(4): 779–785.

Turner, B.L. II, Kasperson, R.E., Matson, P.A. McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A. and Schiller, A. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States*, 100: 8074–8079.

United Nations. 1992. *Earth Summit Agenda 21*. The United Nations programme of action from Rio. 294p.

United Nations. 1997. *Glossary of Environment Statistics*. Studies in Methods, Series F, No. 67.

United Nations. 2008. *Good Governance*. Online http://www.unescap.org/pdd/prs/ProjectActivities/Ongoing/gg/governance.asp

US Department of Commerce. 1996. Online http://caldera.sero.nmfs.gov/fishery/regs/inter600.htm#B

Walker, B.H., Holling, C.S., Carpenter, S.C. and Kinzig, A.P. 2004. Resilience, adaptability and transformability. *Ecology and Society*, 9(2): 3 Online http://www.ecologyandsociety.org/articles/650.html

WCED. 1987. *Our Common Future. World Commission on Environment and Development*. Oxford University Press, New York. 400p.

Weber, M. 1923. *Histoire économique générale*. Ed. 1961. Collier Books, New York.

Young, I.M. 2000. Five faces of oppression. In: *Readings for Diversity and Social Justice*. Adams, M. (ed.). pp. 35–49. Routledge, New York.

Young, O. 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay and Scale*. MIT Press, Cambridge, MA.

Index

access agreement, 121, 122–3
access right, 121, 122, 255, 262, 265, 266, 274, 275
accountability, 68, 291–2
active fishing gears, 176–83, 435
  beach seines, 180–81
  purse seines, 181–2
  seine nets, 179–80
  spears and harpoons, 177
  trawls and dredges, 178–9
adaptive co-management, 58, 67
adaptive enforcement, 381
adaptive management, 44, 58, 67, 70, 72, 96, 208–11, 366–7
advocacy versus science, 342–3
aggregated production models, 351
Alaska, 60, 200, 244, 265, 271, 288, 292, 293
Alaska Department of Fish and Game, 288
Albania, 126, 130
allocation of rights
  foundations, 141–2
  limits, 140–41
  types, 142–3
allowable biological catch (ABC), 231
Angola, 116, 126, 338
Antigua and Barbuda Fisheries Act, 117
aquaculture and capture fisheries, 105, 466
Aquatic Management Board (AMB), 289
area and time restrictions, 196
  advantages, 202–3
    bycatch species protection, 202
    complex fisheries, stock protection of, 202
    conceptual simplicity, 202
    insurance against uncertainty, 203
    sensitive benthic habitats protecting, 202
    tool for continual improvement, 203
  Australia Northwest shelf, case study, 208–11
  conservation management, criteria for, 213–16
  disadvantages, 203–4
    enforcement, 204
    enthusiasm versus appropriateness, 204
    high economic cost, 204
    inter-agency negotiation, 203
  equity issues, 201
    areas/resources multiple use, 201
    valued marine and coastal resources reserving, 201
  fishery-management measure, 197
    excess fishing capacity, avoiding, 199
    fished populations sustainability, habitat protection for, 199
    genetic reservoirs, protecting, 198
    rebuilding phase, of fishery, 198
    specific life stages, limiting harvest of, 198
  Georges Bank, case study, 207
  goals, setting, 212
  Gulf of Mexico, case study, 204–7
  management constituency, 211–12
  Plaice Box, case study, 207–8
  practical steps, 211–17
  site and time selection, criteria for, 212–13
  surf zone fisheries, case study, 207
  underpinning research, 216–17
  as wider conservation measure, 199
    benthic habitats protection, of high conservation value, 200
    bycatch limiting, 200
    ecosystem service, preserving, 200–201
artificial reefs, 24, 47, 50, 182
artisanal fisheries, 15, 69, 98, 147, 202, 206, 264, 270, 274, 292, 361, 377, 384, 390, 392, 400, 411, 414, 421, 436, 439
Asia-Pacific Fisheries International Commission (APFIC), 114, 155
Atlantic Canada, 233, 238, 266, 271
Atlantic salmon, 49
Atlantic silverside, 48
Atlanto-Scandian herring, 449
Australia, 108, 433
  ESD framework in, 311–12
Australian Fisheries Management Act (1991), 107, 130, 238, 436
Australian Fisheries Management Authority (AFMA), 238, 436
Australian Fisheries Policy, 436
Australian Northern Prawn Fishery (NPF) management plan, 436, 437
authorizations, 142, 143

Bacon, Francis, 341, 342
bag limits, 223, 232
Bahaba taipingensis, *see* giant yellow croaker
Barbados, 117
  FMP in, 436–8
Barbados Fisheries Act, 107, 117, 436
Barents Sea bottom trawl fishery, 189, 190
Barents Sea cod fishery, 184
Barndoor skate, 48

Barramundi, 49
Bayesian approach, 217, 356
beach patrols, 386, 390
beach seines, 180–81, 192
beam trawling, 191
Bering Sea pollock fishery, 198, 199, 292
'bet-hedging', 33
biodiversity
  conservation, 43, 47–9, 312, 420–21
  indicators, 326
  threats to, 47–9
bioeconomic equilibrium, of fishery, 84
bioeconomic reasoning, and reference equilibriums, 83
  capital theoretic approach, 88–9
  including more dimensions, 89–90
  maximum sustainable yield, 85–7
  resource rent maximization, 87–8
  unregulated fishery, consequence of, 84–5
bioeconomic theory, 81, 91, 96
biological overfishing, 87, 101, 410
biology and ecology considerations, 21
  bipartite life cycle, 28
  ecosystems and interspecific interactions, 42
    productivity and biodiversity, 43
    species interactions, 43
  emerging issues, 45
    fishing, genetic effects of, 48–9
    invasive species, 48
    mariculture and restocking, 46–7
    marine protected areas, 46
    stressed habitats and climate change, 49
    threatened species, 47–8
  fisheries, monitoring
    catch-per-unit-effort, 45
    landings information, 45
    size information, 45
    species composition, 44
  fisheries science foundation, 29–45
  fishery managers knowledge, 24–45
  habitat needs and shifts, 39
    habitat considerations, 41
    spatial and temporal considerations, 41–2
  stock recruitment relationships, 35
  target and non-target species, biological parameters of, 29
    age, growth and natural mortality, 36–9
    reproductive viability, 34–6
    vulnerability to fishing, 29–33
bipartite life cycle, 28
bureaucracy, 139, 152
bycatch, 184, 187, 191, 200, 202, 232, 434
  marketable, 184
  non-legal, 184
  non-marketable, 184

Cahora Bassa dam, 92
Cambodia, 126, 415
Cambodia's Fisheries Management and Administration Law, 107
Canada, 61, 108, 116, 236, 247, 268, 273, 286, 289, 290, 294, 388, 393, 471
Canada's Atlantic Cod stocks, 451
Canadian Oceans Act, 196
capacity-building, 66, 67, 71, 324
  for small-scale fisheries management, 418–19
capelin, 43
capital stuffing, 228
capital theoretic approach, 88–9
capture-based aquaculture, 39, 466
capture fisheries and aquaculture, interactions between, 466
carcharinidae, 40
Caribbean Fishery Management Council, 438, 439
'carrying capacity', 26, 27, 88
catch curves, 38
'catch history' approach, 271–2
catch limits, 235
  estimation, 232–3
catch management, 117–18, 220, 223, 244–5
  advisory structures, 238–9
  catches, limiting, 231
    controlling catches, limiting fishing by, 234–5
    different forms, 231–2
    effect, 235
    estimation, 232–4
  centralised nature, 236–8
  different forms, 231–2
  discards, 241–2
  in ecosystem management, 244–5
  enforcement, 238–9
  examples, 247–9
  fleet capacity, reducing, 226
    fishing effort, reducing efficiency of, 230
    fishing gear, restricting vessels' use of, 229
    time vessels, reducing amount of, 227–9
    vessels, removing of, 227
  general application, need for, 223
  monitoring, 238–9
  in multispecies fisheries, 243–4
  need for, 223
  non-compliance, 241
  and precautionary approach, 246–7
  restrictive licensing, 225–6
  scientific assessments, problems with, 242
  structures needed for, 236–9
  see also output controls
catch per unit effort (CPUE), 45, 77, 82, 83, 84, 86, 167, 353, 355
catch quality, 185, 190
catch quotas, 225
  see also output controls
catching capacity, 167
catching principle
  beach seines, 180, 181
  gillnets, 169
  handlining, and trolling, 172
  longlining, 173
  pots, 175
  purse seines, 181
  seine nets, 179–80
  spears and harpoons, 177
  trammel nets, 170
  traps, 176
  trawls and dredges, 178
Cayos Cochinos Monument, FMP for, 441–2
Cheilinus undulatus, *see* Napoleon fish
Chief Fisheries Officer, 117, 436
Chile, 126, 264, 413, 415
ciguatera, 49
civil society, 67, 135, 142, 150, 157, 418, 419, 467
  corporative institutions, 151–2
  institutions, 142, 157
climate change, 11, 49
  and stressed habitats, 49
  vulnerability due to, 419–20
closed areas/seasons, 203, 206, 378
  and time restrictions, 458
cofradias, 150, 151, 228

co-management approach, 66, 67, 99, 120, 124, 150–51, 458
for small-scale fisheries, 412–13
command-and-control, 58, 72, 159, 457, 458
commercial/collective servicing, 149–50
common fisheries policy (CFP), 155, 227
common-pool fish stock resource, 80, 83, 97
common pool resources, 53–4, 75, 80, 82, 97
common property, 54, 140, 254, 259
commons, *see* common pool resources
communal-property regimes, 54
community development quota (CDQ) programme, 271, 292, 293
community governance, emphasis on, 420
community management, 155, 384
community quota, 267, 270–71, 294
community rights-based approach, 412
'community waters', 155
Compliance Agreement, 108, 113, 131
compliance incentives, 417
concessions, 142–3
Conferences of the Parties of environmental treaties, 471
Conservation and Management of Straddling Fish Stocks, 108
Conservation of the Living Resources of the High Seas, 129, 449
consumer preferences, 420
control indicators, 316
Convention on Biological Diversity CBD, 22, 111, 129, 420, 451
Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), 48, 111, 112, 460, 467
Convention on the Conservation of Antarctic Living Marine Resources (CCAMLR), 114, 126, 127, 467
'cooperating non-party', 114
co-production of knowledge, 65, 343
coral reefs, 49, 205–7
Corals and Reef Associated Plants and Invertebrates, 438
Coryphaena hippurus, 32
cross-sectoral issues, of fishery manager, 464
culture-based fisheries, 466
customary marine tenure (CMT), 255, 263
and TURFs, 263–4

data and information needs, in fisheries management, 339–40
conflicting objectives identification, 338
decision making process, 338–40
fishing, costs and benefits of, 336–7
sources and uses, 340–41
data-less management, 63–4
decentralization, 69, 420
see also devolution
decision-makers, 340
presenting information to, 363–6
decision-making and institutional environment
fishery management institutional system
institutional complexity, 147–8
'system of systems', 146–7
institutional analysis, 153
characteristics, 153–4
decision process, 157–60
institutional participation, 156–7
management institutions, hierarchy of, 154–6
knowledge in, 362–3
typologies, 148
functional typology, 149–51
socio-political typology, 151–3
decommissioning, 227, 228
deep-sea fisheries, 131, 133, 465
delegated administration, 139–40
demersal trawls, 189, 193
beam trawling, 191
fish trawls, 189–90
shrimp trawling, 190–91
Denmark, 230
development stages, of fisheries, 99–100
devolution, 156, 212, 272, 420, 450, 457
see also decentralization
Diadema antillarum, *see* sea urchins
Dipturus laevis, *see* barndoor skate
direct conservation measures, 220
direct impacts, of fishing, 357–9
on target resources, 353–6
on wider ecosystem, 357
discarding, 184, 241–2, 470
discount rates, 89, 98, 100
dispute settlement mechanism, 144, 417–18
dolphinfish, 32
Dover sole, 224
draft management plan, 430
Driftnet Resolution, 111
drivers of change, 453
duties and responsibilities, of fishery manager, 143–6
dynamite fishing, 43, 435

East Anglia herring fishery, 449
ecologically sustainable development (ESD), 16, 327, 433, 436
framework, 310–11
see also sustainable development
ecology, *see* biology and ecology considerations
economic approach, to fisheries, 75
components, 76–8
costs, 81–2
fish stock resources, 82
fleet diversity, 81–2
harvest production, economics of, 82–3
market failures, 80–81
markets, 81–2
opportunity costs, 78–80
stock fluctuations, 81–2
economic liberty and free access, regime of, 137–8
economic perspective, on fishing, 75
bioeconomic reasoning, and reference equilibriums, 83, 89–90
capital theoretic approach, 88–9
including more dimensions, 89–90
maximum sustainable yield, economics of, 85–7
resource rent maximization, 87–8
unregulated fishery, consequence of, 84–5
economic approach, to fisheries, 75
components, 76–8
costs, 81–2

economic perspective, on fishing, (*cont.*)
fish stock resources, 82
fleet diversity, 81–2
harvest production, economics of, 82–3
market failures, 80–81
markets, 81–2
opportunity costs, 78–80
stock fluctuations, 81–2
economics, politics interference with, 90–91
entry limitation, 94
fisheries development, 96
contextual issues related to, 98–9
development stages, 99–100
market failures and poverty, 97–8
future perspectives, 96
quota regulations, 94–6
resource conservation, history of, 91–2
taxation, 93
technical measures, 92–3
economic rent, 79, 80
Ecopath with Ecosim model, 352, 358
ecosystem and multi-species models, 350, 351
ecosystem approach to fisheries (EAF), 2, 3, 6, 21, 23, 41, 77, 96, 111, 130, 158, 167, 194, 245, 303, 305, 348, 413, 429, 447, 452, 455–6, 460, 461, 465
FMP within context, 433
bycatch, 434
fishing gear on habitat, impacts of, 435
management plans, integration of, 435
trophic chain effects, of harvesting, 435
and indicators, 325–7
and precautionary approach, 129–31, 133
ecosystem effects, of fishing, 183–92, 193
ecosystems and interspecific interactions, 29, 42
productivity and biodiversity, 43
species interactions, 43
Ecuador, 126
effort-dependent costs, 77
effort rights, 265–6
emerging issues
aquaculture, interaction with, 466
biology and ecology considerations, for fishery manager, 45
biodiversity, threats to, 47–9
mariculture and restocking, 46–7
marine protected areas, 46
stressed habitats and climate change, 49
and challenges, 16
ethical issues, 467
extinction, risk of, 466–7
fisheries management, 16
of FMPs, 442–3
intrasectoral and cross-sectoral issues, 464
knowledge gap, filling, 465
legal framework, evolution of, 464–5
management capacity, increasing, 463–4
management objectives, evolution of, 463
multi-functional nature, of fisheries, 462
national and international agendas, articulation between, 466
public goods and fisheries, 463
small-scale fisheries management, considerations for, 419
biodiversity conservation, 420–21
community governance, greater emphasis on, 420
ethical concerns, 420
new consumer preferences, 420
vulnerability, due to climate change, 419–20
empowerment, 66, 291–2
energy efficiency, 185
enforcement, 204, 239, 381–4
of MCS, 125–6, 381–4
and surveillance, 417
entry limitation, 94
environmental NGOs, 156, 451
equilibrium theory, 81
equity
definition, 292
issues, 201
livelihoods, 61
objectives, 61
ERS-2, 390
ethical issues, of fishery manager, 467
Europe, 47, 394, 449
European Union, 126, 151, 155, 237, 240, 246–7, 249, 381
eutrophication, 43
exclusion problem, 53
exclusive economic zones (EEZs), 54, 55, 108, 122, 129, 138, 235, 238, 305, 313, 376, 394, 411, 450, 452, 459, 466
external costs, 97
externalities, 84
extinction, risk of, 466–7

Faeroes, 227
effort management in, 230–31
'fallacy of controllability', 58
FAO Code of Conduct, 3, 4, 22, 69, 72, 111, 113, 116, 128, 129, 131, 135, 136, 143, 147, 154, 156, 158, 170, 182, 183, 185, 197, 199, 211, 220, 223, 224, 255, 257, 258, 260, 265, 266, 270, 325, 340, 341, 346, 374, 376, 380, 405, 425, 426, 451, 456
FAO Committee on Fisheries (COFI), 111, 411
FAO Guidelines on the precautionary approach, 346, 460
FAO Technical Guidelines for Responsible Fisheries, 111, 425
FAO's Advisory Committee on Fishery Research, 100
fecundity, 33, 34
Federal and Local Endangered Species Acts, 440
fish aggregating devices, 182
fish attracting devices, 47
fish stock resources, 75, 82, 88
fish trawls, 189–90
fisher compliance, 381
Fisheries Act Chile (1991), 413
Fisheries Advisory Committee, 436
fisheries development, 96
contextual issues related to, 98–9
development stages, 99–100
market failures and poverty, 97–8
fisheries governance
broader issues, 67
decentralization, 69
governance perspectives, features of, 68

component, 453–5
and fisheries management, 6
future, 467
governance chaos, 469–70
'*market world*', governance of, 468–9
transformed world, 470–71
infrastructure, 454
Fisheries Information and Statistical System (FINSS), 393
fisheries law, 105, 107
institutional framework in, 114–15
international and national fisheries legal frameworks, relationship between, 112–13
international instruments, 108–12
national fisheries and related legislation, 107–8
regional fisheries entities and arrangements, 113–14
fisheries management, 59, 101, 223–5, 336
approaches and tools, 116
effort and catch management, 117–18
fishery plans, 116–17
fishing rights, 118
participatory or partnership management, 120–21
technical measures, use of, 118–20
data and information needs in, 339–40
conflicting objectives identification, 338
decision making process, 338–40
fishing, costs and benefits of, 336–7
sources and uses, 340–41
definitions, 2–4
dimensions of, 11–12, 89–90
emerging issues in, 16
evolution, 304–5
fisher knowledge, 63–4
fisheries governance, 6, 67
decentralization, 69
governance perspectives, features of, 68
in future, 16
goal, 7–8
indicators, *see* indicators, for fisheries management
institutional frameworks, 135
institutions, importance of, 65
in multi-level world, 66–7
vocabulary development, 65–6
key dimensions, 11–12
knowledge and scale, 64–5
management objectives, 60
equity objectives and livelihoods, 61
poverty and resource access, 62–3
and MCS, 124
measure, 197
depleted stocks and habitats, protecting, 198
excess fleet capacity, restraining, 199
genetic reservoirs, protecting, 198–9
specific life stages, limiting harvest of, 198
sustainability of fished populations, habitat protection for, 199
objectives, 62, 223–5
principles for, 6–7
resource management, history of, 57–8
social aspects, 52–72
social–ecological systems, 58–60
'tragedy of the commons', 53
property-rights regimes, in real world, 54–7
science of commons, developing, 53–4
see also rights-based fisheries management; small-scale fisheries management, in developing countries
fisheries management administration (FMA), 114, 115, 116, 119, 122, 132
fisheries management plans (FMPs), 425
within context of EAF, 433
bycatch, 434
fishing gear on habitat, impacts of, 435
management plans, integration of, 435
trophic chain effects, of harvesting, 435
designing
authority in charge for development, 428–9
contents, 426
fishery-specific requirements, 427–8
international fisheries policy requirements, 426–7
national/state fisheries policy requirements, 427
timetable for development, 429–31
emerging issues, 442–3
examples, 436
Australian Northern Prawn Fishery management plan, 436
Barbados FMP, 436–8
Cayos Cochinos Monument, 441–2
Queen Conch FMP, 438–40
Western Australian plan, 440–41
implementation, 431
management objectives in, 428
reviewing and amending, 431
management measures, changing, 432–3
mechanism for review, 432
review strategy, 432
fisheries management regime, in legal framework
approaches and tools, 116
effort and catch management, 117–18
fishery plans, 116–17
fishing rights, 118
participatory or partnership management, 120–21
technical measures, use of, 118–20
fishing access agreements, 121–3
institutional framework, 114–15
legislated management policies, principles and guidelines, 116
management powers and functions, 115
'fisheries patrol vessel', 387
fisheries regulations, economic perspective on, 90
economics, politics interference with, 90–91
entry limitation, 94
future perspectives, 96
quota regulations, 94–6
resource conservation, history of, 91–2
taxation, 93
technical measures, 92–3
fisheries-related international instruments, 109–10

Fisheries Resource Conservation Council (FRCC), 236–7
fisheries science foundation, 29–45
ecosystems and interspecific interactions, 42
productivity and biodiversity, 43
species interactions, 43
habitat needs and shifts, 39
habitat considerations, 41
temporal and spatial considerations, 41–2
monitoring fisheries, 44
landings and CPUE, 45
size information, 45
species composition, 44
target and non-target species, biological parameters of, 29
age, growth and mortality, 36–9
reproductive viability, 34–6
vulnerability to fishing, 29–33
fishery, 100, 147
bureaucrats, 152
components, 76–8
corporations, 157
development, 153
governance, future of, 467
indicators, 303
lobbying, 157
objectives, 9
plans, 116–17
policy, 138
'system of systems', 146–7
technocrats, 152
type, 377–8
Fishery Committee for the Eastern Central Atlantic (CECAF), 114
fishery institutions, 148
functional typology, 149–51
socio-political typology, 151–3
fishery-specific laws, 137
fishery-specific requirements, of FMP, 427–8
fishing access agreements, 121–3
fishing capacity controls, 222
'fishing down the food web', 43
fishing effort, 82, 83
fishing effort management, 117–18, 222, 244–5
advisory structures, 238–9
catches, limiting, 231
controlling catches, limiting fishing by, 234–5
different forms, 231–2
effect, 235
estimation, 232–4
centralised nature, 236–8
in ecosystem management, 244–5
enforcement, 238–9
examples, 247–9
fleet capacity, reducing, 226
fishing effort, reducing efficiency of, 230
fishing gear, restricting vessels' use of, 229
time vessels, reducing amount of, 227–9
vessels, removing of, 227
general application, need for, 223
monitoring, 238–9
in multispecies fisheries, 243–4
and precautionary approach, 246–7
problems, 239–41
restrictive licensing, 225–6
structures needed for, 236–9
see also input controls
fishing gears, 167
active gears, 176, 182–3
beach seines, 180–81
purse seines, 181–2
seine nets, 179–80
spears and harpoons, 177
trawls and dredges, 178–9
classification, 168
on habitat, 435
ideal fishing gear, 168
management considerations, 192, 193
passive gears, 168
hook and line fishing, 171–4
nets, 169–71
pots and traps, 174–6
selectivity and ecosystem effects of fishing, 183–92
and technology, 458
fishing quotas, 270
fishing rights, 118, 256, 459
fixed costs, 77, 83
Flag State, 107, 127, 131
Flag State Measures (FSMs), 465
flatfish species, 224
fleet capacity, 199, 226–31, 333
fleet diversity, 81–2
Food and Agriculture Organization (FAO), 2, 111, 112, 128, 471
food insecurity, 100, 406
food security, 101, 408, 466, 467, 481
food web and trophic level models, 351
foreign exchange earnings, 396, 408
formal legislation, 414
formal scientific knowledge, 341–2, 343
Fortress world, 469, 471
Forum Fisheries Agency (FFA), of western Pacific, 389, 393, 394
free access and economic liberty, regime of, 137–8
fyke nets, 175, 176

Gabon, 115, 116
Gadidae, 40
gears, *see* fishing gears
Georges Bank, 207
Ghana, 117
ghost fishing, 170, 185, 187, 188, 192, 229
ghost gear, 435
giant yellow croaker, 33
gillnets, 169–70, 186–7
Global Record of Fishing Vessels, 401
Golden Rule of optimal economic harvest, 89
gonads, 34
Gordon–Schaefer bioeconomic model, 85, 87, 352
governance chaos, 469–70
governance, *see* fisheries governance
Graham, Michael, 447
Graham's Great Law of Fishing, 447, 449
Great transitions, 470
grey landings, 241
gross domestic product (GDP), 411
growth overfishing, 204, 355
Gulf of Mexico, 41, 204–7, 432, 456

habitat, 209
and behavioural changes, 40
and climatic change, 49
effects, 185
fishing gear impacts on, 435
needs and shifts, 29, 39
considerations, 41
temporal and spatial considerations, 41–2
protection, 198–9, 200, 202
Haliotis sorenseni, *see* white abalone

handlining, 172–3, 187
Hardin, 53, 56, 81
harpoons, 177, 188–9
harvest capacity controls, 459
harvest control rules (HCRs), 96, 316, 465
see also output controls
harvest production, economics of, 82–3
harvest rights/quotas, 267–8
harvesting, trophic chain effects of, 435
hermaphroditism, 32, 34
high grading, 184, 235
Highly Migratory Fish Stocks, 108, 259
Hippocampus spp., 48
historical trends, of fisheries, 448
early phase (1900–1945), 448–9
fisheries crisis (1985–1995), 451
fisheries reform (1996–2015), 451–2
geographic expansion (1960–1985), 449–50
post-war reconstruction and development (1945–1960), 449
hook and line fishing, 171
handlining, 172–3
longlining, 173–4
trolling, 172–3
Human Development Index (HDI), 318, 323
Hungary, 130
hybrid institutions, 152–3
hyperstability, 45

Iceland, 235, 242, 389
illegal, unreported and unregulated (IUU) fishing, 126–7, 132, 133, 373–4, 376, 459
illegal fishing, definition, 373
'illusion of certainty', 58
incidental catch, *see* bycatch
Index of Biological Integrity (IBI), 326
Indian Ocean Tuna Commission (IOTC), 113, 126, 393
indicators, for fisheries management, 303
evolution, 304–6
institutionalisation, 324
issues and challenges, 322
capacity building, 324
EAF and indicators, 325–7
information gaps and uncertainty, 324–5
institutionalisation, 324
inter-sectoral systems, 325
participation, 323
simplification and realism, 323
standards, need for, 323
tensions and trade-offs, 327–8
and measurements for sustainable development, 334–5
operational objectives and data requirements, 333
system development, 306
framework selection, 308–11
objectives, criteria and indicators, selecting, 312, 313
scope and detail, 306–8
success factors for, 321
typology, 315
functions, 314–17
nature, 317–19
quality, 319–20
representation systems, 322
scaling and value judgements, 320
success factors for, 321
testing and evaluation, 320–21
indirect impacts, of fishing, 357–9
individual non-transferable quotas (INTQs), 267
individual transferable quota (ITQ), 95, 118, 235, 267, 450
Indonesia, 115, 415
Inmarsat-C, 389
input controls, 13, 167, 215, 222–3, 243, 244, 249–50, 255, 262, 266, 378
see also fishing effort management
inshore shellfish fishery, 413
institution-building, *see* capacity-building
institutional frameworks, of fishery management, 12, 135
and decision-making, 146
fishery institutions, typologies of, 148–53
fishery management institutional system, 146–8
institutional analysis, 153–60
in fisheries law, 114–15
managers in, 136
allocation of rights, 140–43
duties and responsibilities, 143–6
legal regimes, diversity of, 136–40
response indicators, 310
Integrated Coastal Area Management (ICAM), 327, 435
integrated management, 290, 325, 464
intelligence-driven enforcement, 381
interest group, 151, 152
representation, 150
intergovernmental management, 155–6
international and national fisheries legal frameworks, relationship between, 112–13
International Collective in Support of Fishworkers (ICSF), 406, 418
International Convention on the Conservation of Atlantic Tuna (ICCAT), 113, 126, 127, 177
International Council for the Exploration of the Sea (ICES), 91, 203, 246, 247
international fisheries policy requirements, 426–7
international instruments, of fisheries law, 108–12
International Plan of Action (IPOA), 113, 187, 231
International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU), 111, 113, 128, 240, 373–4, 375
International Plans of Action (IPOA), 452
International Union for Conservation of Nature (IUCN), 48, 196
inter-professional institutions, 153
intra-marginal rent, 79
intrasectoral issues, of fishery manager, 464
invasive species, 48
Ireland, 235

Japanese fisheries cooperatives, 413
juvenile fish, 189, 190, 199, 345
juvenile habitat, 41
juvenile red snapper, 41

keystone species, 43

labour costs, 79–80
Lake Kariba, 92
Large Marine Ecosystem projects, 311
large-scope partnerships, 284–7
Lates calcarifer, *see* Barramundi
law and fisheries manager, 4, 131–2
learning-by-doing approach, 58
legal aspects, of fisheries, 12, 105, 414
  evolution, 464–5
  fisheries law
    international and national fisheries legal frameworks, relationship between, 112–13
    international instruments, 108–12
    national fisheries and related legislation, 107–8
    regional fisheries entities and arrangements, 113–14
  fisheries management regime, in legal framework
    approaches and tools, 116–21
    fishing access agreements, 121–3
    institutional framework, 114–15
    legislated management policies, principles and guidelines, 116
    management powers and functions, 115
  fisheries manager and law, 105–7
  law review and manager, 131–2
  MCS systems
    enforcement, 125–6
    and fisheries management, 124
    IUU fishing, 126–7
    and law, 123–4
    and participatory management, 124–5
    Port States Measures, 127–8
    vessel monitoring systems, 125
  and significant issues
    deep-sea fisheries, 131
    EAF and precautionary approach, 129–31
    sustainable development, 128–9
legal regimes, diversity of, 136
  delegated administration, 139–40
  free access and economic liberty, 137–8
  public administration, 138–9
legislated management policies, principles and guidelines, 116
Lethrinus, 209, 210, 211
limited entry, 265
Limnothrissa miodon, 92
Lisbon Principles, 70
Lithuania, 116, 130
livelihood, definition of, 61
local economic development of small-scale fisheries, 407–8
logbooks, 387
London Overfishing Conventions, 449
longlining, 173–4, 187–8
LOS Convention, 108, 113, 117, 128, 129
Lutjanidae, 40
Lutjanus, 210, 211
Lutjanus campechanus, *see* juvenile red snapper

Magnuson-Stevens Act, 426, 438, 440
Mallotus villosus, *see* capelin
Malta, 126
management approaches, for small-scale fisheries, 410
  co-management approach, 412–13
  community rights-based approach, 412
  ecosystem approach, 413
  preferential access approach, 411–12
management capacity, 463–4
management constituency, 211–12
management demands, 5
management environment, 452–3
management implementation, 14–15
management institutions, hierarchy of, 154–6
management instruments, of fisheries, 457–62
  closed areas and time restrictions, 458
  from command-and-control to co-management, 458
  economic incentives and disincentives, 459–60
  gear and technology, regulation of, 458
  harvest capacity controls, 459
  indicators, 460
  monitoring, control and surveillance, 461–2
  partnerships, 460–61
  trade-related measures, 460
management measures, 9–10
management objectives
  evolution, 463
  for small-scale fisheries, 410
management plans, 3, 9–10, 16
  integration, 435
  for small-scale fisheries, 414–16
management procedure evaluation (MPE), 348
management rights, 257–8
management strategies, 8, 9–10
management strategy evaluations (MSEs), 316, 348, 465
mariculture, 24, 466
  and restocking, 21, 46–7
    genetic effects, 48–9
marine invasive species, 48
marine protected areas (MPAs), 46, 111, 196, 200, 214, 215
marine reserve, 217
Marine Stewardship Council, 320, 443
market and fishing development, relation between, 99
market failures
  in fisheries, 80–81
  and poverty, 97–8
market regulations, 78
'*Market world*', governance of, 468–9, 471
marketable bycatch, 184
Marshall Islands, 117, 126
maximum economic yield (MEY), 60, 61, 87–8, 89, 308, 352
maximum sustainable yield (MSY), 26, 59, 60, 61, 85–7, 308, 352, 447
Mediterranean countries, 227
Menidia menidia, *see* Atlantic silverside
Millennium Development Goals (MDGs), 58, 72, 404, 452
Millennium Summit (2000), 451–2
mixed-species fisheries, 184, 189
Model Scheme on Port State Measures to Combat Illegal, Unreported and Unregulated Fishing, 128, 401
monitoring, control and surveillance (MCS) system, 15, 106, 374, 386, 411–12, 461–2
  administrative options, 391–2

compliance, 381–4
core components, 384, 385, 386
before fishing, 384–5
while fishing, 385, 387–91
during landing, 391
post landing, 391
definition, 375
enforcement, 125–6, 381–4
fisheries management, 124, 376
future, 400–401
historical perspective, 376
information management and sharing, 392–3
international and regional cooperation, 393–5
IUU fishing, 126–7, 373–4
and law, 123–4
management options, 393
and participatory management, 124–5
Port States Measures, 127–8
solution, 376
balancing trade-offs, 384
compliance/enforcement, 381–4
dimensions, 380–81
financial requirements, 380
fishery types, 377–8
human resources, 379–80
legal framework, 379
management measure, types of, 378
targeted MCS, 381
system performance and planning, 395
assessing compliance, 396–7
cost analysis, 395–6
risk assessment and planning, 398–9
system performance, 397–8
vessel monitoring systems, 125
monopoly rent, 79
Monte Carlo analyses, 356
moving gears, *see* passive fishing gears
Mozambican kapenta fishery, 92
Mozambique, 92, 115, 126, 248–9, 393
deep-water shrimp fishery, 248–9
Multiannual Guidance Programme, 240, 249
multi-functional nature, of fisheries, 462
multi-species and ecosystem models, 350, 351
multi-species fisheries, 7, 43, 378
effort and catch management, 243–4
multi-species per-recruit models, 351
multi-species stock recruit models, 351
multi-species surplus production models, 351
multi-species VPA method, 351
multi-stakeholder process, 66, 419, 461, 464

Namibia, 116, 235, 247, 275, 395, 396
Marine Resources Act, 128
Napoleon fish, 48
national and international fisheries legal frameworks, relationship between, 112–13
National Environmental Policy Act, 440
national fisheries and related legislation, 107–8
National Plans of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated fishing (NPOA-IUU), 111, 375
national/state fisheries policy requirements, 427
natural mortality, 25, 32, 37–8, 39
Nauru, 107, 128
navy and coastguard, of MCS systems, 386, 390–91
net present value (NPV), 360, 361
nets, 169–76
New Zealand, 107, 116, 130, 146, 184, 235, 247
Newfoundland, 229
no-take reserve, 197
non-economic bycatches, 184
non-FAO fisheries instruments, 111
non-governmental organizations (NGOs), 140, 156, 157, 284, 285, 415, 418, 442, 443, 451, 452, 453, 461
non-legal bycatch, 184
non-marketable bycatch, 184
non-profit-making association, 150
'non-property', 253
non-transferable versus transferable quota systems, 95–6
normal profit, 78–9
North Atlantic, 247, 448, 449
North East Atlantic Fisheries Commission (NEAFC), 126, 127, 394
North Sea, 203, 208, 243, 246, 449
Northern Prawn Fishery (NPF), 436, 437
Northwest Atlantic Fisheries Organization (NAFO), 126, 127, 236, 238
Northwest Atlantic Marine Alliance (NAMA), 294–5
Norway, 242, 246, 393
Norway's Act Relating to Sea-Water Fisheries, 107
Norwegian Lofoten Act, 75
nursery habitat/area, 24, 39, 41

observer programmes, 388
open access fishery, 54, 80, 81–2, 99, 101, 258–9
operational costs, 78, 395, 396
operational management procedures (OMPs), 316, 459
operational objectives, 9, 10
opportunity cost, 78–80, 84, 100
optimum sustainable yield (OSY), 60, 61
Organization for Economic Cooperation and Development (OECD), 215, 216, 309
otter trawl, 178, 179, 189
output controls, 13, 220, 223, 378
see also catch management; catch quotas; harvest control rules (HCR)
Overfishing Committee, 91
ownership, 115, 255

Pacific Forum Fisheries Agency, *see* Forum Fisheries Agency (FFA), of western Pacific
pair trawl, 178, 179
Panulirus cygnus, *see* western rock lobster
Papua New Guinea, 107, 126
participatory management systems, 120–21, 400, 450, 456
and MCS, 124–5
partnership management systems, 120–21
partnerships, in management, 460–61
accountability, 291–2
characteristics, 296–7
with community empowerment levels, 291–2
community partners and value addition to resource, 297–8

partnerships, in management, (*cont.*)
conditions for effectiveness, 296
with dual/multiple parties, 289–91
external actors on regional boards, 294–6
large-scope partnerships, 284–7
offshore fisheries to coastal communities, liking between, 292–4
problems solving, 283–4, 292
resources, characteristics of, 297
small and large scale partnerships, 287–9
small-scope partnerships, 284–7
passive fishing gears, 168
hook and line fishing, 171–4
nets, 169–71
pots and traps, 174–6
past management to future governance, perspective view, 447
emerging practices
changes in approach, 455–6
changing management environment, 452–3
dealing with complexity, 456–7
management instruments, 457–62
from management to governance, 453–5
manager, evolving role for, 457
selected issues, 462–7
fishery governance, future of, 467
governance chaos, 469–70
'*market world*', governance of, 468–9
transformed world, 470–71
historical trends, 448
early phase (1900–1945), 448–9
fisheries crisis (1985–1995), 451
fisheries reform (1996–2015), 451–2
geographic expansion (1960–1985), 449–50
post-war reconstruction and development (1945–1960), 449
patrol aircrafts, 387–8
patrol vessels, 386, 387
Pauly, Daniel, 39
pelagic fish, 174, 192
pelagic trawls, 179, 189
perfect markets, 78, 79
personal right, 141
Peruvian anchoveta fishery, 449
Philippines, 116, 206, 384, 415
Philippines' Fisheries Code, 107
Plaice Box, 207–8
pollution, 186
Popper, Karl, 342
population growth rate, 26, 27
Port State inspections, 401
Port State Measures (PSMs), 127–8, 465
Portugal, 126
potential yield, 354
pots, 174–5, 188
poverty
and market failures, 97–8
prevention, 408–9
and resource access, 62–3
poverty alleviation, 98, 99
precautionary approach
catch management, 246–7
and EAF, 129–31
fishing effort management, 246–7
and uncertainty, 343
precautionary approaches to fisheries (PAF), 246, 452
precautionary principle, 23
preferential access approach, 411–12
prejudice, 144
Pressure-State-Response (PSR) framework, 309–10
Principle-Criteria-Indicators (PCI) model, 312
private property, 54, 253–4
privatization, 452
professional discipline, 151
property rights, 54, 55, 118, 253–4
Protection of Nature, 157
prud'homies (industrial tribunals), 150
public administration, 138–9, 153
public consultation period, 430
public goods and fisheries, 463
public ownership, 115
Puerto Rico and US Virgin Islands Queen Conch FMP for, 438–40
purse seines, 181–2, 191–2

quantitative input rights, 265–6
quantitative output rights, 267–8
quantitative withdrawal rights, 255, 262, 265
Queen Conch FMP, 28, 34
for Puerto Rico and US Virgin Islands, 438–40
quota regulations, 94–6, 241

rabbitfishes, 28
RADARSAT-1, 390
real right, 137, 141
recruitment overfishing, 34
red snapper fish, 34, 41
reference direction, 10, 59
reference point, 8, 10, 84, 85, 86, 87, 303, 443
reference value, *see* reference point
regime shift, 315, 316
regional fisheries bodies (RFBs), 113, 114, 126
regional fisheries management organizations (RFMOs), 113, 114, 126, 127, 131, 143, 459
Regional Fishery Councils, 438
rent, 94, 308
reproductive mode, 32
res communes, 137, 140, 141
resilience, 52, 72, 463
resource
allotment, 142
conservation, 91–2
harvesting, 149
management, 57–8, 59
meaning, 57
resource rent, 79, 84, 85, 87, 95, 99
restrictive licensing, requirement for, 225–6
Ricker model, 36
'right', definition of, 118
rights-based fisheries management, 253
management rights, 257–8
property rights, 253–4
use rights, 254–6, 262–3
allocation mechanisms, 271–4
assessment process, 279
choices, 268–9
duration, 274–5
effort rights, 265–6
establishment, 260–61
harvest rights/quotas, 267–8
holders, 269–71
and human rights, relationship between, 256–7
limited entry, 265
and management rights, 257–8
open access fisheries, 258–9
policy framework, 261
principle for, 259–60
territorial use rights and CMT, 263–4
transferability, 275–7
see also fisheries management
Rio Declaration on Environment and Development (Rio Declaration), 116, 130

risk
assessment, 398–9
management, 345
and uncertainty, 343–5
robustness testing, 345
rockfishes, 28
Romania, 130
Rotenone, 183
running costs, 78
Russel, 448, 449

'S-shaped' logistic curve, 26, 27
safety-net function, of fisheries, 408–9
Salmo salar, *see* Atlantic salmon
Salmonidae, 40
Samoa, 121, 264
satellite imagery and remote sensing, 390
Sciaenidae, 40
science versus advocacy, 342–3
scientific advice, for management, 239
societal goals and impacts, 360–62
target resources, direct impacts on, 353–6
wider ecosystem, direct and indirect impacts on, 357–60
scientific information, use of
adaptive management, 366–7
data and information needs, in fisheries management
conflicting objectives identification, 338
decision-making process, 338–40
fishing, costs and benefits of, 336–7
sources and uses, 340–41
decision-makers, presenting information to, 363–6
decision-making, knowledge in, 362–3
information generation, tools used in
benefits to society, consideration of, 350, 352
models, role of, 347–8
multi-species and ecosystem models, 350, 351
single-species methods, 348–50
precautionary approach, 346–7
risk management, 345
scientific advice, for management
societal goals and impacts, 360–62
target resources, direct impacts on, 353–6
wider ecosystem, direct and indirect impacts on, 357–60
scientist's role
advocacy versus science, 342–3
formal scientific knowledge, 341–2
and knowledge types, 341–3
traditional/local knowledge, 343
uncertainty and risk, 343–5
scientific institutions, 157
Scombridae, 40
sea urchins, 43, 59
seamount, 29, 131
Sebastes spp., *see* rockfishes
security of tenure, 118
seine nets, 179–80, 191
selectivity, of fishing method, 183
self-organization, 60
Senegal, 126
Senegal's Marine Fisheries Code, 107
sensitivity analyses, 356
Serranidae, 40
Shallow Water Reef Fish, 438
shifting baselines, 44
shrimp trawling, 190–91
Siganidae, *see* rabbitfishes
single fishery, 147
single-species methods, 348–50
Bayesian approaches, 356
Monte Carlo analyses, 356
sensitivity analyses, 356
small-scale fisheries management, in developing countries, 15–16
capacity building for, 418–19
characterization, 405–6
emerging issues, 419
biodiversity conservation, 420–21
community governance, greater emphasis on, 420
ethical concerns, 420
new consumer preferences, 420
vulnerability due to climate change, 419–20
implementation, 416
communications, 417
compliance incentives, 417
dispute settlement mechanism, 417–18
monitoring and evaluation, 418
norms and regulations, making, 416
surveillance and enforcement, 417
institutional arrangements for, 413–14
management approaches for, 410
co-management approach, 412–13
community rights-based approach, 412
ecosystem approach, 413
preferential access approach, 411–12
management objectives for, 410
management plans for, 414–16
need for, 404–5
substantive contribution, 407
culture and traditions, maintaining, 409
food security, 408
foreign exchange earnings, 408
local economic development, 407–8
poverty prevention, 408–9
safety-net function, 408–9
socio-economic performance, 407
unfathomed knowledge base, 409
vision for, 406–7
see also artisanal fisheries; fisheries management
small-scope partnerships, 284–7
Smith, Adam, 75
social–ecological system, 53, 58–60
societal goals and impacts, 360–62
sole, 179, 180, 224, 243
Solomon Islands, 116, 264
South Africa, 115, 116, 130, 242, 247, 311
South Africa Marine Living Resources Act (1998), 128–9
South Atlantic Snapper-grouper fishery, 432
South East Atlantic Fisheries Organization (SEAFO), 126
Southern bluefin tuna, 33, 39, 427
southern Newfoundland, 229
Spain, 126
spawner-recruit (S–R) relationship curve, 35–6
spawning potential ratio (SPR), 36
spawning stock biomass (SSB), 246
spears and harpoons, 177, 188–9
Spiny Lobster, 229, 438, 441
stakeholder, 65, 339, 343

state governance, *see* state property
State institutions, 151, 152
state property, 54, 254
stationary' fishing gears, *see* passive fishing gears
stock fluctuations, 81–2
stock-output elasticity, 82–3
stock recruitment relationships, 35
Strombus gigas, *see* queen conch
stupefying devices, 182–3
subsidiarity principle, 60
subsistence fishery, 82
subtractability problem, 53
sunk costs, 78
supranational management, 155
surf zone fisheries, 207
surplus yield models, 26, 27
sustainability barometer, 308–9
sustainability first scenario, 470
sustainable development, 128–9
  see also ecologically sustainable development (ESD)
Sustainable Development Reference Systems (SDRS), 306
Sustainable Livelihood Approach (SLA) to fisheries, 311
sustainable livelihoods, 72
synthetic aperture radar (SAR), 390
system of indicators, development of, 306
  evaluation, 320–21
  framework selection, 308–11
  issues and challenges, 322
    capacity building, 324
    EAF and indicators, 325–7
    information gaps and uncertainty, 324–5
    institutionalisation, 324
    inter-sectoral systems, 325
    participation, 323
    simplification and realism, 323
    standards, need for, 323
    tensions and trade-offs, 327–8
  objectives, criteria and indicators, selecting, 312, 313
  scope and detail, 306–8
  success factors for, 321
System of Integrated Environmental and Economics Accounting (SEEA), 318

Tanganyika sardine, 92
Tanzania, 116, 121
targeted MCS, use of, 381
taxation, 93
technical measures, of fishing, 92–3, 118–20
territorial use rights in fishing (TURFs), 10, 255, 269, 278, 413
  and CMT, 263–4
Thompson, D'Arcy, 448
threatened species, 47–8
Thunnus maccoyii, *see* southern bluefin tuna
tidal traps, 176
timetable, for management plan development, 429–31
Tonga, 116, 117
total allowable catch (TAC), 94, 95, 117, 215, 223, 266, 267, 450
trade-related measures, 460
traditional ecological knowledge (TEK), 44, 63, 64, 261, 343
'tragedy of the commons', 53, 81
  property-rights regimes, in real world, 54–7
  science of the commons, developing, 53–4
trammel nets, 170–71, 187
transferability, 275–7
transferable versus non-transferable quota systems, 95–6
transformed world, 470–71
traps, 174, 176, 188
trawls and dredges, 178–9
trolling, 172–3, 187

UK Sea Fisheries Act (1993), 228
ultra vires, 114
UN Fish Stocks Agreement, 108, 113, 128, 129, 131, 451
UN General Assembly (UNGA) Resolutions, 111, 127, 131, 451, 471
unaccounted mortality, 184–5, 188, 189
UNCED Agenda 21, 116, 303
UNCED Earth Summit, 451
uncertainty
  versus insurance, 203
  and risk, 344–5
  in single-species methods, 356
unfathomed knowledge base, 409
UNGA Resolution 59/25, 131
UNGA Resolution 61/105, 131
United Nations Conference on Environment and Development (UNCED), 116, 128, 452, 460
United Nations Convention on the Law of the Sea (LOSC), 108, 376, 426
United Nations Development Programme (UNDP), 68, 318, 323
United Nations Environment Programme (UNEP), 450
United States, 126, 232, 286, 326, 432
Universal Declaration of Human Rights, 256
unregulated fisheries, 84–5, 101
unregulated fishing, definition, 373–4
unreported fishing, definition, 373
unsustainable fishing, 143–4
USA Caribbean, 438, 439
use rights, role of, *see* rights-based fisheries management

variable costs, 78
vessel monitoring systems (VMS), 125, 377, 388–9, 458
vessel usage controls, 222
Vietnam, 115, 126
Vietnam's Fisheries Law, 107
Village Fono Act, 121
voluntary compliance, 381–4
von Bertalanffy growth function, 37
vulnerability, 29–33, 419–20
vulnerable marine ecosystems (VMEs), 131, 133
vulnerable species, 39, 244

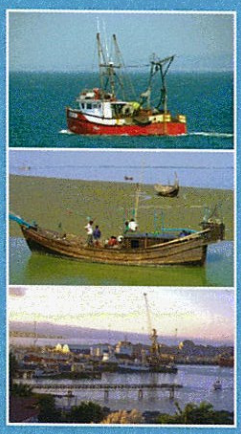
weak institutional capacity, 414
Western and Central Pacific Fisheries Commission (WCPFC), 113–14, 126, 394
Western Australian plan, for new fisheries development, 440–41
western rock lobster, 57
white abalone, 34
working principles for fisheries management, 6–7
World Summit on Sustainable Development (WSSD), 111, 433, 451, 468

Yemen's Fisheries Law, 107
yield- and biomass-per-recruit curves, 354

Zambia's Fisheries Act, 107

A FISHERY MANAGER'S GUIDEBOOK

SECOND EDITION



Fisheries around the world make essential contributions to human well-being including the provision of basic food supplies, employment, recreational opportunities, foreign currency and others, providing benefits to hundreds of millions of people. Despite these benefits, our record of managing fisheries so that the benefits can be sustained has been poor, at best, and most fisheries around the world are experiencing serious ecological, social or economic problems and usually all three. Today there is global concern about the state of fishery resources and aquatic ecosystems, their resilience to future stresses such as climate change and their ability to continue to provide benefits.

Fisheries management is the process that has evolved to try to ensure that fisheries operate in a manner that provides the immediate benefits in a sustainable manner. The widely accepted goal is that the full range of benefits should not only be available for this generation but for generations to come. Fisheries management has been successful in some cases but there have also been many, many cases of failure.

This volume is intended to contribute to improving this unsatisfactory state by addressing the widespread need for information and guidance on the broad and often complex task of fisheries management. It is an updated and expanded edition of *A Fishery Manager's Guidebook* which was published as a FAO Fisheries Technical Paper in 2002.

The major part of this new edition is divided into five parts intended to cover the range of concerns, tools and techniques essential to the modern fisheries manager, whether that manager is an individual or a formal or informal group. Following the Introduction:

- Part I examines the primary dimensions of fisheries: biological, ecological, social and economic
- Part II looks at the legal and institutional characteristics of fisheries
- Part III explores the tools that fishery managers have to achieve the objectives expected from a fishery
- Part IV discusses the role of scientific information of indicators and reference points
- Part V moves into implementation of fisheries management and includes a chapter on special considerations in small-scale fisheries

It concludes with a chapter that summarises the current state of knowledge and best practices and looks ahead to possible futures for fisheries governance.

This landmark publication is intended to be a practical guide to those actively engaged in fisheries management and will be of particular interest to fishery managers and scientists. All libraries in research establishments and universities where fisheries and aquatic sciences are studied and taught will need copies of this important volume.

About the Editors
Kevern L. Cochrane is Chief, Fisheries Management and Conservation Service of the Food and Agriculture Organization of the United Nations, Rome, Italy.
Serge M. Garcia is the former Director of the Fisheries and Aquaculture Management Division of the Food and Agriculture Organization of the United Nations, Rome, Italy.

Cover Design: Dan Patching Creative Design

ISBN 978-92-5-105963-0

9 789251 059630

I0053E/2/09.10

WILEY-BLACKWELL
www.wiley.com/wiley-blackwell