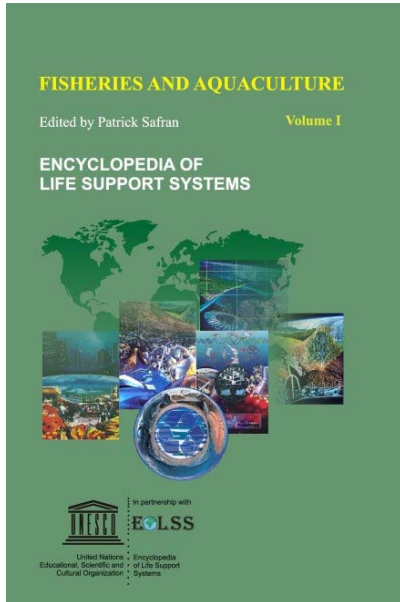


CONTENTS

FISHERIES AND AQUACULTURE



Fisheries and Aquaculture - Volume 1

No. of Pages: 338

ISBN: 978-1-84826-108-2 (eBook)

ISBN: 978-1-84826-558-5 (Print Volume)

Fisheries and Aquaculture - Volume 2

No. of Pages: 438

ISBN: 978-1-84826-109-9 (eBook)

ISBN: 978-1-84826-559-2 (Print Volume)

Fisheries and Aquaculture - Volume 3

No. of Pages: 470

ISBN: 978-1-84826-110-5 (eBook)

ISBN: 978-1-84826-560-8 (Print Volume)

Fisheries and Aquaculture - Volume 4

No. of Pages: 378

ISBN: 978-1-84826-111-2 (eBook)

ISBN: 978-1-84826-561-5 (Print Volume)

Fisheries and Aquaculture - Volume 5

No. of Pages: 458

ISBN: 978-1-84826-112-9 (eBook)

ISBN: 978-1-84826-562-2 (Print Volume)

For more information of e-book and Print Volume(s) order, please [click here](#)

Or [contact : eolessunesco@gmail.com](mailto:eolessunesco@gmail.com)

CONTENTS

VOLUME I

Fisheries and Aquaculture : Towards Sustainable Aquatic Living Resources Management 1

P. Safran, Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Paris, France (Present address: Asian Development Bank (ADB), Manila, Philippines)

1. Introduction
2. The Role of Fisheries
 - 2.1. An Important Agricultural Resource
 - 2.2. A Source of Foreign Exchange Earnings
 - 2.3. A Source of Protein
 - 2.4. A Source of Income
 - 2.5. A Source of Employment
 - 2.6. A Valuable Ecological Resource
 - 2.7. Towards Sustainable Fisheries Development
3. An Outline of Fisheries
 - 3.1. Artisanal Fisheries
 - 3.2. Industrial Fisheries
 - 3.3. Aquaculture
 - 3.4. Marine Fisheries
4. Fisheries Economic Outlook
 - 4.1. Fish Production
 - 4.2. Fish Trade
5. Fisheries Issues
 - 5.1. Coastal Resource Management
 - 5.1.1. The Law of the Sea
 - 5.1.2. Integrated Coastal Fisheries Management
 - 5.2. Economic Issues
 - 5.2.1. Overfishing
 - 5.2.2. Overcapacity
 - 5.2.3. Postharvest Losses
 - 5.2.4. Bycatch and Discards
 - 5.2.5. Subsidies
 - 5.3. Environmental Issues
 - 5.3.1. Ecosystems Degradation
 - 5.3.2. Destructive Fishing Practices
 - 5.3.3. Negative Impacts of Aquaculture
 - 5.3.4. Water Pollution
 - 5.4. Policy and Institutional Issues
6. Perspectives
 - 6.1. Fish Supply Outlook
 - 6.2. Towards Responsible Fisheries Management
7. Conclusion

Harvesting the Seas

26

Jean-Paul Troadec, Menez Perroz, Plouguerneau, France

1. Introduction
2. Historical Development
 - 2.1. Overview
 - 2.2. Intensification, Diversification and Geographical Expansion
 - 2.3. Development Factors
3. Fishery Systems
 - 3.1. Structure of Fisheries

- 3.2. Resource Units
 - 3.2.1. Nature and Composition
 - 3.2.2. Distribution and Migration Patterns
 - 3.2.3. Variability
- 3.3. Fishing or Production Systems
- 3.4. Exploitation Systems
- 3.5. Regulatory Systems
 - 3.5.1. Exclusivity Systems
 - 3.5.2. Mechanisms
 - 3.5.3. Structures
- 4. State of World Fisheries
 - 4.1. Resources
 - 4.1.1. Global Extension of Overfishing
 - 4.1.2. Discards
 - 4.1.3. World Fishery Potential
 - 4.2. Effects of Fishing on the Environment and Biodiversity
- 5. The Dynamics of Overfishing
 - 5.1. Cause, Nature and Effects
 - 5.2. Weaknesses of Conventional Methods of Access Regulation
 - 5.2.1. Conflicts
 - 5.2.2. Fishery Policies
 - 5.2.3. Crises
- 6. Conclusions

World Yields of Marine Organisms

54

C. Aliaume, *Laboratoire Hydrobiologie Marine et Continentale, Universit de Montpellier, France*

S. M. Garcia, *FAO, Fisheries Department, Italy*

R. J. R. Grainger, *FAO, Fisheries Department, Italy*

T. Do Chi, *Laboratoire Hydrobiologie Marine et Continentale, Universit de Montpellier, France*

- 1. Introduction
- 2. World Fishery Production over the last Half of Century with Recent Trends
- 3. Profile of Catches by FAO Fishing Area
 - 3.1. Northwest Atlantic (Area 21)
 - 3.2. Northeast Atlantic (Area 27)
 - 3.3. Western Central Atlantic (Area 31)
 - 3.4. Eastern Central Atlantic (Area 34)
 - 3.5. Mediterranean and Black Sea (Area 37)
 - 3.6. Southwest Atlantic (Area 41)
 - 3.7. Southeast Atlantic (Area 47)
 - 3.8. Western Indian Ocean (Area 51)
 - 3.9. Eastern Indian Ocean (Area 57)
 - 3.10. Northwest Pacific (Area 61)
 - 3.11. Northeast Pacific (Area 67)
 - 3.12. Western Central Pacific (Area 71)
 - 3.13. Eastern Central Pacific (Area 77)
 - 3.14. Southwest Pacific (Area 81)
 - 3.15. Southeast Pacific (Area 87)
- 4. Conclusion

Rational Exploitation and Conservation of Marine Ecosystems

80

Jean-Paul Troadec, *Menez Perroz, Plouguerneau, France*

- 1. Introduction
- 2. The Exploitation and Conservation of Natural Resources
 - 2.1. Technological Intensification and Production Systems
 - 2.2. Relationships between Production Systems and Ecosystems

- 2.2.1. Direct Impacts
- 2.2.2. Indirect Impacts
- 2.2.3. Exogenous Pollution
- 2.3. Adjustment of Production Systems to Ecosystem Capacity
- 3. Rationalization of Uses
 - 3.1. The Dynamics of Overfishing
 - 3.2. Management Objectives
 - 3.3. Biological and Economic Conditions of Sustainable Development
- 4. Effects on Wealth Distribution
- 5. Conclusions

Forecast of Yields**98**C. Aliaume, *Laboratoire Hydrobiologie Marine et Continentale, Universit de Montpellier, France*S. M. Garcia, *FAO, Fisheries Department, Italy*R. J. R. Grainger, *FAO, Fisheries Department, Italy*T. Do Chi, *Laboratoire Hydrobiologie Marine et Continentale, Universit de Montpellier, France*

- 1. Introduction
- 2. A perspective on Fisheries Trends Offered by Estimates of Production per Shelf Area
- 3. Development Trends and Potential
 - 3.1. Trends in Fishery Development
 - 3.2. Potential of Marine Fisheries
 - 3.3. Implications for Management and Development
- 4. El Nino: the Consequences for Fisheries
- 5. A Framework for Sustainable Fisheries
- 6. Conclusion

Pollution of the Hydrosphere and Quality Control in Natural Waters**116**Teruhisa Komatsu, *Ocean Research Institute, The University of Tokyo, Japan*

- 1. Introduction
- 2. Pollution Occurring in the Hydrosphere
 - 2.1. Reversible Pollution
 - 2.1.1. Acid Precipitation and UV-B Radiation
 - 2.1.2. Harmful Algal Blooms
 - 2.1.3. Heat
 - 2.1.4. Man-Made Debris
 - 2.1.5. Oil Pollution
 - 2.1.6. Metals
 - 2.1.7. Fishing and Aquaculture
 - 2.1.8. Global Warming
 - 2.2. Irreversible Pollution
 - 2.2.1. Chemical Pollutants and Environmental Endocrine Disrupters
 - 2.2.2. Radiation
 - 2.2.3. Introduction of Non-Indigenous Species
 - 2.2.4. Construction and Reclamation
- 3. Monitoring and Assessment
 - 3.1. Representative Monitoring Programs in the Hydrosphere
- 4. Water Quality Control and Environmental Management
 - 4.1. International and Regional Agreements Regulating Pollution
 - 4.2. National and Social Efforts to Regulate Pollution
 - 4.2.1. Waste Reduction
 - 4.2.2. Regulation and Management
- 5. Conclusion

Marine Organisms as Food, Forage, Industrial, and Medical Products**144**K. J. Whittle, *Torry Research Ltd., Aberdeenshire, Scotland, UK*

1. Historical Perspective
 - 1.1. Food Use
 - 1.1.1. Early to Classical Times
 - 1.1.2. Middle Ages to the Twentieth Century
 - 1.2. Non-food UsesBy-products
 - 1.3. Seaweeds
2. The Current Picture of Food and Non-food Uses
 - 2.1. Gross Disposal of World Fish Production from 1948 to 1996
 - 2.2. Fish and Shellfish as Food
 - 2.2.1. Characteristics of Seafood
 - 2.2.2. Nutrition and Health
 - 2.2.3. Process Yields the Edible Portion
 - 2.2.4. Potential for Increased Availability for Food
 - 2.3. Seafood Products
 - 2.3.1. Live Fish and Shellfish and Chilled Products
 - 2.3.2. Frozen Fish and Products
 - 2.3.3. Canned and Other Thermally Processed Products
 - 2.3.4. Cured and Preserved Products
 - 2.4. Non-food Uses of Fish
 - 2.4.1. Fish Meal and Oils
 - 2.4.2. Fish as Feed, Silage and Hydrolysates
 - 2.4.3. Crustacean Wastes- Chitin and Chitosan
 - 2.4.4. Secondary Metabolites of Marine Organisms- Uses in Medicine, Health and Nutrition
 - 2.4.5. Products from Cultured Microorganisms and Uses
 - 2.4.6. Seaweeds and Uses of Seaweeds
3. Future Prospects

Allocation of Use Rights and Adjustment of Institutions**178**Jean-Paul Troadec, *Menez Perroz, Plouguerneau, France*

1. Introduction
2. Exclusivity Systems
 - 2.1. State Sovereignty
 - 2.2. Resource Property
 - 2.3. Use Rights
3. Allocation Mechanisms
 - 3.1. Social Controls
 - 3.2. Command and Control
 - 3.3. Market
 - 3.4. Taxation
 - 3.5. Co-management
4. Regulatory Bodies
5. Conclusions

Subsidies to Fishing**198**Ronald P. Steenblik, *Organisation for Economic Co-operation and Development (OECD), France*F.J. Paul Wallis, *Ministry of Fisheries, Wellington, New Zealand*

1. Introduction
2. Why do Governments Subsidize Fisheries?
 - 2.1. National Defense
 - 2.2. Competition for Common-Pool Resources
 - 2.3. UNCLOS and New Sovereign Rights

- 2.4. Perceived Market Failures and Structural Problems
3. Subsidies and Their Classification
4. Effects of Subsidies
 - 4.1. Static Analysis
 - 4.1.1. Effect of Revenue-Enhancing Subsidies
 - 4.1.2. Effects of Cost-Reducing Subsidies
 - 4.1.3. Effects of Capacity-Reducing Subsidies
 - 4.2. Dynamic Effects and the Political Economy of Subsidies
5. Subsidy Reform
 - 5.1. Multilateral Frameworks: a Historical Background
 - 5.2. Current and Future Multilateral Frameworks
 - 5.3. A Case Study in Reform: Norway

Fishing Port Management, the Forgotten Subject

216

Roland Bernd Scheffczyk, *Senior Port Management Consultant, Bremerhaven, Germany*

1. Historical Development of Service Functions of Fishing Ports
2. Definitions Applied
 - 2.1. Fishing Port—System Approach
 - 2.2. Fishing Port—Operational Approach
 - 2.3. Fishing Port—Functional Approach
3. Key Functions of a Modern Fishing Port
 - 3.1. General Management Function
 - 3.2. Operation Function
 - 3.3. Service Function
4. Differentiation of Port Functions and Services
 - 4.1. Port Infrastructure versus Suprastructure Facilities
 - 4.1.1. Port Infrastructure Facilities
 - 4.1.2. Port Suprastructure Facilities
 - 4.2. Differentiation of Port Users and Customers
5. Fishing Port Management Planning
 - 5.1. Some Essential Considerations for Port Management Planning
 - 5.1.1. Some Basic Considerations in Planning Fishing Port Management Concepts
 - 5.1.2. Port Operation and Business Environment
 - 5.2. Components of Management Planning
 - 5.3. The Role of a Fishing Port Authority
6. Basic Concepts of Management Structures
 - 6.1. Management Structures and Organization
 - 6.1.1. Minor Fishing Harbor under Government Administration
 - 6.1.2. Major Fishing Port Managed by a Semi-Autonomous Port Management
 - 6.1.3. Nucleus and Plasma Port, Autonomous Fishing Port Authority
 - 6.1.4. Landlord Port
7. Introduction to Fishing Port Operation Management
 - 7.1. Operation Management Parameters
 - 7.1.1. Definition of Port Operation
 - 7.2. Objectives of Operation Management
 - 7.2.1. Operational Efficiency
 - 7.2.2. Management Efficiency
8. Management Planning
 - 8.1. Control Systems in Port Operations
 - 8.2. Organization of Port Operations
 - 8.2.1. Authorities
 - 8.2.2. Organization by Functions
 - 8.3. Technical Management in Port Operations
 - 8.3.1. Port Infrastructure Development Projects
 - 8.3.2. Technical Management in Project Implementation
 - 8.3.3. Maintenance Works Planning

9. Inventory Management and Control
10. Port Operation and Fishing Fleet Management
 - 10.1. Effective Fleet Management
 - 10.2. Mobility of Fishing Fleets
 - 10.3. Training as a Management Tool

Index 245

About EOLSS 253

VOLUME II

Marine Fish and Invertebrates: Biology and Harvesting Technology 1
 R. Radtke, *University of Hawai'i at Manoa, Hawai'i Institute of Geophysics and Planetology, Honolulu, USA*

1. Introduction
2. New approaches
3. Biology and Harvesting of Major Species
 - 3.1. Schooling Finfish (Cods, Herrings, Sardines, Mackerels, and others)
 - 3.2. Tunas, Billfish and Sharks
 - 3.3. Shrimp and Krill
 - 3.4. Crabs and Lobsters
 - 3.5. Shelled Molluscs (Clams, Oysters, Scallops, Pearl Oysters, and Abalone)
 - 3.6. Cephalopods: Octopus and Squid
 - 3.7. Orange Roughy and Other Benthic Finfish
 - 3.8. Flatfishes and Skates
4. Marine Plants: Production and Utilization
5. Commercial Sea-Cucumbers and Trepanng Markets
6. Importance of Non-commercial Fish
7. The Problem of Discards in Fisheries
8. Fisheries Engineering and Technology: Fishing Operation and Economic Considerations
9. Subsistence Hunting of Marine Mammals

Schooling Finfish (Cods, Herrings, Sardines, Mackerels, and Others) 23
 Y. Sakurai, *Hokkaido University, Graduate School of Fisheries Sciences, Hakodate, Hokkaido, Japan*
 Jean-Claude Quero, *IFREMER-La Rochelle, L'Houmeau, France*

1. Introduction
2. Peruvian Anchoveta (*Engraulis ringens*, Jenyns 1842)
3. Alaska Pollock (*Theragra chalcogramma*, Pallas 1811)
4. Chilean Jack Mackerel (*Trachurus murphyi*, Nichols 1920)
5. Atlantic Herring (*Clupea harengus*, Linné 1758)
6. Chub Mackerel (*Scomber japonicus*, Houttuyn 1782)
7. Capelin (*Mallotus villosus*, Müller 1776)
8. South America Pilchard (*Sardinops sagax*, Jenyns 1842)
9. Atlantic Cod (*Gadus morhua*, Linnaeus 1758)
10. Pacific Cod (*Gadus macrocephalus*, Tilesius 1810)
11. Japanese Anchovy (*Engraulis japonicus*, Temminck and Schlegel 1846)
12. Sardine (*Sardina pilchardus*, Walbaum 1792)

Schooling Finfish: an Overview of the Tunas, Billfishes and Sharks

42

Alain Fonteneau, *Institut de Recherches pour le Développement, Victoria, Seychelles Islands*Tom Nishida, *National Research Institute of Far Seas Fisheries, Shimizu-shi, Japan*Izumi Nakamura, *Kyoto University, Fisheries Research Station, Maizuru, Kyoto, Japan*Bernard Seret, *Museum d'Histoire Naturelle, Ichthyologie, Paris, France*

1. An Overview of the Tunas, Billfishes and Sharks
 - 1.1. Systematics
 - 1.2. Tuna Anatomy, Biology, Behavior and Physiology
 - 1.3. Tuna Migration and Movement
 - 1.4. Ecosystem Overview of Tunas and Other Species in the Pelagic Offshore Ecosystem
 - 1.5. Overview of the World Tuna Fisheries
 - 1.5.1. Fishing Gear
 - 1.5.2. Fishing Areas
 - 1.5.3. Overfishing and Tuna Resources
 - 1.5.4. Tuna Management and Tuna Commissions
 - 1.5.5. Tuna Markets: A Short Overview
2. Species by Species Overview and Discussion
 - 2.1. Skipjack Tuna (*Katsuwonus pelamis*)
 - 2.1.1. Biology
 - 2.1.2. Overview of the Fisheries
 - 2.1.3. General Discussion on Stock Status
 - 2.2. Bigeye Tuna (*Thunnus obesus*)
 - 2.2.1. Biology
 - 2.2.2. Overview of the Fisheries
 - 2.2.3. General Discussion on Stock Status
 - 2.3. Albacore Tuna (*Thunnus alalunga*)
 - 2.3.1. Biology
 - 2.3.2. Overview of the Fisheries
 - 2.3.3. General Discussion on Stock Status
 - 2.4. Yellowfin Tuna (*Thunnus albacares*)
 - 2.4.1. Biology
 - 2.4.2. Overview of the Fisheries
 - 2.4.3. General Discussion on Stock Status
 - 2.5. Northern Bluefin Tuna (*Thunnus thynnus*)
 - 2.5.1. Pacific Northern Bluefin Tuna (*Thunnus thynnus orientalis*)
 - 2.5.1.1. Biology
 - 2.5.1.2. Overview of the Fisheries
 - 2.5.1.3. General Discussion on Stock Status
 - 2.5.2. Atlantic Northern Bluefin Tuna (*Thunnus thynnus thynnus*)
 - 2.5.2.1. Biology
 - 2.5.2.2. Overview of the Fisheries
 - 2.5.2.3. General Discussion on Stock Status
 - 2.6. Southern Bluefin Tuna (*Thunnus thynnus maccoyii*)
 - 2.6.1. Biology
 - 2.6.2. Overview of the Fisheries
 - 2.6.3. General Discussion on Stock Status
 - 2.7. Minor Tunas
3. Overview of Sharks
 - 3.1. Systematics
 - 3.2. Biology
 - 3.3. Overview of the World Shark Fisheries
 - 3.4. Management of Shark Resources
4. Billfishes
 - 4.1. Systematics
 - 4.2. Biology
 - 4.3. Overview of the Fisheries
 - 4.4. General Discussion on Stock Status

- 4.5. Market
5. Recommendations

Shrimps and Krill

80

J. Marin, *Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Centre Halieutique Méditerranéen et Tropical, Sète, France*

1. Shrimps
 - 1.1. Introduction
 - 1.2. Taxonomy
 - 1.3. General Distribution
 - 1.4. Biology
 - 1.4.1. Habits
 - 1.4.2. Reproduction
 - 1.4.3. Growth
 - 1.4.4. Feeding
 - 1.5. Harvesting
 - 1.5.1. Production Systems
 - 1.5.1.1. Industrial Fisheries
 - 1.5.1.2. Small-Scale and Artisanal Fisheries
 - 1.5.2. Landings
 - 1.5.2.1. Landings by Major Fishing Areas
 - 1.5.2.2. Main Commercial Species
 - 1.5.2.3. Main Producing Countries
 - 1.6. Management
2. Krill
 - 2.1. Introduction
 - 2.2. Morphological Characteristics
 - 2.3. General Distribution
 - 2.4. Biology
 - 2.4.1. Habits
 - 2.4.2. Reproduction
 - 2.4.3. Growth
 - 2.4.4. Feeding
 - 2.5. Harvesting
 - 2.6. Management

Crabs and Lobsters

112

D. Latrouite, *Department of Fisheries, IFREMER, BP 70, 29 280 Plouzané, France*

J. D. Booth, *NIWA, Wellington, New Zealand*

G. S. Jamieson, *Fisheries and Oceans, Canada*

1. Introduction
2. Species and Fisheries
 - 2.1. Crabs
 - 2.1.1. The Dungeness Crab (*Cancer magister*) Fishery
 - 2.1.2. The Blue Crab (*Callinectes sapidus*) Fishery of the USA
 - 2.1.3. The Snow Crab (*Chionoecetes opilio*) Fishery
 - 2.1.4. Other Crab Fisheries
 - 2.2. Lobsters
 - 2.2.1. Clawed Lobster Fisheries
 - 2.2.2. The Norway Lobster (*Nephrops norvegicus*) Fishery
 - 2.2.3. The American Lobster (*Homarus americanus*) Fishery
 - 2.2.4. The European Lobster (*Homarus gammarus*) Fishery
 - 2.2.5. Other Clawed Lobster Fisheries
 - 2.2.6. Spiny Lobster and Slipper Lobster Fisheries

- 2.2.7. The Caribbean Spiny Lobster (*Panulirus argus*) Fishery
- 2.2.8. The Western Australian Rock Lobster (*Panulirus cygnus*) Fishery
- 2.2.9. The Red (New Zealand)/Southern (Australian) Rock Lobster (*Jasus edwardsii*) Fisheries
- 2.3. Other Spiny Lobster Fisheries, and Slipper Lobster Fisheries
- 3. Harvesting
 - 3.1. Traps
 - 3.2. Nets
 - 3.3. Trawls
 - 3.4. Diving
 - 3.5. Hand
- 4. Biology
 - 4.1. General Ecology
 - 4.2. Growth
 - 4.3. Reproduction
 - 4.4. Larval Stage in Relation to Dispersal and Stock Abundance
 - 4.5. Migration
- 5. Stock Assessment and Management Approaches
 - 5.1. Stock Assessment
 - 5.1.1. Assessments Based on Catch per Unit Effort
 - 5.1.2. Assessments Based on Size Frequency Distributions
 - 5.1.3. Direct Assessment
 - 5.1.4. Post-larval Settlement and Pre-recruit Indices
 - 5.2. Selective Impact of Fishing
 - 5.3. Management Strategies
 - 5.3.1. Regulation of Harvested Individuals
 - 5.3.2. Population Harvest Controls
 - 5.4. Sanctuaries or Refugia
- 6. Issues for the Future

Shelled Molluscs

135

Berthou P., *Institut Français de Recherche pour l'Exploitation de la Mer, Plouzané, France*

Poutiers J. M., *Muséum National d'Histoire Naturelle, Paris, France*

Gouletquer P., *Institut Français de Recherche pour l'Exploitation de la Mer, La Tremblade, France*

Dao J.C., *Institut Français de Recherche pour l'Exploitation de la Mer, Plouzané, France*

- 1. Introduction
 - 1.1. Uses of Shellfish: An Overview
 - 1.2. Production
- 2. Species and Fisheries
 - 2.1. Diversity of Species
 - 2.1.1. Edible Species
 - 2.1.2. Shellfish Species Not Used as Food
 - 2.2. Shelled Molluscs Fisheries
 - 2.2.1. Gastropods
 - 2.2.2. Oysters
 - 2.2.3. Mussels
 - 2.2.4. Scallops
 - 2.2.5. Clams
 - 2.3. Shelled Molluscs Cultivation
 - 2.3.1. Gastropods
 - 2.3.2. Oysters
 - 2.3.3. Mussels
 - 2.3.4. Scallops
 - 2.3.5. Clams
- 3. Harvesting and Cultivation Techniques
 - 3.1. Harvesting

- 3.2. Cultivation techniques
4. Biology
 - 4.1. General Ecology
 - 4.2. Growth
 - 4.3. Reproduction
 - 4.4. Larval Stage in Relation to Dispersal and Stock Abundance
 - 4.5. Migration
5. Stock Assessment and Management Approaches
 - 5.1. Stock Assessment
 - 5.2. Management Strategies
6. Issues for the Future

Squid, Octopus and the Living Cephalopods

159

R. K. O'Dor, *Biology Department, Dalhousie University, Halifax, NS, Canada*

T. Okutani, *College of Bioresource Science, Nihon University, Kanagawa-ken, Japan*

C. O. Inejih, *Centre de Recherches Oceanographiques et des Peches Nouadhibou, Mauritania*

1. Introduction
2. Taxonomy
3. Distribution
4. Life History
5. Ecology
6. Production and Biomass
7. Size Spectra
8. Fisheries Management
9. Aquaculture

Orange Roughy and Other Deepwater Benthic Fishes

174

M. R. Clark, *National Institute of Water and Atmospheric Research, P O Box 14-901, Wellington, New Zealand*

J. C. Quero, *IFREMER-La Rochelle, BP 7 - 17137 L'Houmeau, France*

1. Foreword
2. The Deepwater Environment
3. Orange Roughy, *Hoplostethus atlanticus*, Collett, 1889
4. Round Nose Grenadier, *Coryphaenoides rupestris*, Gunnerus, 1765
5. Black Scabbard Fish, *Aphanopus carbo*, Lowe, 1839
6. Alfonsinos, *Beryx* spp
7. Oreos, *Allocyttus niger*, James, Inada and Nakamura 1988; *Pseudocyttus maculatus* Gilchrist 1906
8. Black Cardinal Fish, *Epigonus telescopus*, Risso, 1810
9. Tooth Fish, *Dissostichus eleginoides*, Smitt, 1898; *D. mawsoni*, Norman, 1937

Flatfishes and Skates

189

J. C. Quero, *IFREMER -La Rochelle, L'Houmeau, France*

1. Introduction
2. Plaice, *Pleuronectes platessa*, Linnaeus, 1758
3. Greenland Halibut, *Reinhardtius hippoglossoides*, Walbaum, 1792
4. The Yellow Fin Sole, *Limanda aspera*, Pallas, 1811
5. Common Sole, *Solea solea*, Linnaeus, 1758
6. Atlantic Halibut, *Hippoglossus hippoglossus*, Linnaeus, 1758
7. The Other Flatfish

Marine Plants: Production and Utilization**197**Rene Perez, *Institut Français de Recherches pour L'Exploitation de la Mer (IFREMER), Nantes Seaweed production and biotechnology Laboratory, France*

1. Foreword
2. Alginophyts and Alginic Acid
 - 2.1. Structure of Alginic Acid (Figure 5)
 - 2.2. Properties of Alginic Acid
 - 2.3. Species Concerned
 - 2.4. Markets of Alginic Acid (Figure 9)
3. Agarophyts and Agars
 - 3.1. Agar Structure (Figure 11)
 - 3.1.1. Agarose Types
 - 3.1.2. "Loaded" Agarose Types
 - 3.1.3. Galactan Types
 - 3.2. Species Concerned
 - 3.2.1. Gelidiaceae
 - 3.2.2. Gigartinaceae
 - 3.3. Agar Properties
 - 3.4. Agar Uses (Figure 14)
 - 3.5. Agar Market
4. Carrageenophyts and Carrageenans
 - 4.1. Chemical Structure (Figure 16)
 - 4.2. Carrageenophyts (Figure 17 and 18)
 - 4.3. Types of Carrageenans
 - 4.4. "Semi-refined" or P.N.G. (Philippin National Gum) Carrageenans
 - 4.5. Carrageenan Properties
 - 4.5.1. Reactions with Proteins
 - 4.5.2. Reactions with Milk
 - 4.5.3. Reactions with Lipids
 - 4.6. Production and Utilizations of Carrageenans
 - 4.6.1. Milk Derivatives (Figure 21)
 - 4.6.2. Water Gels
 - 4.6.3. Structured Products
 - 4.6.4. Diet Foods
 - 4.6.5. Cosmetics
 - 4.6.6. Animal Food
 - 4.6.7. Deodorant Gels
 - 4.7. World Production
5. Conclusion

Commercial Sea Cucumbers and Trepang Markets**221**C. Conand, *Laboratoire d'Ecologie Marine, Université de La Réunion, Saint-Denis, France*

1. Introduction
 - 1.1. General Remarks on Sea Cucumbers
 - 1.2. The Holothurian Fishery System
2. The Commercial Sea Cucumbers
 - 2.1. Tropical Species
 - 2.1.1. Species of the Traditional Western Pacific and Indian Ocean Fisheries
 - 2.1.2. Species of the Recent Tropical Fisheries
 - 2.2. Temperate Species
 - 2.2.1. Species of the Traditional Western Pacific Fisheries
 - 2.2.2. Species of the Recent Temperate Fisheries
3. Collecting and Processing Methods for Trepang
 - 3.1. Collecting Methods

- 3.1.1. Processing Methods
- 3.2. Grading and Storing
- 4. The Main World Fisheries
 - 4.1. Tropical Fisheries
 - 4.1.1. Traditional Western Pacific and Indian Ocean Fisheries
 - 4.1.2. Western Central Pacific Countries
 - 4.1.3. Indian Ocean Countries
 - 4.1.4. Recent Eastern Pacific and Atlantic Fisheries
 - 4.2. Temperate Fisheries
 - 4.2.1. Traditional Western Pacific Fisheries
 - 4.2.2. Recent Temperate Fisheries
 - 4.3. Conflicts between Users
- 5. The Main World Markets
 - 5.1. Hong Kong
 - 5.2. Singapore
 - 5.3. Taiwan
 - 5.4. Interactions between the Markets
- 6. Over-exploitation and Sustainable Management
 - 6.1. Over-exploitation
 - 6.2. Sustainable Management
- 7. Conclusion: A Short Guide for Further Study

The Importance of Non-Commercial Fish

251

E. Baran, *ICLARM, Penang, Malaysia*

- 1. Introduction
- 2. Importance of Non-commercial Fish in Terms of Global Harvests
- 3. Importance of Non-commercial Fish for Humans
- 4. Importance of an Ecosystem Approach for the Sustainability of the Resource

The Problem of Discards in Fisheries

259

Y. Morizur, *IFREMER, Brest, France*B. Caillart, *COFREPECHE, Brest, France*D. Tingley, *MacAlister Elliott and Partners Ltd, Lymington, UK*

- 1. Introduction
- 2. Controversial Definitions
- 3. Reasons for Discarding
- 4. Variability in Discarding Practices
- 5. Case Studies
 - 5.1. The Northwest Atlantic Fisheries
 - 5.2. The European Union Fisheries
 - 5.3. The Shrimp Fishery in Madagascar
- 6. Impacts of Discards
 - 6.1. Biological and Ecological Impact
 - 6.2. Stock Assessment Impact
 - 6.3. Economic and Social Impact
 - 6.3.1. Valuation of Discards
 - 6.3.2. Economic Impacts
 - 6.3.2.1. Commercial Species Discards
 - 6.3.2.2. Discards of Non-commercial Species
 - 6.3.2.3. Costs of Managing Discards
 - 6.3.3. Social Impacts
- 7. Solutions
 - 7.1. Improve the Trade Utilization of Species
 - 7.2. Improve the Selectivity of Fishing Operations

- 7.2.1. Adequate use of Existing Gears
- 7.2.2. Increase Mesh-size and Improve Gear Selectivity
- 7.2.3. Spatial and Temporal Management of Fishing Effort
- 7.3. Modify Management Policy
- 8. Conclusions

Fisheries Engineering and Technology; Fishing Fleet Operation and Economical Considerations

283

Joel Prado, *Fishery Industries Division, Fisheries Department, FAO; Via delle Terme di Caracalla, 00100 Roma, Italy*

1. Evolution Regarding Fishing Technology and Equipment; the Effectiveness of an Individual Fishing Unit
 - 1.1. Fishing Vessels
 - 1.2. Fishing Gear
 - 1.2.1. Trawl
 - 1.2.2. Purse Seines
 - 1.2.3. Pots or Traps
 - 1.2.4. Hooks and Lines
 - 1.2.5. Gillnets
 - 1.2.6. Dredge
 - 1.2.7. Related Research
 - 1.3. Equipment and Auxiliaries for Fishing Gear Operation
 - 1.4. On Board Fish Conservation and Processing see, *Marine Organisms as Food, Forage, Industrial and Medical Products*
2. Fishing Fleets: Technical and Economical Features; Capacity and Effort; Evolution
 - 2.1. Fleet Identification
 - 2.2. Main Types of Fishing Fleets and Operations: Technological and Economical Considerations
 - 2.3. Multipurpose Vessels
 - 2.4. Fishing Fleet Productivity
 - 2.4.1. Fishing Power and Efficiency
 - 2.4.2. Costs of Operation
 - 2.4.3. Value of the Catch
 - 2.4.4. Fishing Capacity
 - 2.5. Evolution of Fishing Fleet Effectiveness
 - 2.6. Recommendations for Investment in Fishing Units and Equipment
3. Alternative Methods for the Exploitation of Aquatic Resources
 - 3.1. Species being Fished
 - 3.2. Fishing Depth (see, *Figure 1*)
 - 3.3. Characteristics of the Sea Bed (see, *Figure 1*)
 - 3.4. Value of the Catch
 - 3.5. Technical Considerations
 - 3.6. Human, Social and Political Considerations
 - 3.7. Consideration of Factors Affecting Fishing Technique Selection
4. New Conditions for Fishing Operations; Context for the Development of Fishing Fleets; Opportunities
 - 4.1. New Conditions for Fishing Operations and Relevant Research
 - 4.1.1. Selective Fishing
 - 4.1.2. Monitoring and Control of Fishing Operations
 - 4.1.3. Careful Evaluation of Fishing Power and Effort and Impact of Fishing Operations
 - 4.1.4. Safety and Working Conditions of Fishing Operations
 - 4.1.5. Waste Generated by Fishing Vessels
 - 4.2. Context for the Development of Fishing Fleets, Opportunities

Subsistence Hunting of Marine Mammals**321**

Emer Rogan, *Department of Zoology and Animal Ecology, University College, Cork, Ireland*
 Donna Kwan, *School of Tropical Environment Studies and Geography, James Cook University, Townsville, Australia*
 Greg Donovan, *International Whaling Commission, Cambridge, England*

1. Introduction
2. Polar bears
 - 2.1. Hunting and Management
3. Sirenians
 - 3.1. Distribution
 - 3.2. Historical Evidence of Subsistence hunting
 - 3.3. Utilisation
 - 3.3.1. Consumption
 - 3.3.2. Medicinal
 - 3.3.3. Utility
 - 3.3.4. Other uses
 - 3.4. Hunting Methods
 - 3.5. Management
4. Pinnipeds
 - 4.1. Otariidae: sea lions and fur seals
 - 4.2. Odobenidae: Walruses
 - 4.3. Phocidae: true seals
 - 4.3.1. Harbor seals (*Phoca vitulina*)
 - 4.3.2. Ringed seals (*Phoca hispida*)
 - 4.3.3. Harp seal (*Pagophilus groenlandicus*)
 - 4.3.4. Hooded seals (*Cystophora cristata*)
 - 4.4. Management
5. Cetaceans
 - 5.1. Present aboriginal subsistence whaling operations regulated by the IWC.
 - 5.1.1. Bering-Chukchi-Beaufort Seas stock of bowhead whales
 - 5.1.2. Eastern North Pacific gray whales
 - 5.1.3. Greenlandic whaling
 - 5.1.4. Humpback whales taken by St Vincent and The Grenadines
 - 5.2. Aboriginal subsistence whaling operations outside the IWC
 - 5.2.1. Catches of bowhead whales by Canada from the Baffin Bay/Davis Strait and Hudson Bay/Foxe Basin stocks
 - 5.2.2. Catches of white whales and narwhals
 - 5.3. Management

Index**343****About EOLSS****351****VOLUME III****Inland Fisheries****1**

R. L. Welcomme, *RRAG, T.H. Huxley School, Imperial College, University of London, London, UK*

1. Introduction
2. Types of Inland Water
 - 2.1. Lakes
 - 2.2. Rivers
 - 2.3. Swamps, Marshes and Rice Fields
 - 2.4. Reservoirs

- 2.5. Coastal Lagoons
- 3. Fisheries Ecology
 - 3.1. Lakes
 - 3.2. Rivers
 - 3.3. Swamps, Marshes and Rice Fields
 - 3.4. Reservoirs
 - 3.5. Coastal Lagoons
- 4. Characteristics of Fisheries
 - 4.1. Purposes of Management
 - 4.1.1. Food Fisheries
 - 4.1.2. Recreational Fisheries
 - 4.1.3. Fisheries for Ornamental Species
 - 4.1.4. Management for other Purposes
 - 4.2. Types of Fisherfolk
 - 4.2.1. Full-time Fishers
 - 4.2.2. Part-time Fishers
 - 4.2.3. Subsistence Fishers
 - 4.2.4. Recreational Fishers
- 5. Types of Fishery
 - 5.1. Conventional Fisheries
 - 5.1.1. Lakes and Reservoirs
 - 5.1.1.1. Demersal Fisheries
 - 5.1.1.2. Pelagic Fisheries
 - 5.1.2. Rivers
 - 5.1.3. Coastal Lagoons
 - 5.1.4. Potential
 - 5.1.4.1. Lakes and Reservoirs
 - 5.1.4.2. Rivers
 - 5.2. Enhanced Fisheries
- 6. Environmental Impacts of Other Users
 - 6.1. Eutrophication
 - 6.2. Pollution
 - 6.3. Sediment
 - 6.4. Acidification
 - 6.5. Dam Building
 - 6.6. Levee Construction
 - 6.7. Changes in Discharge
- 7. Sustainable Management of Fisheries
 - 7.1. Management of the Environment
 - 7.2. Management of the Fishery

Trends in World Yields for Inland Waters

22

R. L. Welcomme, *RRAG, T.H. Huxley School, Imperial College, University of London, London, UK*

- 1. Introduction
- 2. Global Trends in Catch
 - 2.1. Tonnage Caught (Figure 1)
 - 2.2. Proportion of Catch by Region (Figure 2)
- 3. Regional Trends in Catch
 - 3.1. Africa
 - 3.1.1. Total Production (Figure 3)
 - 3.1.2. Regional Production (Figure 4)
 - 3.2. Asia
 - 3.2.1. Total Production (Figure 5)
 - 3.2.2. Regional Production (Figure 6)
 - 3.3. Europe
 - 3.3.1. Total Catch (Figure 7)

- 3.3.2. Regional Analysis (Figure 8)
- 3.4. North America
 - 3.4.1. Total Catch (Figure 9)
 - 3.4.2. Regional Analysis (Figure 10)
- 3.5. South America
 - 3.5.1. Total Catch (Figure 11)
 - 3.5.2. Regional Analysis (Figure 12)
- 3.6. Oceania (Figure 13)
- 3.7. Russia and Associated Territories (Figure 14)
- 4. Species Composition
 - 4.1. Global Trends (Figure 15)
 - 4.2. Regional Trends
 - 4.2.1. Asia (Figure 17)
 - 4.2.2. Africa (Figure 18)
 - 4.2.3. Europe (Figure 19)
 - 4.2.4. North America (Figure 20)
 - 4.2.5. South America (Figure 21)
 - 4.2.6. Oceania (Figure 22)
 - 4.2.7. Russia and Associated Areas (Figure 23)
- 5. Prognosis

Salmonid Fish: Biology, Conservation Status, and Economic Importance of Wild and Cultured Stocks 42

William Pennell, *Malaspina University College, Nanaimo, British Columbia, Canada*
 Patrick Prouzet, *IFREMER, Laboratoire Halieutique d'Aquitaine, France*

- 1. Introduction
 - 1.1. Classification
- 2. Nomenclature and Distributions of the Salmonids.
- 3. General Life History and Biology
- 4. Environmental Requirements
 - 4.1. Temperature
 - 4.2. Salinity
 - 4.3. pH
- 5. Human and Natural Environmental Influences on Salmonid Populations
- 6. A Detailed Life History Account of a Representative Salmonid Species, the Atlantic Salmon
 - 6.1. Evolutionary History
 - 6.2. Fresh Water Life
 - 6.3. Marine life: its importance and conservation
- 7. Economic and Cultural Importance of Salmonids

Commercially Important Catadromous Fish 66

E. Feunteun, *Laboratoire d'Evolution des Systèmes Naturels et Modifiés, UMR 6553 "EcoBio," Université de Rennes 1, Campus Beaulieu, Rennes Cedex, France*
 P. Laffaille, *Laboratoire d'Evolution des Systèmes Naturels et Modifiés, UMR 6553 "EcoBio," Université de Rennes 1, Campus Beaulieu, Rennes Cedex, France*
 J. Aoyama, *Ocean Research Institute, University of Tokyo, Japan*
 M.N. De Casamajor, *IFREMER, Saint Pée sur Nivelle, France*
 P. Dumont, *Faune et Parcs Québec, 201 Place Charles-Lemoyne, Longueuil, Québec, Canada*
 D. Jellyman, *National Institute of Water and Atmospheric Research Ltd, Christchurch, New Zealand*

- 1. Generalities on the Anguillids
 - 1.1. Systematics and Description
 - 1.2. General Biology and Ecology
 - 1.2.1. Biological Cycle
 - 1.2.2. Reproduction

- 1.2.3. Leptocephali Stage
- 1.2.4. Glass Eel Stage
- 1.2.5. Yellow Eel Stage
- 1.2.6. The Silver Eel Stage
- 1.3. Ecology
 - 1.3.1. Distribution
 - 1.3.2. Diet
 - 1.3.3. Role in Aquatic Biocenose
- 1.4. Evolution
- 2. Atlantic Eels
 - 2.1. Distribution and Stocks
 - 2.1.1. European Eels
 - 2.1.2. American Eels
 - 2.2. Biology and Ecology
 - 2.2.1. Biological Cycle
 - 2.3. Population Dynamics
 - 2.3.1. Growth
 - 2.3.2. Age
 - 2.3.3. Sex Ratio
 - 2.3.4. Mortality
 - 2.3.5. Upstream and Downstream Migration
 - 2.3.6. Status of the Stock
 - 2.4. Socio-economy
 - 2.4.1. Fisheries
 - 2.4.2. Eel Farming
- 3. Japanese Eels
 - 3.1. Distribution and Stocks
 - 3.2. Biological Cycle
 - 3.3. Population Dynamics
 - 3.4. Socio-economy
- 4. Indo Pacific Eels
 - 4.1. Distribution and Stocks
 - 4.2. Biology and Ecology
 - 4.2.1. Life History
 - 4.3. Population Dynamics
 - 4.3.1. Growth
 - 4.4. Socio-economy
- 5. Status of the Species: A General Decline?
 - 5.1. Marine Causes
 - 5.2. Continental Causes
 - 5.2.1. Migration Obstructions
 - 5.2.2. Fisheries
 - 5.2.3. Habitat Loss
 - 5.2.4. Parasites and Diseases
 - 5.2.5. Effects of Pollutants
- 6. Baseline for Sustainable Management
 - 6.1. Local Restoration Program
 - 6.1.1. Step 1: Characterizing the Stocks and Defining Restoration Targets
 - 6.1.2. Step 2: Defining Restoration Actions
 - 6.1.3. Step 3: Monitoring the Population Parameters
 - 6.2. International Cooperation (Adapted to Distribution Range)
 - 6.2.1. Step 4: Comparing Trends and Adapting Restoration Techniques and Targets
 - 6.3. Interest of Eel Population Restoration and Management

Shad of the Northeastern Atlantic and the Western Mediterranean : Biology, Ecology, and Harvesting 93

R. Sabatie, *Fisheries Biologist, Fisheries and Aquatic Sciences Center, Agrocampus-Rennes, France.*

J. L. Bagliniere, *UMR INRA-ENSA Ecobiology and Quality of Continental Hydrosystems, Institut National de la Recherche Agronomique, France*

P. Boisneau, *National Freshwater Fishermen Association, France*

1. Introduction
2. Systematics and General Characteristics
3. Distribution and Biology
 - 3.1. Distribution
 - 3.2. Biology–Ecology
4. Threats and Conservation
 - 4.1. Declining Populations
 - 4.2. Conservation
 - 4.3. Restoration
5. Harvesting
 - 5.1. Introduction
 - 5.2. Commercial Fishing
 - 5.3. Recreational Fishing
 - 5.4. Fishing Techniques
 - 5.4.1. Commercial Fisheries
 - 5.5. Sport Fishing
6. Conclusion

Dams, Pollution and Other Impediments to Migration and Spawning 118

A. Bardonnnet, *Institut National de la Recherche Agronomique, Unite de Recherches en Hydrobiologie, St Pée sur Nivelle, France.*

R. Radtke, *University of Hawaii at Manoa, Hawaii Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, USA*

1. Introduction
2. Impediments to Migration: River Obstacle Construction, Fishing, and Water Quality
 - 2.1. Physical Obstacles
 - 2.2. Fishing
 - 2.3. Water quality, flow regime and other factors
 - 2.3.1. Water quality
 - 2.3.2. Flow regime
 - 2.3.3. Other factors
3. Reproduction: Impact of pollutants and temperature, modifications of spawning habitat characteristics and danger of hybridization
 - 3.1. Water pollution and Temperature
 - 3.2. Spawning habitat
 - 3.2.1. Consequences of impoundment
 - 3.2.2. Consequences of channelization, water and gravel removal
 - 3.3. Hybridization
4. Perspectives

Freshwater Fish: Harvest Technology 136

R. L. Welcomme, *RRAG, Imperial College, University of London, UK*

1. Background
2. Choice of Fishing Method and Gear
 - 2.1. Depth of Water
 - 2.1.1. Characteristics of Lake and River Bed
 - 2.2. Species being fished

- 2.3. Season of Year and the Flow Regime
- 2.4. Value
- 2.5. Economic Considerations
- 3. Principal Types of Gear
 - 3.1. Static Gear
 - 3.1.1. Gillnets
 - 3.1.2. Long Lines
 - 3.1.3. The Mid-water Long Line
 - 3.1.4. The Bottom Long Line
 - 3.1.5. Traps
 - 3.1.6. Fyke Nets
 - 3.1.7. Baited Fish Traps
 - 3.1.8. Barriers
 - 3.1.9. Fish Trapping Fences
 - 3.2. Active Gears
 - 3.2.1. Trawls
 - 3.2.2. Demersal Trawls
 - 3.2.3. Mid-water Trawling and Pelagic Trawls
 - 3.2.4. Seines
 - 3.2.5. Scoop Nets
 - 3.2.6. Lift-nets
 - 3.2.7. Plunge Baskets
 - 3.2.8. Cast Nets
 - 3.3. Other Methods
 - 3.3.1. Trolling
 - 3.3.2. Rod and Line
 - 3.3.3. Harpoons and Bows, and Arrows
 - 3.3.4. Fishing Poisons
 - 3.3.5. Explosives
 - 3.3.6. Electrical Fishing
 - 3.3.7. Fishing without Gear
 - 3.3.8. Fish Parks
 - 3.3.9. Fish Holes
- 4. Improved Technology
 - 4.1. Fish Detection
 - 4.2. Echo Sounding, Echo Ranging, and Aerial Scouting
 - 4.2.1. Echo Sounding
 - 4.2.2. Mobile Telephones
 - 4.2.3. Fishing Craft
 - 4.2.4. Gear
- 5. Social and Policy Implications of Fishing Technology

Coldwater Fish: Whitefish and Smelt

160

Anthony J. Novotny, *Fisheries Research Biologist, Marinka International, 1919 E. Calhoun, Seattle, WA 98112-2644, USA*

- 1. Introduction
- 2. World Production of Smelt in Fresh and Brackish Waters by Capture
 - 2.1. World Smelt Production by Capture in Inland Fresh Waters - 1984-1997
 - 2.2. World Freshwater Smelt Production by Capture in Fresh and Brackish Waters, other than Inland Waters - 1984-1997
- 3. World Production of the Whitefish (whitefish) in Fresh and Brackish Waters by Capture and Aquaculture
 - 3.1. World Production of Wild Whitefish (whitefish) in Fresh and Brackish Waters by Capture: 1984-1997
 - 3.2. World Aquaculture Production of the Whitefish (whitefish)
 - 3.2.1. Whitefish Aquaculture Technology

- 3.2.2. Production of the Cultured Whitefish
- 3.2.3. Value of Farmed Whitefish

Warm Water Fish: the Carp Family**182**Roland Billard, *Museum National d'Histoire Naturelle, Paris, France*

- 1. Introduction
- 2. Biogeography
- 3. Morphology, Classification, and Systematics
- 4. Genetics
- 5. Habitats and Social Interaction
- 6. Tolerance to Environmental Changes
- 7. Food Regime and Growth
- 8. Reproductive Biology
- 9. Culture and Fisheries of Cyprinids
- 10. Introductions of Cyprinids Outside its Natural Range
- 11. Conclusion

Warm Water Fish: the Perch, Pike, and Bass Families**200**P. Kestemont, *Unité de Recherches en Biologie des Organismes, Facultés Universitaires N.D. de la Paix, Namur, Belgium.*J. F. Craig, *ICLARM Egypt, Cairo 11511, Egypt. Present address, Whiteside, Dunscore, Dumfries DG2 0UU, Scotland.*R. Harrell, *Horn Point Laboratory, Center for Environmental Science and Cooperative Extension Sea Grant Extension Program, University System of Maryland, Cambridge, Maryland, USA.*

- 1. Introduction
- 2. The Perch family
 - 2.1. Biology and Fisheries of Percidae
 - 2.1.1. Taxonomy
 - 2.1.2. Distribution
 - 2.1.3. Body Form
 - 2.1.4. Growth, Mortality and Longevity
 - 2.1.5. Diet
 - 2.1.6. Reproduction
 - 2.1.7. Populations and Communities
 - 2.1.8. Fisheries
 - 2.2. Aquaculture of Major Percid Species
 - 2.2.1. Control of Reproductive Cycle and Spawning
 - 2.2.2. Culture of Early Life Stages
 - 2.2.3. Ongrowing
 - 2.2.4. Genetic Manipulation
 - 2.2.5. Parasites and Disease
- 3. The Pike Family
 - 3.1. Biology and Fisheries of Esocidae
 - 3.1.1. Taxonomy
 - 3.1.2. Distribution
 - 3.1.3. Body Form
 - 3.1.4. Growth, Mortality and Longevity
 - 3.1.5. Diet
 - 3.1.6. Reproduction
 - 3.1.7. Populations and Communities
 - 3.1.8. Fisheries
 - 3.2. Aquaculture of Northern Pike and Muskellunge
 - 3.2.1. Induction of Ovulation and Spawning
 - 3.2.2. Fingerling Production in Ponds

- 3.2.3. Intensive Rearing Techniques
- 3.2.4. Parasites and Diseases
- 4. The Bass Family
 - 4.1. Biology and Fisheries of Bass Species
 - 4.1.1. Taxonomy and Distribution
 - 4.1.2. Body Form
 - 4.1.3. Growth and Mortality
 - 4.1.4. Reproduction, Reproductive Cycle, and Endocrine Regulation
 - 4.1.5. Larval Development and Feeding Habits
 - 4.1.6. Fisheries
 - 4.2. Aquaculture of North American Bass
 - 4.2.1. Control of Reproductive Cycle and Spawning
 - 4.2.2. Culture of Early Life Stages
 - 4.2.3. Ongrowing
 - 4.2.4. Genetic Manipulation
 - 4.2.5. Parasites and Diseases

The Tilapiini Tribe: Environmental, and Social Aspects of Reproduction and Growth **230**
 J.F. Baroiller, *Unité de Recherche Aquaculture CIRAD-EMVT, c/o Cemagref, 361, J.F. Breton, BP 5095, 34033 Montpellier Cédex 1, France*
 A. Toguyeni, *Institut du Développement Rural—Université Polytechnique de Bobo, 01 BP 1091 Bobo Dioulasso 01, Burkina Faso*

- 1. Introduction
- 2. Taxonomy and Parental Behavior
- 3. Biology and Physiology of Reproduction in Tilapias
 - 3.1. Sex Determination and Gonadal Sex Differentiation
 - 3.1.1. Genetic Sex Determination
 - 3.1.2. Gonadal Sex Differentiation
 - 3.1.3. Endocrine Factors
 - 3.1.4. Environmental Factors: Temperature Influence
 - 3.1.5. Genotype/Temperature Interactions
 - 3.2. Spawning and Reproductive Behavior
 - 3.2.1. Annual Cycle of Reproductive Activity in *Oreochromis spp.* under Natural Conditions
 - 3.2.2. Egg Size
 - 3.3. Influence of External and Social Factors on the Reproductive Efficiency
 - 3.3.1. Influence of Water Temperature, Seasonal Photoperiodicity, and Light Intensity
 - 3.3.2. Influence of Nycthemeral Periodicity
 - 3.3.3. Influence of Salinity
 - 3.3.4. Environmental Complexity
 - 3.3.5. Influence of Parental Behavior: Interactions between Breeding Cycles and Parental Care
 - 3.3.6. Influence of Social Interactions
 - 3.3.7. Influence of Nutrition
- 4. Growth Characteristics of Tilapias
 - 4.1. Analyses of Somatic Growth Components
 - 4.1.1. Growth Allometry of Different Body Trait
 - 4.1.2. Characteristics of Muscle Growth
 - 4.2. Factors Influencing Growth
 - 4.2.1. Food Availability
 - 4.2.2. Social Interactions
 - 4.3. Sexual Dimorphism Growth

Overview of the Catfishes Aquaculture

257

Philippe Cacot, *CIRAD-EMVT (Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Département d'Élevage et de Médecine Vétérinaire), Groupe Aquaculture. Montpellier, France*

Le Thanh Hung, *CAF (College of Agriculture and Forestry), Faculty of Fishery and Aquaculture. Thu-Duc, Ho-Chi-Minh-City, Vietnam*

1. Introduction
2. Interest of catfishes for aquaculture
 - 2.1. Fast Growth
 - 2.2. Omnivorous Regime
 - 2.3. Low Requirement in Water Quality
 - 2.4. Quality of Flesh
3. Technical bases of the aquaculture systems
 - 3.1. Reproduction
 - 3.1.1. Natural Reproduction
 - 3.1.2. Artificial Reproduction
 - 3.1.3. Development of Gonads and Fish Fecundity
 - 3.1.4. Fishing of Juveniles
 - 3.2. Larval Rearing and Nursing Phase
 - 3.2.1. Feeding Requirement of Larva
 - 3.2.2. Rearing Techniques
 - 3.2.3. Survival of Larva and Quality of Gametes
 - 3.3. Growing Phase
 - 3.3.1. Extensive Conditions
 - 3.3.2. Semi-intensive Conditions
 - 3.3.3. Intensive Conditions
 - 3.3.4. Yield of Productions
4. Hybridization between different species
 - 4.1. The Main Hybrids in Catfishes
 - 4.2. Limit of the Hybridization
5. The production outlets
 - 5.1. The Fish Markets
 - 5.2. The Fish Processing
6. Conclusion

Sturgeons and Caviar

278

R. Billard, *Muséum National d'Histoire Naturelle, Paris, France*

1. Introduction
2. General Morphology
3. Systematics
4. Biogeography and Way of Life
5. Reproduction
 - 5.1. Gametogenesis
 - 5.2. Artificial Reproduction
 - 5.3. Early Sexing and Monosex Female Population
6. The Sturgeon Exploitation by Fishing and Farming
7. Threats to the Sturgeon
8. Caviar, Sturgeon Meat, and Gastronomy
 - 8.1. History and Present Production
 - 8.2. Caviar Processing
 - 8.3. Caviar Composition
 - 8.4. Sensory Analysis
9. Conclusion

Edible Frogs**305**A. Neveu, *Research Director, Aquatic Ecology Unit, Institut National de la Recherche Agronomique, France*

1. Introduction
2. Historical Relations with Humans
 - 2.1. Gastronomy
 - 2.2. Laboratory Animal
 - 2.3. The Frog as a Symbol in Relation to Beliefs
 - 2.3.1. Symbol of Fertility
 - 2.3.2. Symbol of Evil Influence
 - 2.3.3. Meteorological Symbol
 - 2.3.4. Symbol of Wonder
 - 2.4. The Medicinal Use of Frogs
3. Biology and Ecology
 - 3.1. Developmental Cycle
 - 3.1.1. Reproduction
 - 3.1.2. Larval Stage
 - 3.1.3. Adult Phase
 - 3.2. Diseases
 - 3.3. Natural Predators
 - 3.4. Skin Biochemistry as a Means of Defense
4. Harvesting and Trade
5. Decline in Wild Populations
 - 5.1. Role of Disease
 - 5.2. Physical Transformation of Aquatic Habitats
 - 5.3. Changes in Chemical Water Quality
 - 5.4. Effects of Predation
6. Is Raniculture the Answer to Declining Stocks?
7. Conclusions

Crustaceans**323**Jacques C. V. Arrignon, *Compiègne, France*Hans Ackefors, *Department of Zoology, Stockholm University, Stockholm, Sweden*

1. Introduction
2. Classification
 - 2.1. Crayfish
 - 2.2. Freshwater Prawn
3. Distribution
 - 3.1. Crayfish
 - 3.2. Freshwater Prawn
4. Morphology
 - 4.1. Crayfish
 - 4.1.1. Appendages
 - 4.1.2. Exoskeleton
 - 4.1.3. Color
 - 4.2. Freshwater Prawn
 - 4.2.1. Cephalothorax and Appendages
 - 4.2.2. Color
5. Physiology
 - 5.1. Crayfish
 - 5.1.1. Digestive System
 - 5.1.2. Circulatory System
 - 5.1.3. Nervous System
 - 5.1.4. Excretory System
 - 5.1.5. Muscular System
 - 5.1.6. Reproductive System

- 5.2. Freshwater Prawn
 - 5.2.1. Osmoregulation
 - 5.2.2. Reproduction
 - 5.2.3. Behavior
- 6. Adversity
 - 6.1. Crayfish
 - 6.1.1. Enemies
 - 6.1.2. Diseases
 - 6.1.3. Toxic Substances
 - 6.2. Freshwater Prawn
- 7. Main Species
 - 7.1. Crayfish
 - 7.2. Freshwater Prawn and Shrimps
- 8. Exploitation
 - 8.1. Crayfish
 - 8.2. Freshwater Prawn
- 9. Management
 - 9.1. Crayfish Management and Cultivation Methods
 - 9.1.1. Management of Wild Stocks
 - 9.1.2. Rearing Crayfish
 - 9.1.3. Freshwater Prawn
- 10. Conclusions

Recreational Sport Fishing in Fresh Waters

355

I. G. Cowx, *University of Hull, International Fisheries Institute, UK*

- 1. Introduction
- 2. Status of Recreational Fisheries
- 3. Types of Recreational Fishing
 - 3.1. Fishing Gear
 - 3.2. Recreational Fishermen
 - 3.2.1. Leisure
 - 3.2.2. Match
 - 3.2.3. Game
 - 3.2.4. Specimen
 - 3.2.5. Domestic Consumption
 - 3.3. Types of Fishery
 - 3.3.1. Natural Fisheries
 - 3.3.2. Stocked Fisheries
- 4. Components of Recreational Fisheries
 - 4.1. Stock Enhancement
 - 4.2. Habitat Management
 - 4.3. Elimination of Unwanted Species
 - 4.3.1. Predator Control
 - 4.4. Fishery Regulations
- 5. Assessment of the Status of Recreational Fisheries
- 6. Constraints on the Development of Recreational Fisheries
 - 6.1. Sub-sector Interactions
 - 6.1.1. Interactions between Commercial and Sport Fisheries
 - 6.1.2. Interaction between Groups of Recreational Fishermen
 - 6.1.3. Other Recreational Users
 - 6.1.4. Other Aquatic Resource Users
 - 6.1.5. Pollution
 - 6.1.6. Water Supply Schemes
 - 6.1.7. Land Drainage
 - 6.2. Ecological Impact of Recreational Fisheries
 - 6.2.1. Stock Enhancement
 - 6.2.2. Angling Practices

- 6.2.2.1. Damage
- 6.2.2.2. Disturbance
- 6.2.3. Litter
- 6.2.4. Ground baiting
- 6.2.5. Habitat Management
- 6.3. Value
- 7. Recreational Fisheries beyond the Year 2000

Index	375
About EOLSS	385

VOLUME IV

Aquaculture: Principles and Prospects	1
R. Billard, <i>Muséum National d'Histoire Naturelle, Paris, France</i>	

1. Introduction
2. Historical Perspective
3. Aquaculture Production and the Number of Cultivated Species
 - 3.1. Aquaculture Systems
 - 3.2. Production Systems in Open Waters
 - 3.2.1. Culture in Open Water in Coastal Zones: Algae and Mollusks
 - 3.2.2. Fattening Tuna
 - 3.2.3. Aquaculture and Stocking: The Ranching
 - 3.2.4. Capture of Juveniles in the Wild, and Growing out in Captivity
 - 3.2.5. Problems Faced by Production Systems Operating in the Wild
 - 3.3. Fully Controlled Aquaculture Systems but Still Depending on Open Waters
 - 3.3.1. The Feeds Originate Mostly from the Ecosystem (Example Pond Fish Culture)
 - 3.3.2. Feeds are Entirely Exogenous (Intensive Form of Aquaculture)
 - 3.4. Toward the Production in Heated/Recirculated Water in Closed Systems Independent of the Environment
 - 3.5. Interaction between the Various Aquaculture Systems and Integration with other Activities
4. Aquaculture Products and Marketing
 - 4.1. The Products
 - 4.2. Marketing and Economics
5. Aquaculture and Environment Interdependencies
 - 5.1. Aquaculture and Water
 - 5.2. Aquaculture and Landscape
 - 5.3. Aquaculture and Biodiversity
 - 5.4. Aquaculture and Species Conservation
 - 5.5. Allocation of Resources and Property Rights
6. Research and Development
 - 6.1. Research
 - 6.2. Extension, Training
7. Prospect of Aquaculture
8. Conclusion

Marine Shrimp Farming	28
------------------------------	-----------

- L. Chim, *IFREMER, Laboratoire Aquacole de Nouvelle Calédonie, BP 2059, 98846 Nouméa, New Caledonia, French Polynesia*
- H. Lucien-Brun, *SEPIA, Immeuble International A2, 13 avenue de la Gare, 78181 Saint Quentin en Yvelines, France*
- G. Le Moullac, *IFREMER, Centre de Tahiti, Vairao, BP 7004, 98719 Taravao, Tahiti, French Polynesia*

1. Introduction

2. Penaeid Biology
 - 2.1. Adult Shrimp
 - 2.2. Natural Distribution
 - 2.3. Ecology and Life History
3. History of Shrimp Farming and its World Production
4. Culture Methods
 - 4.1. Hatchery
 - 4.1.1. Reproduction
 - 4.1.2. Larval Rearing in "Clear Water" with Biological Filter
 - 4.2. Farm
 - 4.2.1. Nursery
 - 4.2.2. Grow-out
 - 4.3. Harvesting
5. Processing and Packaging
6. Market
7. Problems
8. Conclusion and Perspectives

Freshwater Aquaculture and Polyculture

55

Jerome Lazard, *Unite de Recherche Aquaculture, CIRAD-EMVT/GAMET, France*
 Lionel Dabbadie, *Estado da Agricultura e do Abastecimento, CIRAD-EMVT, Brazil*

1. Introduction
2. Brief Review of the State of World Freshwater Aquaculture
3. The Different Types of Freshwater Fish culture and Polyculture
4. The Main Cultivated Species in Freshwater Aquaculture
 - 4.1. Carps
 - 4.1.1. Grass Carp
 - 4.1.2. Silver Carp
 - 4.1.3. Bighead Carp
 - 4.1.4. Common Carp
 - 4.2. Catla
 - 4.3. Rohu
 - 4.4. Mrigal
 - 4.5. Tilapias
5. Freshwater Fish Farming Management
 - 5.1. Reproduction
 - 5.2. Nutrition and Feeding
 - 5.3. Fish Pond Ecosystem Management
 - 5.3.1. Pond Dynamics
 - 5.3.2. Chemical Fertilization
 - 5.3.3. Organic Fertilization
 - 5.4. Fish Populations Management
 - 5.4.1. Polyculture and Monoculture
 - 5.5. Pond Stocking
6. Freshwater Fish Farming Economics
7. Conclusion and Prospects

Engineering and Bio-Technologies in Aquaculture

97

R. Billard, *Muséum National d'Histoire Naturelle, Paris, France*
 L. Varadi, *Fish Culture Research Institute, Szarvas, Hungary*

1. Introduction
2. Engineering Technologies
 - 2.1. Culture of Juvenile in Hatcheries
 - 2.2. Culture of Mollusks and Algae in Open Water

- 2.3. Culture in Ponds
- 2.4. Culture in Raceways and Tanks
- 2.5. Culture in Cages or Enclosures
- 2.6. Fish Production in Closed System
- 2.7. Technologies for Fish Harvesting and Fish Transportation
3. Bio-manipulation of Ecosystems
4. Bio-technologies
 - 4.1. Bio-technologies for Artificial Reproduction (induced breeding)
 - 4.2. Bio-technologies Used for the Control of Sex
 - 4.3. Bio-technologies for Genetics Improvement
5. Technologies for Fish Processing and Marketing
6. Examples of Impact of Technologies on Aquaculture Development
 - 6.1. Simple Technologies
 - 6.2. Complex Technologies
 - 6.3. Bio-technologies and Domestication of Species
 - 6.4. Implementation of Technologies
 - 6.5. Perspectives

Diseases and Pathology of Aquatic Organisms

114

Maire F. Mulcahy, *National University of Ireland, Cork, Ireland*
Philippe Roch, *CNRS and Université de Montpellier 2, France*

1. Introduction
2. The Significance of Disease in Cultured Species
 - 2.1. The Diseases and Pathologies of Cultured Species
 - 2.2. Diseases of Aquatic Mollusks
 - 2.3. Major Diseases of Crustaceans
 - 2.4. Diseases of Fish
3. Host Pathogen Interactions
 - 3.1. Phagocytosis-associated Oxidative Killing
 - 3.2. Peroxynitrite Anions
 - 3.3. Stress Proteins and Proteases
 - 3.4. Lysozyme
 - 3.5. Humoral Cytotoxicity
 - 3.6. Anti-microbial Peptides
 - 3.7. Anti Viral Activities
 - 3.8. Defense Mechanisms of Fish
4. Disease Prevention and Control Methods
 - 4.1. Immune Diagnosis
 - 4.2. Nucleic Acid Hybridization Methods
 - 4.3. Genetic Selection
 - 4.4. Eradication
5. Towards the Future
 - 5.1. Genetically Modified Organisms (GMO)
 - 5.2. Expressed Sequence Tag (EST) Libraries and Macro-micro Arrays
 - 5.3. Miscellaneous

Fish Farming in the Tropics

134

R. D. Guerrero III, *Philippine Council for Aquatic and Marine Research and Development, Los Baños, Laguna, Philippines*

1. Definition and Brief History of Fish Farming
2. Principles of Fish Farming
3. Tilapia Farming: A Case Study
 - 3.1. Fish Characteristics
 - 3.2. Seed Production
 - 3.3. Breeding and Hatchery Practices

- 3.4. Grow-out Methods
 - 3.4.1. Pond Grow-Out
 - 3.4.2. Tank Grow-Out
 - 3.4.3. Cage Grow-Out
4. Induced Breeding and Genetic Improvement of Cultured Fishes
5. Production of Monosex Fishes for Culture
6. Parasites and Diseases of Cultured Fishes
7. Polyculture and Integrated Fish Farming Systems
8. Harvesting, Processing, and Marketing of Cultured Fishes
9. Profitability of Fish Farming
10. Future Outlook

Marine Plant Aquaculture

154

Rene Perez, *IFREMER, Laboratoire d'Algologie Appliquee, France*

1. Foreword
2. Seeding with Elements from the Reproduction Cycle: The Example of *Laminaria japonica*
 - 2.1. Growth in a Seeding Facility (see Figure 5)
 - 2.2. Pre-cultivation
 - 2.3. Development of Plants in the Open Sea
 - 2.4. Harvesting
3. Seeding by Propagation of Cuttings: The Example of *Kappaphycus alvarezii*
 - 3.1. Choice of Site
 - 3.2. The Farming Area
 - 3.3. Cuttings for Seeding
 - 3.4. Development of the Cuttings and Drying
4. Cultivation from Cuttings in Land Facilities: The Example of *Chondrus crispus*
5. Conclusion

Acclimatization of Aquatic Organisms in Culture

175

Gilles Boeuf, *Laboratoire Arago, Université Pierre et Marie Curie/CNRS, BP 44, 66650 Banyuls-sur-mer, France*

1. Introduction
2. Biological Characteristics of Aquatic Species
 - 2.1. They Live and Breathe in Water
 - 2.1.1. Stabilization and Movements
 - 2.1.2. Respiration and Excretion
 - 2.2. Salinity and Light
 - 2.2.1. Salinity
 - 2.2.2. Light
 - 2.3. They Do Not Control their Internal Temperature
 - 2.4. They Are Often "Carnivorous"
3. From the Wild to Domestication
 - 3.1. Rearing Based on Juvenile or Breeder Capture from the Wild
 - 3.1.1. Capture of Juveniles
 - 3.1.2. Capture of Wild Breeders
 - 3.1.3. Juvenile Releases into the Wild
 - 3.1.4. Entire Completion of Rearing Cycle
4. Conclusions

Aquaculture Management

191

Dirk Reyntjens, *Rue de la Mattée 3, 7133 Buvrinnes, Belgium*
 Charles Angell, *Seattle, USA*

1. Introduction

2. The Concept of Sustainability
3. National Aspects
 - 3.1. Regulatory Framework
 - 3.2. Development and Support Planning
 - 3.3. Equity Aspects, Local Communities
4. International Aspects
5. Genetics
6. Production
7. Case Studies
 - 7.1. Tiger Shrimp Farming in Thailand
 - 7.2. Salmon Farming in British Columbia

Environmental Impact of Aquaculture

208

A. Dosdat, *IFREMER, Station Expérimentale d'Aquaculture, Palavas-Les-Flots, France*

1. Introduction
2. Biological Basis of Fish Production
 - 2.1. Nutritional Metabolism
 - 2.2. Therapeutic Agents
 - 2.3. Breeding and Selection
3. Characterization of Discharge and Release
 - 3.1. Metabolic Wastes
 - 3.1.1. Digestion Products
 - 3.1.2. Excretory Products
 - 3.2. Drug Discharge
 - 3.3. Other Exports
4. Environmental Effects and Impacts
 - 4.1. Space Effects
 - 4.2. Effects on the Water Body
 - 4.2.1. Physical
 - 4.2.2. Chemicals
 - 4.2.3. Biological Effects
 - 4.3. Effects on the Benthos
 - 4.4. Effects on the Wild Fauna
 - 4.4.1. Benthic Macrofauna
 - 4.4.2. Genetic Issues
 - 4.4.3. Spread of Disease
 - 4.4.4. Others
5. Reducing the Impact: Towards Sustainability
 - 5.1. Upstream Management
 - 5.1.1. Site Selection
 - 5.1.2. Feed and Feeding Practice Improvement
 - 5.1.3. Disease Control
 - 5.1.4. Genetic Issues
 - 5.2. Downstream Management
 - 5.2.1. Mitigating Impacts
 - 5.2.2. Waste Treatment
 - 5.2.3. Integrating Systems
6. Conclusion

Environmental Impact of Introduced Alien Species

230

Jerome Lazard, *Unite de Recherche Aquaculture, CIRAD-EMVT/GAMET, France*
 Lionel Dabbadie, *Estado da Agricultura e do Abastecimento, CIRAD-EMVT, Brazil*

1. Introduction
2. Trends in Introduction

3. Reasons for Introduction
 - 3.1. Aquaculture
 - 3.2. Management of Inland Waters
 - 3.2.1. Recreational Fishing
 - 3.2.2. Improvement of Wild Stocks
 - 3.3. Example of Africa
 - 3.4. Example of Asia
 - 3.5. Example of America
 - 3.6. Ornamental
 - 3.7. Biological Control
 - 3.7.1. Unwanted Aquatic Organisms
 - 3.7.2. Aquatic Vegetation
 - 3.7.3. Blooms of Phytoplankton
 - 3.8. Accident
4. Impact of Introductions
 - 4.1. Fish Interactions
 - 4.2. Environment Alterations
 - 4.3. Habitat Alteration
 - 4.4. Genetic Deterioration
 - 4.5. Introduction of Parasites, Pathogens, and Diseases
 - 4.6. Socioeconomic Impact
 - 4.7. General Overview of Fish Introductions Impacts
5. Codes of Practice
6. Conclusion and Prospects

Trends in Aquaculture Production and Nutrient Supply	258
<i>U. C. Barg, Fisheries Department, FAO, Rome 00100, Italy</i> <i>A..G. J. Tacon, 45-112 Halliday Place, Kaneohe, HI 96744, USA</i>	

1. Global Aquaculture Production and Food Supply
2. Global Finfish and Crustacean Production by Species Groups
3. Global Production by Feeding Habit and Nutrient Supply
4. Compound Aqua feed Production
5. Global Challenges to Nutrient Supply
6. Concluding Remarks

Index	293
--------------	------------

About EOLSS	301
--------------------	------------

VOLUME V

Economics of Fisheries and Aquaculture	1
<i>Ragnar Arnason, Department of Economics, University of Iceland, and European Commission Joint Research Centre (Agriculture and Fisheries Unit), Iceland</i>	

1. Introduction
2. Fisheries and fish farming in a historical context
3. Fisheries and fish farming in modern times
4. Global fisheries inefficiency: The common property problem
5. Future fish supply: The expansion of fish farming
6. Some important issues in the world's fisheries

A Dynamic Theory of Fisheries Investment**20**Ola Flaaten, *University of Tromsø, N-9037 Tromsø, Norway*

1. Fish Stock Investment
 - 1.1. Discounting
2. Fish Stocks As Capital
3. Long-run Optimal Stock Levels
4. Transition to Long-run Optimum
5. Adjusted Transition Paths

Spatial Bioeconomic Dynamics of Marine Fisheries**38**J. C. Seijo, *Universidad Marista de Mérida, México*

1. Introduction
2. Models of exploited populations incorporating spatial structure
3. Heterogeneous recruitment density in space and time
4. Spatial allocation of effort
 - 4.1. Case 1: Small-scale littoral fisheries
 - 4.2. Case 2: Small scale fisheries in bays, coastal lagoons and estuaries
 - 4.3. Case 3: Fisheries in exposed coastal zones
 - 4.4. Case 4: Fisheries with high information costs
5. Spatial management of fisheries and metapopulations
 - 5.1. Management of metapopulations and source-sink theory
 - 5.2. Marine protected areas
 - 5.3. Modelling of potential effects of marine reserves

The Situation in World Fisheries**53**Andy Thorpe, *CEMARE, University of Portsmouth, UK*
David Whitmarsh, *CEMARE, University of Portsmouth, UK*
Pierre Failler, *CEMARE, University of Portsmouth, UK*

1. Introduction
2. Recent Trends in Fisheries Production
 - 2.1. The Global Position
 - 2.2. The Regional Perspective
 - 2.2.1. Asia
 - 2.2.2. Africa
 - 2.2.3. Europe
 - 2.2.4. Latin America and the Caribbean
 - 2.2.5. North America
 - 2.2.6. Oceania
3. Reasons for Production Growth
 - 3.1. The Technological Revolution
 - 3.2. Government and Donor Support
 - 3.3. The Property Rights Regime
 - 3.4. The Attraction of Fishing
 - 3.5. Changing Consumer Tastes
 - 3.6. The Growing Demand for Fishmeal
4. The Sustainability of World Fisheries
 - 4.1. International and Regional Responses
 - 4.2. National Responses
 - 4.3. Fisheries and Climate Change
5. Conclusion

Fisheries Management: Basic Principles**80**Ragnar Arnason, *Department of Economics, University of Iceland, and European Commission Joint Research Centre (Agriculture and Fisheries Unit), Iceland*

1. Introduction
2. The Fisheries Problem
3. The Fisheries Management Regime
4. Fisheries Management Systems
 - 4.1. Biological fisheries management
 - 4.2. Direct economic restrictions
 - 4.3. Indirect economic fisheries management
 - 4.3.1. Taxation
 - 4.3.2. Property rights
 - 4.3.2.1. Fishing licences
 - 4.3.2.2. sole ownership
 - 4.3.2.3. Territorial use rights
 - 4.3.2.4. Individual quotas
 - 4.3.2.5. community fishing rights
 - 4.4. The most effective fisheries management system
5. Monitoring, Control and Surveillance
6. The Fisheries Judicial System
7. Fisheries Management: Future Developments
 - 7.1. Expanded use of ITQs
 - 7.2. Improvement of existing ITQ systems
 - 7.3. Community fishing rights

Community Fisheries Management**100**Susan Hanna, *Coastal Oregon Marine Experiment Station, Oregon State University, USA*

1. Introduction
2. Perspectives on Community
3. The Economic Interest of Fishing Communities
4. Communities and the Sustainability Problem
5. Structure of Community Fishery Management
 - 5.1. Co-Management
 - 5.2. Community-Based Management
 - 5.3. Community Rights
6. Performance of Community Fishery Management
 - 6.1. Structural Inertia
 - 6.2. Mismatched Incentives
 - 6.2.1. Power Ambiguity
 - 6.2.2. Low-intensive incentives
 - 6.2.3. Bounded rationality
 - 6.3. Transactions Costs
 - 6.3.1. Types of Transactions Costs
 - 6.3.2. Transactions Costs and Management
7. Future Trends

Management of Straddling Fish Stocks: A Bioeconomic Approach**113**P. Pintassilgo, *Faculty of Economics, University of Algarve, Portugal*M. Lindroos, *Department of Economics and Management, University of Helsinki, Finland*

1. Introduction
2. Bioeconomic Modeling of Straddling Fish Stocks
 - 2.1. Dynamic Model of the Fishery
 - 2.1.1. The Social Manager

- 2.1.2. Open-access
- 2.2. Modeling the Strategic Interaction between Fishing Agents
 - 2.2.1. Non-cooperation
 - 2.2.2. Cooperation
- 2.3. Advances in Bioeconomic Modeling
- 3. Threats to Cooperative Management
 - 3.1. Illegal, Unreported and Unregulated Fishing
 - 3.2. New Members
- 4. The Northeastern Bluefin Tuna Fishery
- 5. The Norwegian Spring-Spawning Herring Fishery
- 6. Conclusion

Economics Of Aquaculture

131

David Whitmarsh, *CEMARE, University of Portsmouth, UK*
 J. C. Seijo, *Universidad Marista de Merida, Mexico*

- 1. Introduction
- 2. An overview of World aquaculture
- 3. The role of aquaculture in food security and economic development
 - 3.1. Aquaculture production and food security
 - 3.2. The challenge of rural aquaculture development
 - 3.3. Indicators and reference points for aquaculture production
 - 3.4. Aquaculture indicators and reference points: location, time and uncertainty
 - 3.5. Performance indicators and corresponding limit reference points
- 4. Environmental costs and sustainability
 - 4.1. Externalities and market failure
 - 4.2. Externalities from shrimp aquaculture - an example
 - 4.3. Responding to the challenge
 - 4.3.1. Incentive-based control measures.
 - 4.3.2. Social acceptability
- 5. Conclusion

Game Theory and Fisheries

149

M. Lindroos, *University of Helsinki, Finland*
 P. Pintassilgo, *University of Algarve, Portugal*

- 1. Introduction
- 2. Non-Cooperative Games
 - 2.1. A Two-Player Game
 - 2.1.1. The Bioeconomic Model
 - 2.1.2. The Fishing Strategies and Payoffs
 - 2.1.3. The Prisoners Dilemma in Fisheries
 - 2.1.4. A Numerical Example
 - 2.2. A Game of Coalition Formation
 - 2.2.1. The Game Setting
 - 2.2.2. Stability and Equilibrium
 - 2.2.3. A Numerical Example
 - 2.3. Applications
- 3. Cooperative Games
 - 3.1. Characteristic Function Games
 - 3.2. Sharing Rules
 - 3.3. Stability of Cooperative Agreements
 - 3.4. The New Entrants Threat
- 4. Conclusion

Adaptations To Life In Estuaries**166**James G. Wilson, *Zoology Department, TCD, Dublin 2, Ireland*

1. Salinity and sampling
2. Opportunism, tolerance and competition
3. Osmoregulation and other strategies
4. Sediments and turbidity
5. Hypoxia and anoxia
6. Fish and fisheries
7. Climate change

Adaptations to Life in Marine Caves**183**Thomas M. Iliffe, *Department of Marine Biology, Texas A&M University at Galveston, USA*Renee E. Bishop, *Department of Biology, Penn State University at Worthington Scranton, USA*

1. Introduction
 - 1.1. Definition of anchialine and marine caves
 - 1.2. Biological significance
 - 1.3. Adaptation
2. Geological origins, age and distribution of anchialine habitats
3. Anchialine cave ecology
 - 3.1. Diving investigations
 - 3.2. Physical and chemical characteristics
 - 3.3. Trophic relationships
4. Biodiversity
 - 4.1. Fish
 - 4.2. Non-crustacean invertebrates
 - 4.3. Crustaceans
 - 4.3.1. Remipedes
 - 4.3.2. Thermosbaenaceans
 - 4.3.3. Mictaceans
 - 4.3.4. Bochsaceans
 - 4.3.5. Copepods
 - 4.3.6. Ostracods
 - 4.3.7. Mysids
 - 4.3.8. Isopods
 - 4.3.9. Amphipods
 - 4.3.10. Decapods
 - 4.3.11. Other crustacean stygofauna
5. Biogeography
6. Evolutionary origins
7. Adaptation to life in anchialine caves
 - 7.1. Behavioral adaptations
 - 7.2. Morphological adaptations
 - 7.2.1. Regressive features
 - 7.2.2. Constructive features
 - 7.3. Physiological adaptations
 - 7.3.1. Adaptations to a low food environment
 - 7.3.2. Adaptation to hypoxia and anoxia
 - 7.4. Biochemical adaptations
8. Conservation

Phytoplankton and Primary Production

206

E. W. Helbling, *Estación de Fotobiología Playa Unión & Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Chubut, Argentina*

V. E. Villafane, *Estación de Fotobiología Playa Unión & Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Chubut, Argentina*

1. Introduction
2. Methodological aspects
 - 2.1. Techniques to measure phytoplankton production
 - 2.1.1. Radiocarbon incorporation
 - 2.1.2. Oxygen production
 - 2.1.3. Carbon-13
 - 2.1.4. Estimation from remote sensors
 - 2.1.5. Natural fluorescence at 683 nm
 - 2.1.6. Measurements of pulsed fluorescence
 - 2.2. Incubations
 - 2.2.1. *In situ* incubations
 - 2.2.2. Simulated *in situ* incubation
 - 2.2.3. Radiation sources
3. Phytoplankton primary production in the oceans
4. Photosynthesis versus irradiance relationships: P vs E curves
5. Regenerated vs. New Production
6. Solar radiation and phytoplankton primary productivity
 - 6.1. Solar radiation at the ground level
 - 6.2. The underwater radiation field
 - 6.3. Effects of UVR on phytoplankton photosynthesis
7. Other factors influencing primary production
 - 7.1. Temperature
 - 7.2. Stratification and turbulence
 - 7.3. Carbon dioxide
 - 7.4. Nutrients
 - 7.5. Grazing
8. Conclusion

Microzooplankton, key organisms in the pelagic food web

227

Albert Calbet, *Institut de Ciències del Mar, CSIC, Barcelona, Spain*

Miguel Alcaraz, *Institut de Ciències del Mar, CSIC, Barcelona, Spain*

1. Introduction
2. Main microzooplankton groups
3. Microzooplankton grazing impacts in marine ecosystems
 - 3.1. How much of the primary production is daily consumed by microzooplankton?
 - 3.2. Breaking old paradigms on the role of zooplankton in marine ecosystems
4. Microzooplankton and the biogeochemical cycles
5. Microzooplankton as prey
 - 5.1. Contribution of microzooplankton to copepod diet
 - 5.2. Impacts of copepod grazing on microzooplankton populations
6. Human and climate forcing of microzooplankton populations
 - 6.1. Top-down effects
 - 6.2. Bottom-up and direct effects
 - 6.3. Climatic and physical effects

Large Zooplankton: its Role in Pelagic Food Webs

243

Miguel Alcaraz, *Institut de Ciències del Mar, CSIC, Barcelona, Catalonia, Spain*

Albert Calbet, *Institut de Ciències del Mar-CMIMA, CSIC, Spain*

1. Introduction

2. Food chains or food webs?
 - 2.1. Properties of Food Webs: Relationships between Structure and Function
 - 2.2. The Microbial and Metazoan Side of Pelagic Food Webs
3. Zooplankton feeding habits: microphagy versus macrophagy
 - 3.1. Crustacean Microphages
 - 3.2. Gelatinous Microphages: “Baleen-whale” Zooplankton.
 - 3.3. Macrophagous and Carnivorous Zooplankton
4. Quantitative role of zooplankton in pelagic food webs
 - 4.1. Man-made Disruptions: Fishing Down Pelagic Food Webs
 - 4.2. Climate Variability, Zooplankton and Pelagic Ecosystems

Effects of Rising Seawater Temperature on Coral Reefs

266

Thomas J. Goreau, *Global Coral Reef Alliance, Cambridge, MA, USA*

Raymond L. Hayes, *Howard University, Washington, DC, USA*

1. Introduction
2. Direct Thermal Effects
 - 2.1. Sea Level Rise
 - 2.2. The Solubility of Carbon Dioxide and Oxygen in Seawater
 - 2.3. Limestone Solubility in Seawater
 - 2.4. Influences of the Hydrological cycle
 - 2.4.1. Salinity
 - 2.4.2. Light Penetration
 - 2.5. Ocean Thermoclines and Upwelling
 - 2.6. Dynamics of Reef Frame Growth
 - 2.7. Global Distribution of Coral Reefs
 - 2.8. Coral Reef Bleaching
 - 2.8.1. Historical Observations
 - 2.8.2. Mass Bleaching Events
 - 2.9. Coral Reproduction
 - 2.10. Proliferation, Mutation and Virulence of Marine Microbes
3. Indirect Thermal Effects
 - 3.1. Impacts from Mass Bleaching Events
 - 3.2. Impacts from Emerging Marine Infectious Diseases
 - 3.3. Impacts from Extreme Events: Tropical Storms
 - 3.4. Impacts from Losses in Natural Shoreline Protection
 - 3.5. Impacts of Losses in Other Reef Benefits
4. Reef and Pelagic Fisheries
5. Coral Reefs as Endangered Marine Ecosystems
 - 5.1. Threats from Coral Reef Collapses
 - 5.2. Resilience of Reef Organisms
6. Needs and Recommendations

Reef Restoration as a Fisheries Management Tool

290

Thomas J. Goreau, *Global Coral Reef Alliance, Cambridge, MA, USA*

Wolf Hilbertz, *Global Coral Reef Alliance, Cambridge, MA, USA*

1. Introduction: Coral Reef Fisheries
2. Coral Reef Fisheries Decline
3. Causes of Decline: Overfishing
4. Causes of Decline: Habitat Degradation
5. Marine Protected Areas in Reef Fisheries Management
 - 5.1. The Marine Protected Area Strategy
 - 5.2. Top Down and Bottom Up Management Strategies
 - 5.3. Global Change and Marine Protected Areas
6. Natural Reef Regeneration

7. Restoration Methods
 - 7.1. Stress Abatement
 - 7.2. Artisanal Restoration
 - 7.3. Artificial Reefs
 - 7.4. Coral Growth on Exotic Materials
8. Electrical Reef Restoration
 - 8.1. A Promising New Coral Reef Restoration Method
 - 8.2. Coral Recruitment
 - 8.3. Fish and Invertebrate Recruitment
 - 8.4. Mariculture
 - 8.5. Shore Protection
9. Conclusions

Climate Change and Fisheries

317

Salvador E. Lluch-Cota, *Centro de Investigaciones Biológicas del Noroeste (CIBNOR), P.O. BOX 128, La Paz, Baja California Sur 23000, Mexico*

1. Climate change
2. Fisheries
3. Fisheries and climate
4. Climate changes in the interannual to multidecadal scales
 - 4.1. ENSO impacting fisheries
 - 4.2. Other interannual signals
 - 4.3. Pacific Decadal Oscillation
 - 4.4. North Atlantic Oscillation
 - 4.5. Multidecadal regimes
 - 4.6. Regime shifts
5. Global warming
6. Economic and social aspects of climate change and fisheries
7. Conclusions

Melting of Polar Icecaps - Impact on Fisheries

330

Mark Belchier, *British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge, UK.*

1. Introduction
2. Climate change and the melting of polar icecaps
3. Impacts on marine fisheries
4. Sea-level rise
5. Impact of sea level rise on marine fisheries
 - 5.1. Ecosystem impacts
 - 5.2. Infrastructure impacts on fishing communities
6. Reduction of Sea-Ice cover
7. Ice shelves and icebergs
8. Impact of salinity changes
 - 8.1. Ecosystem impacts
9. Discussion

Melting of Polar Icecaps: Impact on Marine Biodiversity

345

David K.A. Barnes, *British Antarctic Survey, N.E.R.C., High Cross, Madingley Road, Cambridge, UK*
 Stefanie Kaiser, *Biozentrum Grindel & Zoological Museum, Martin-Luther-King-Platz, Hamburg, Germany*

1. Introduction
2. Historical precedent

3. Impact on Antarctic continental shelf biodiversity
 - 3.1. Life on Antarctica's continental shelf
 - 3.2. A changing coastline
 - 3.3. A changing water column and seabed
4. Impact on Arctic biodiversity
5. Impact on deep sea organisms
6. Impact on temperate and tropical shelf biodiversity
7. Conclusions

Index **365**

About EOLSS **373**