ACP – EU Fisheries Research Report Number 6

ACP – EU Fisheries Research Initiative Workshop

Proceedings of the Conference on Sustainable Use of Aquatic Biodiversity: Data, Tools and Cooperation

Lisbon, Portugal, 3-5 September 1998

Convened by
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Edited by
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Brussels
September 1999

Copies are available free of charge from the Information Officer, European Commission, Directorate General for Development, 200 rue de la Loi, B-1049 Brussels.

Preparation of this document

This document was prepared by the International Center for Living Aquatic Resources Management (ICLARM), Manila, Philippines. ICLARM also provided administrative and organisational support to IPIMAR and the European Commission Directorates General for Development and Research to run the conference.

The report aims to provide a record of the findings of the conference on *Sustainable Use of Aquatic Biodiversity: Data, Tools and Cooperation* organised by Drs. Rainer Froese and Roger Pullin (ICLARM), Dr. Carlos Costa Monteiro (IPIMAR, Portugal) and Dr. Fred Bugenyi (FIRI, Uganda) on behalf of the ACP-EU Fisheries Research Initiative and the European Commission (DG VIII). It was based on the papers presented by and discussions held among meeting's participants. The editors of this report were Roger S.V. Pullin, Rainer Froese and Christine Marie V. Casal, all of ICLARM.

The report contributes to the series of ACP-EU Fisheries Research Reports, published by the European Commission Directorate General for Development on a regular basis.

The document has four chapters:

- Introduction
- Organisation and Dynamics of the Meeting
- Summary of input papers
- Synthesis: recommendations and conclusions

Further Annexes provide details of various aspects of workshop and the texts of keynote papers given by 9 invited resource persons. These papers have been fully reviewed and edited for publication. A CD-ROM is attached, containing the contents of 35 other presentations given at the conference. The CD-ROM also contains full details of the participants' contact addresses and electronic linkages.

ACP-EU Fisheries Research Report Series
The ACP-EU Fisheries Research Report Series is a series of publications that aim to maximise the impact of the ACP-EU Fisheries Research Initiative activities, and will include proceedings of workshops and conferences, and statements on policy and research activities under the Initiative.

Abstract

A three day scientific conference on 'Sustainable Use of Aquatic Biodiversity: Data, Tools and Cooperation' was held from 3-5 September 1998 at the Instituto de Investição das Pescas e do Mar (IPIMAR) in Lisbon, Portugal, under the auspices of the ACP-EU Fisheries Research Initiative and the European Commission (DG VIII). The conference aimed at bringing together researchers, conservationists, fisheries managers, educators and decision makers, to gain a better and joint understanding of aquatic biodiversity issues and in particular to explore data gathering and sharing mechanisms and cooperative arrangements to address these issues. Over 100 participants from 28 countries contributed to the conference: mostly from Africa, the Caribbean, the Pacific and Europe.

Its proceedings are published as a report that includes the full, edited texts of nine keynote papers and the summaries of working group and plenary sessions, accompanied by a CD-ROM containing texts of 35 additional presentations made at the conference. The text of the proceedings volume (but not the CD-ROM contents) is available in English and French. The CD-ROM items are available only in the language originally used: French, or English, except where authors provided an abstract or full text in translation.

The keynote papers review the following topics: 'The Crisis of Aquatic Biodiversity'; 'The History of Aquatic Biodiversity'; 'Current Approaches to the Sustainable Use of Biodiversity'; 'The Challenge of Naming Life on Earth'; 'Analysis of Biodiversity Data: Drops from the Ocean'; 'Sustainable Use of Biodiversity'; 'Ecosystem Management'; 'The Economics of Biodiversity'; and 'Governance of Biodiversity.' Additional papers, contributed to six Working Groups, were as follows: 'Naming Life on Earth'; 'Understanding Biodiversity - Data and Tools'; 'Sustainable Aquaculture'; 'Sustainable Fisheries'; 'Economics of Biodiversity'; and 'Institutions and Governance of Biodiversity.'

The conference, also included a Special Session for practical demonstrations of biodiversity tools including: the ERIN (Environmental Resources Information Network) System, FishBase, ReefBase, EcoSim, WorldMap, Species 2000, ETI (Expert Center for Taxonomic Identification) Software, Reef Fish Mapping Software, and Aquatic Species Distribution Mapping – a Watershed Level Approach. Details of how to obtain these tools are included in the published proceedings and in the CD-ROM.

The papers presented and discussions held at the conference illustrate the seriousness of threats to aquatic biodiversity world-wide and the difficulties of achieving conservation and sustainable use objectives – common problems for developed and developing countries alike, and faced by both aquaculture and capture fisheries. The conference showed, however, that awareness is growing of the importance of aquatic biodiversity and ecosystems as the biological basis of fish production. Moreover, powerful information systems, management tools and ecosystem-based codes of conduct and guidelines are emerging for application in aquaculture and fisheries. This is evident from the outputs of the Working Groups and the recommendations made and discussed at the conference. It is hoped that these conference proceedings will contribute to such positive moves for the development of sustainable aquaculture and fisheries.

For bibliographic purposes this report should be cited as follows:

Pullin, R.S.V., R. Froese and C.M.V. Casal (eds.), 1999. ACP-EU Fisheries Research Initiative. Proceedings of the Conference on Sustainable Use of Aquatic Biodiversity: Data, Tools and Cooperation. Lisbon, Portugal, 3-5 September 1998. *ACP-EU Fish.Res.Rep.*, (6):70 p.

ISSN 1025-3971.

Preface

These proceedings cover the last of a series of three EXPO 98 conferences convened under the aegis of the ACP-EU Fisheries Research Initiative. The other two addressed ocean food webs and economic productivity and integrated coastal zone management respectively. In several ways, the subject of the last conference covered the widest range of issues and showed interesting opportunities for scientific and managerial communities, which do not usually interact systematically, at best along disciplinary lines. The conference may therefore be construed as one of a series of attempts to bridge the current communication gaps, now understood to be a major constraint on achieving more sustainable use patterns of aquatic biodiversity, resources and their environment.

The European Commission has supported, from its beginning, the concept of the ACP-EU Fisheries Research Initiative aiming at sustainable economic and social benefits to resource users and other stakeholder, while reducing environmental degradation. The underlying principles of shared responsibility and benefits and promotion of the proactive role of voluntary collaborative in support of economic and political planning and decision making is fundamental to the European Commission's approach to all forms of international cooperation.

This EXPO 98 conference offered new insights into the multifaceted concept of biodiversity with its range of biological, ecological, economic and political interpretations. It also offered interesting avenues for future collaborative research, which would address some of the most pressing problems touched upon during the conference, especially as far as enabling policies for rehabilitation and more sustainable resource uses and underpinning socio-economic and ecosystem research are concerned. These represent the great challenges for the future, and the international component of the 5th Science Framework Programme of the European Union (INCO-Dev) prioritises them for funding. It thus offers interesting opportunities to follow-up through new North-South collaborations.

Conference participants and other interested readers of these proceedings are welcome to use this and other mechanisms and the research results already on the table to join in the wide forum of the Initiative.

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Table of Abbreviations

ACP	African, Caribbean and Pacific countries entertaining development co-operation with the European Union in the framework of the Lomé Convention
ALCOM	Aquaculture for Local Community Development Programme
CARICOM	Caribbean Community
CBD	Convention on Biological Diversity
CFRAMP	CARICOM Fisheries Resource Assessment and Management Program
CNRS	Centre National de la Recherche Scientifique
CTA	Technical Centre for Agricultural and Rural Cooperation (ACP-EU Lomé Convention)
ETI	Expert Center for Taxonomic Identification
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GBIF	Global Biodiversity Information Facility
GEF	Global Environment Facility
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Pollution
GIS	Geographic Information System
ICLARM	International Center for Living Aquatic Resources Management
IPIMAR	Instituto de Investigação das Pescas e do Mar
IUBS	International Union of Biological Sciences
IUCN	The World Conservation Union
IUMS	International Union of Microbiological Society
NHM	Natural History Museum
OATA	Ornamental Aquatic Trade Association
OECD	Organization for Economic Cooperation and Development
ORSTOM	The French Institute for Research in Cooperation, now renamed IRD (Institut de Recherche pour le Développement)
OVI	Ocean Voice International
SPC	Secretariat of the Pacific Community
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
WRI	Water Research Institute, Ghana
WWF	Worldwide Fund for Nature
YugNIRO	Southern Scientific Research Institute of Marine Fisheries and Oceanography
ZADI	German Centre for Documentation and Information in Agriculture

Acknowledgements

Thanks are due to the many sponsors and helpers who made this conference possible. Financial support for the overall conference was provided from the European Commission's Environment Budget Line, in support of the ACP-EU Fisheries Research Initiative. This conference was one in the series of conferences promoted by the Commission's Task Force for the ACP-EU Fisheries Research Initiative, comprising the Directorates General for Research and for Development in coordination with the Directorate General for Fisheries. Among the many sources of support for individual participants, the generous sponsorship given by the Technical Center for Agricultural and Rural Cooperation (CTA), to participants from the ACP countries, is especially acknowledged.


INSTITUTO DE INVESTIGAÇÃO DAS PESCAS E DO MAR
ACP - EU Fisheries Research Initiative
SUSTAINABLE USE OF AQUATIC BIODIVERSITY:
DATA, TOOLS AND COOPERATION
LISBON, EXPO'98 EU PAVILION and IPIMAR, 3 - 5 September 1998

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Chapter 1 Introduction

Context of the ACP-EU Fisheries Research Initiative

When the ACP-EU Joint Assembly passed a Resolution on fisheries cooperation in October 1993, asking for a Joint Initiative on fisheries and aquaculture research, a major step in the progress towards the sustainable use of aquatic living resources was made. The Joint Assembly based its Resolution on the grave concern felt in ACP countries and in Europe for the continuing existence of an important share of our common heritage – aquatic organisms and the ecosystems in which they live – as well as the livelihood of countless fisherfolk, particularly in developing countries, and the wealth of their societies. The European Commission was asked by the ACP-EU Joint Assembly to implement its Resolution.

The sad state in which many fisheries resources find themselves nowadays can certainly be ascribed to poor management practices. Fast expanding demand for fish and its products, resulting from demographic growth and higher purchasing power has increased substantially human pressure on the resources and, in some cases, has led to their outright 'mining'. Unsustainable fishing practices coupled with an excessive level of investment in fishing capacity have resulted in serious degradation and low yields in northern hemisphere fish stocks, creating new pressures on resources located in developing countries. These pressures are largely transnational, highlighting the importance of regional aspects of resource management.

The danger of desertification of the seas is at last perceived as a real possibility, alerting many directly and indirectly concerned people and institutions all over the world, in developing as well as industrialised societies. Their voices and concerns have been heard through political representatives not only in international fora but also more directly through the scientific and technical press and more recently the mass media.

Against this backdrop of growing concern for the conservation of these vital natural resources, some prospective analyses and discussions were carried through in the late eighties and early nineties between development support organisations in industrialised countries and the authorities and scientific and technical communities of developing countries. This exercise, known under the acronym SIFR (Study of International Fisheries Research) aimed at identifying knowledge gaps in fisheries and aquaculture which were preventing the harmonious development of these sectors. The SIFR findings have been disseminated world-wide and are to a large extent valid today.

SIFR's impact went beyond the identification of technological needs to improve resource management. It emphasised the promotion of cooperation between industrialised and developing economies in relation to a natural resource which was shared by both. This reflected the emergence, in the early nineties, of a global market for fish and its products and the transnational exploitation of fish stocks by several fishing fleets. A voluntary joint effort of the scientific and technological communities of developing and industrialised countries, working in partnership with all stakeholders was accepted as the key mode of operation in future research on fisheries and aquaculture. This marked a shift from traditional donor-recipient relations to a new style of scientific and technological cooperation based on voluntary partnerships. This shift is made possible by scientific complementarities on an international scale.

This important message was not lost in the minds of the Members of the ACP-EU Joint Assembly, echoing the concern felt in both regions for the sustainable use of aquatic resources. Their Resolution on fisheries cooperation constitutes the starting point for such a collaborative mode, based on an open and constructive dialogue at intra- and inter-regional levels. The European Commission put together a task force involving DGs VIII and XII services for this purpose.

The Commission recognised the importance of a careful and detailed preparation phase, based on open and constructive dialogue and focusing upon concrete activities and mechanisms for cooperation that might be required in the implementation of the Initiative. An initial consultation was carried out inside Europe involving bilateral cooperation agencies of EU Member States and Associated States as well as the Commission in order to identify priorities and perceptions and to reinforce the political support and co-ordination instruments needed for a broad based Initiative.

This Conference is a contribution to the agenda of the Initiative towards more sustainable use of aquatic biodiversity. It coincides with an emerging work programme of the Convention on Biological Diversity; prioritising marine/coastal and inland aquatic biodiversity.

Brief presentation of the meeting

These are the proceedings of the Conference on Sustainable Use of Aquatic Biodiversity: Data Tools and Cooperation, held in Lisbon. Through the ACP-EU Fisheries Research Initiative, the European Commission organised this conference, in the context of Expo 98 and the 'Year of the Ocean', to bring together researchers, conservationists, fisheries managers, educators and decisionmakers to gain a better and joint understanding of aquatic biodiversity issues and the various options to address these. The conference was one of three scientific conferences held at Expo 98 in Lisbon, during its World Exhibition on Oceans.

The proceedings comprise an introduction to the ACP-EU Fisheries Research Initiative and to the specific objectives and structure of the conference, together with full details of its input papers, discussions and recommendations. The edited texts of nine keynote papers are published in full and other inputs are presented on a CD-ROM.

Chapter 2 Objectives and Structure of the Conference

Background

World fisheries and aquaculture production peaked in 1996 at 130 million tonnes, as reported by FAO. This total masks, however, stock collapses in many parts of the world and the replacement, with increasing frequency, of overexploited stocks by others. The growth of aquaculture production has compensated to some extent for the decline in some capture fisheries but some aquaculture operations have contributed to environmental degradation and to conflicts over limited resources, especially in the coastal zone. The future viability of both fisheries and aquaculture depends upon fuller understanding of the interdependence of ecological and socio-economic factors. Fisheries and aquaculture management should include management of ecosystems and human activities.

In 1993, the Joint Assembly, a body composed of representatives of African, Caribbean and Pacific (ACP) countries and Members of the European Parliament concluded a round of debates on fisheries cooperation and called for a special research effort to clarify options for decisionmakers that would ensure sustainable benefits from the sector for developing-country economics. As a consequence, the ACP-EU Fisheries Research Initiative was started.

As a contribution towards ACP-EU activities and broader linkages, three thematically and organizationally integrated conferences were held at EXPO ’98, the World Exhibition in Lisbon, dedicated to the International Year of the Oceans. These conferences were on: 1.Ocean Food Webs and Economic Productivity (1 – 3 July); 2. Integrated Coastal Zone Management (13 – 17 July); and 3. Sustainable Use of Aquatic Biodiversity: Data, Tools and Cooperation (3 – 5 September). All were sponsored by the European Commission’s Directorates General for Science and for Development, and with the cooperation of the Directorate General for Fisheries. These conferences consolidated the results obtained so far from ongoing ACP-EU collaborations and prepared the way for new activities, based on solid and effective partnerships among the scientific communities of Europe and those in the developing regions, with special emphasis on the ACP regions.

Aquatic Biodiversity

Biodiversity is an essential feature for the proper functioning of all the living resource systems of planet Earth. However, increasing numbers of humans in all parts of the globe have impacted biodiversity. Species extinction and adverse effects from alien species introductions continue, as economic development is often considered more important than conservation, whatever the ecological consequences.

Biodiversity losses and species extinction have been just as serious in aquatic ecosystems as on the land. Freshwater fishes are the most threatened group of exploited vertebrates and freshwater habitats are being devastated in the increasing conflicts over scarce water resources. In coastal zones, increasing human populations, land-based pollution and overexploitation of natural resources are causing severe environmental degradation and threatening biodiversity. The Parties to the Convention on Biological Diversity (CBD) have recognised the urgency of these problems and the CBD’s agenda now emphasises aquatic biodiversity.

This conference was convened as a contribution to addressing these problems by summarising current understanding of some of the issues involved and the trade-offs that might be possible under different scenarios.

Objectives

The overall objective of this conference, and of the series of conferences to which it contributed, was to promote a coordinated approach to research, and more specifically to science and technology cooperation among European and developing-country scientists as well as to create interfaces between scientists and decisionmakers.

Within this overall objective, the Initiative has three major and closely interrelated areas, namely:

- Understanding resource systems, for effective policymaking and governance;
- Data, information, knowledge and communication among stakeholders; and,
- Interdisciplinary scientific paradigms, approaches and methodologies.

The European Commission has provided some support to activities in all three areas. Their scope extends, however, well beyond the geographical scope of ACP-EU partnerships, and addresses themes of global scientific, environmental and economic importance. These require the coordinated attention of scientific communities world-wide, as well as from other actors, private and public, involved in the exploitation of aquatic ecosystems.

This conference aimed to:

- consider the history of and likely future trends in the major factors that affect conservation of aquatic biodiversity for sustainable and equitable use,
- identify knowledge gaps;
- review mechanisms and tools for gathering, handling and sharing data; and
- explore research needs and partnerships.

Structure

The conference agenda was organised by the following Scientific Convenors: Dr. Fred Bugenyi (FIRI, Uganda); Dr. Carlos Costa Monteiro (IPIMAR, Portugal), and Drs. Rainer Froese and Roger Pullin (ICLARM). The 110 participants, mostly scientists from the EU and developing-countries, included partners that are currently involved in activities supported by the Commission. The list of participants is given in Annex 1 and the Conference Programme in Annex 2. Chapter 3 summarises the input papers and Chapter 4 the outputs of Working Groups and plenary discussions. Nine keynote papers are published here as Annexes 3 – 11 and a CD-ROM is attached, giving details of all other inputs, including a Special Session on methods and tools for handling data on aquatic biodiversity.

Chapter 3 Summary of input papers

Keynote Papers

Annex 3: The crisis of aquatic biodiversity
Don E. McAllister (OVI, Canada)

Annex 4: The history of aquatic biodiversity
Rosemary Lowe-McConnell (UK)

Annex 5: Current approaches to the sustainable use of biodiversity: key implications for fisheries research
Jeffrey A. McNeely (IUCN, Switzerland)

Annex 6: The challenge of naming life on earth
David L. Hawksworth (Myconova, UK)

Annex 7: Analysis of biodiversity data: drops from the ocean
Arthur Chapman (ERIN, Australia)

Annex 8: Sustainable use of biodiversity
Barbara Becker (ZADI / IGR, Germany)

Annex 9: Ecosystem management: a biological basis
Astrid Jarre-Teichman (Danish Institute for Fisheries Research, Denmark)

Annex 10: The economics of aquatic biodiversity
Adrian Winnett (University of Bath, UK)

Annex 11: Governance and sustainable use of aquatic biodiversity
Jan Kooiman (Netherlands)

CD-ROM Contents

The CD-ROM that accompanies this volume contains the above-mentioned keynote papers, the papers from the different sessions, some of the software that was presented, and the list of participants. The files on the CD-ROM can be accessed as follows:

- Load the CD-ROM on a CD drive.
- Wait for the Splash Screen to appear on the monitor.
- Wait for 3-5 seconds or click anywhere on the Splash Screen to get to the list of the files.
- Click on a file to open the document or a presentation.
- Click on the email address on the document to open your local mailer (Eudora, Netscape, Outlook, etc.).
- Further instructions are on the CD sleeve.

Session 2 Naming Life on Earth

The Species 2000 Approach
Frank A. Bisby (University of Reading, UK)

The Brazilian Experience in Documenting Species
Vanderlei Perez Canhos (Tropical Database, Brazil)

Session 3 Understanding Biodiversity: Data and Tools

Biodiversity: Concepts, data, and preliminary results
Rainer Froese (ICLARM, Philippines)
Coral Reef Fish Mapping and Equal-Area Grid GIS Analyses
Don McAllister (Ocean Voice International and Canadian Museum of Nature, Canada)
Gap Analysis in Biodiversity Studies
Miguel Araujo (Natural History Museum, UK)
Mapping biodiversity in the Indian Ocean
Charles Sheppard (University of Warwick, UK)
Aquatic species distribution mapping, a watershed level approach: Combining sub-watersheds with point distributions in a GIS
Gayle Johnson, L. Verheust (ALCOM, Zimbabwe) and P.H. Skelton (J.L.B. Smith Institute of Ichthyology, South Africa)

Session 4 Sustainable Aquaculture

Trends in Aquaculture in the Next Century
Michael B. New (UK)
Habitat Monitoring and Protection
Andre Kamdem Toham (WWF-Central Africa Regional Program Office, Gabon) and Guy G. Teugels (MRAC, Belgium)
The ecological footprint – concept and practical considerations for the assessment of resource use and development limitations in aquaculture
Nils Kautsky, Carl Folke, Patrik Rönnbäck and Max Troell (Stockholm University and The Royal Swedish Academy of Science, Sweden)
Génétique et utilisation durable des ressources naturelles pour l'aquaculture
Jean François Agnèse (CNRS/ORSTOM, France) and Rashid Aman (National Museums of Kenya, Kenya)
Impacts of introductions on the conservation and sustainable use of aquatic biodiversity
Devin M. Bartley (FAO, Rome) and Christine Marie V. Casal (ICLARM, Philippines)
Culture of fish larvae in developing countries: information needs
Bernd Ueberschär (Institute for Marine Research, Germany)
Sustainable aquaculture in the coastal zone
Malcolm C.M. Beveridge, Trevor C. Telfer and James F. Muir (University of Stirling, Scotland)
Traditional semi-intensive aquaculture in Asia
Zubaida U. Basiao (SEAFDEC, Philippines)
Small-scale fish farming in Côte d'Ivoire: Does developing socially and ecologically sustainable fish farming represent a challenge to using biodiversity in a sustainable manner?
Marc Oswald (APDRA-F, France)

Session 5 Sustainable Fisheries

Overfishing: a selection factor in evolution
Alain Fonteneau (IRD, France)
The use of Amazon fish biodiversity
Victoria J. Isaac (Universidade Federal do Pará, Brazil)
Approaches to fisheries on micro-economic level in dry parts of southern Africa with emphasis on the role of small-scale fishing in the economy of the household and on food security
Freddy Magagula (Ministry of Agriculture and Cooperatives, Swaziland)

Marine protected areas as a management tool
Adrian D. Rjinsdorp (Netherlands Institute for Fisheries Research, Netherlands)
Utilisation durable de la biodiversite aquatique en Afrique
Jean C. Njock (Ministère de l' Elevage des Pêches et des Industries Animales, Cameroon)
Traditional sustainable use of aquatic resources in Guinée
Ibrahima Cisse (Centre National des Sciences Halieutiques de Boussourra, Guinée)
Artificial reefs: a tool to promote sustainable fisheries and biodiversity
Miguel Neves Santos and Carlos Costa Monteiro (IPIMAR, Portugal)
Multidisciplinary forecasting monitoring of marine ecosystems and fisheries
Boris Panov and Boris Trotsenko (YugNIRO, Ukraine)
Octopus-finfish connection: fishery used or induced biodiversity?
J.M.F. Pereira, L. Coelho and A. Moreno (IPIMAR, Portugal)

Session 6 Economics of Biodiversity

Economics of shark watching in the Maldives
R. Charles Anderson (Ministry of Fisheries, Agriculture and Marine Resources, Republic of Maldives).
Economics and sustainable use of aquarium fishes
Keith Davenport (Ornamental Aquatic Trade Association, UK)
Economics and aquatic biodiversity in the Caribbean
Boris Fabres (CFRAMP, St. Vincent and the Grenadines)
The shell trade and sustainable use of marine molluscs
Sue Wells (WWF International, Switzerland)

Session 7 Institutions and Governance of Biodiversity

European-African collaboration on collecting biodiversity data on African fish
Guy G. Teugels (MRAC, Belgium)
Options and tools for collaborative research on African fish biodiversity for their sustainable use
Eddie Kofi Abban (WRI, Ghana)
Institutions and governance of aquatic biodiversity in the Pacific Community region
Tim Adams and Being Yeeting (Secretariat of the Pacific Community, New Caledonia)
Informed decision-making in biodiversity
Crick Carleton (Nautilus Consultants, Scotland)
Developing policies for aquatic biodiversity
Roger S.V. Pullin (ICLARM, Philippines)
Biodiversity Institutions in Germany
Johann-Wolfgang Wägele (Ruhr Universität Bochum, Germany)

CD-ROM Citation

The contents of the CD-ROM can be cited as individual contributions by giving authorship, year and full title followed by:

Available on the CD-ROM, distributed with; Pullin, R.S.V., R. Froese and C.M.V. Casal, Editors. 1999. ACP-EU Fisheries Research Initiative. Proceedings of the Conference on Sustainable Use of Aquatic Biodiversity: Data, Tools and Cooperation. Lisbon, Portugal, 3-5 September 1998, ACP-EU Fish. Res. Rep., (6):70p.

Chapter 4 Synthesis. Recommendations and conclusions of working groups, with additional comments made and views given in plenary discussions: see asterisked (*) paragraphs

Working Group: Naming Life on Earth

Given that species names are the key which links all information on biodiversity and its sustainable use; that only 13% of life on earth has been named in over 250 years of scientific endeavour; and that the number of taxonomists working on the task of naming life on earth is decreasing, it is recommended that governments and multilateral funding agencies:

- recognise the scale of the problems related to this taxonomic impediment;
- support local and global initiatives to increase capacity in efforts to name and to catalogue life on earth, including initiatives such as the Global Biodiversity Information Facility (GBIF), Species 2000, Diversitas, and the CBD Global Taxonomic Initiative Program; and
- support the integration and the dissemination of core biodiversity information to all who require such information.

Working Group: Understanding Biodiversity: Data and Tools

Given the growing need for generating and sharing existing data on biodiversity, it is recommended that:

- It be recognised that essential (core) biodiversity data comprises four items: species name, locality, date, source; and that such core data, of which millions of records exist and more are continuously created by numerous projects, need to be stored, validated, and made available in a user-friendly fashion that, nevertheless, allows powerful analyses.

  *For databases and information systems, the present coverage of finfish (e.g., in FishBase) is not matched by comparable coverage of Crustacea or Mollusca.

- Mechanisms for collaboration, strategic partnerships, and data sharing are needed for biodiversity, similar to the networks that exist for meteorology and oceanography.

  *It is suggested that databases on national collections and some of the collections themselves be repatriated to their countries of origin, with adequate support for staff and facilities to maintain these. Further support is suggested for more biological surveys, carried out on a regular grid, that would provide new specimens for research with excellent core and accessory data.

- In addition to scientific data, biodiversity networks will need contributions from knowledgeable laypersons from among such as indigenous peoples, bird watchers and fishers.

Working Group: Sustainable Aquaculture

Given that certain types of aquaculture use introduced (alien) species and that other types are the result of commercial and scientific pressures to broaden the number of species cultured, it is recommended that:

- International codes of conducts for introductions and transfers be rigorously followed;

- Those who provide resources for aquaculture research should consider supporting more research on the species currently under culture, rather than proliferating the number of species cultured.

  *It is not advisable to recommend that future research efforts be limited to work on those few aquatic species that have been farmed successfully up to this point in human history. If recommended, this would discourage research on new candidate species for aquaculture and would *de facto* force countries that wish to develop aquaculture, but lack suitable examples of proven aquaculture species within their borders, to introduce alien species. For example, many Latin American countries lack any of the fish species that have been farmed successfully but have many indigenous species that could be investigated for aquaculture potential. The same applies to some ACP countries. However, the use of local species can sometimes be an obstacle to the development of aquaculture in countries that need to increase their fish consumption. Alien species have already made an essential contribution to aquaculture. The risks of introducing alien species must be considered against the needs of local communities and responsible decisions taken. Insurance against such risks could be taken out, even when these risks are hard to evaluate.

Given that three of the major sustainable means of increasing production are fisheries enhancement, recirculation technology and offshore fish farming and that technology for these is either currently available or can be developed in the short- to medium-term, it is recognised that:

- Major efforts will be necessary to solve the ownership problems related to fisheries enhancement;

- Offshore aquaculture may require subsidies similar to capture fisheries.

  *It is not advisable to recommend subsidies for aquaculture, in the way that the fishing industry is subsidised. Such subsidies have been widely recognised as perverse incentives and identified as one of the main culprits for the world's present fishing overcapacity and consequent overfishing. The same should not occur for offshore aquaculture or other types of aquaculture. Subsidies for wild capture fisheries are being phased out. For aquaculture, subsidies (if any) should be for ecologically and socially sustainable operations.

Given the need to ensure protection of existing habitats and to achieve the potential of aquaculture, it is essential not only that the environment and social context be protected from the possible adverse impacts from aquaculture but also that aquaculture, once in operation (e.g., within an 'Aquaculture Zone'), be protected from adverse impacts from other resource users, it is recommended that:

- The delineation of Aquaculture Zones be supported.

  *There is no consensus on the need to delineate Aquaculture Zones (AZs) exclusively for aquaculture development. The social and environmental implications of this require prior and thorough discussions.

Given that the primary factor governing decisions on the implementation of development schemes for rural aquaculture should be the necessity to provide food but that, at the intensive (commercial) level of aquaculture, implementation of research results (e.g., on fishmeal replacement) is more likely to be driven by economic considerations, it is recommended that:

- these factors be taken into account in the development of policies and plans.

  *The effects of a production-targeted monoculture approach to aquaculture and fisheries on both the environment and the poorest sectors of rural societies, have made themselves evident much too often (overfishing, displacement, environmental degradation, genetic erosion). These lessons, have still to be learned and applied.

  *As genetically modified organisms become more available for aquaculture, aquaculture operations might move progressively away from natural water, e.g., inland.

Given that voluntary codes of conduct for responsible aquaculture, such as those developed by FAO, are expected to have a significant impact on public and private activities and attitudes, as are other initiatives such as certification (or ecolabelling), it is recommended that:

- The efforts that are being made to harmonise certification standards and implementation be supported, in order to ensure consumer acceptance.

  *In many international fora (e.g., The Convention on Biological Diversity and the FAO Committee on Fisheries, ecolabelling is a highly contentious issue that requires serious and in depth discussion. Some ecolabelling initiatives might help to promote sustainable aquaculture and these initiatives should be studied carefully to examine harmonisation of certification standards, transparency of processes, data collection and analysis, and impacts on trade and benefit sharing of aquatic biodiversity components.

Given that the failure rate in aquaculture, both in publicly supported projects and in commercial ventures, has been substantial, insufficient attention has been paid to the causes for and impacts of such failures, it is recommended that:

- detailed analyses of these causes and impacts should be supported, so that the success rate of aquaculture can be improved and the potential social and environmental damage caused by such failures can be minimised.

Given that considerable benefits would accrue from comparative studies, of alternative aquaculture and terrestrial livestock production systems, it is recommended that:

- Information exchange among these different sectors be supported in order to facilitate the application to the development of sustainable aquaculture.

Although the need to support data collection and the development of further tools for the analysis of data of value to sustainable aquaculture was noted in this and other Working Groups, it is, recommended that:

- Great care be taken to assess the use to which this data will be put. Its collation and analysis must clearly advance the sustainability of aquaculture. The collection, analysis and dissemination of data whose value cannot be demonstrated should not be supported. It is the value of the data, not the tools themselves, which is paramount.

Whereas the concept of ecological footprints is considered to be of considerable value to the development of sustainable aquaculture, particularly to facilitate decisions on the type of aquaculture which should be supported in individual locations (however, aquaculture should not be considered in isolation), it is recommended that:

- The concept of ecological footprints be applied to alternative activities requiring similar resources to aquaculture.

  *The use of 'ecological footprints' to audit the environmental impact of aquaculture operations should be extended to cover their *social* impacts. In this context, the scientific community should note an NGOs' declaration on sustainable aquaculture that was produced during negotiations on the FAO Code of Conduct.

Given that regulations are relatively simple to formulate but the political will to implement them is often lacking, it is recommended that:

- When further regulations are considered, great care be taken to consider not only their potential benefit but also the feasibility of their implementation.

Working Group: Sustainable Fisheries

Given that biodiversity is crucially important for maintaining the functioning of ecosystems, it is recommended that:

- Fishery management evolve towards ecosystem management, concentrating not only on species but also on the habitats they require, and respective interactions. This implies, for example, the use of highly selective and non-destructive fishing gears. It might also imply a true reduction in fishing effort.

It is further recommended that:

- Ecosystems be clearly defined, for which the basic data requirements (for biodiversity/ecosystem management) need to be identified and recommended to governments, for action by research institutions that can collect data. Moreover, historic data and knowledge, including indigenous knowledge, need to be included to the largest possible extent. This large knowledge base should be used to assess the causes of problems rather than their symptoms. Research needs to proceed at different scales and to be interdisciplinary.

Working Group: Economics of Biodiversity

The Working Group agreed on the following issues and recommendations:

Case studies show that market solutions are possible but they depend on appropriate institutional arrangements to be in place. It is therefore recommended that:

- More case studies be conducted and collated, for comparisons and lessons to be learned.

For economic evaluation and environmental goods (willingness to pay) studies, it is recommended that:

- Capacity building in evaluation techniques be facilitated.

For economic models, it is recommended:

- To include intersectoral linkages (not only fisheries and aquaculture) in economic models.

Regarding trade regulations and biodiversity, it is recommended:

- To learn from experiences gained in regulating other commodities (e.g., tropical forest products) when devising and implementing trade regulations that have implications for aquatic biodiversity.

Regarding economics and the definition of sustainability, it is recommended:

- To develop location-specific definitions of sustainability.

Working Group: Policies, Institutions and Governance of Biodiversity

The group agreed on the following recommendations and observations:

Policies and Institutions

- International conventions, such as the Convention on Biological Diversity (CBD) have been signed. National governments should pass laws to implement these, so that biodiversity issues become legal requirements.

  *It is not appropriate for meetings like this to address recommendations to national governments. Governments are influenced by their political constituencies. The more appropriate recommendation is that all stakeholders (forestry, tourism, mining, industry, as well as Ministry of Agriculture and Fisheries, public and private sectors) must be involved and awareness raised as part of fisheries development policy. Information and communication should be paramount in this regard.

- The formulation of adequate policies to meet current challenges requires:

➢ promotion of international collaboration for the implementation of the CBD's agenda;

➢ seeking a middle road between conservation and exploitation of natural resources, and with impact assessments done not only at the ecosystem, species and population/stocks levels but also at the gene level.

- The formulation and the implementation of more effective policies requires allocation of more resources, to be mobilised by international, regional, national and local institutions.

Capacity building

- Training - emphasis should be put on the training of ACP partners

- Research -

➢ promote more joint research activities based on the principle of benefit sharing;

➢ promote cooperation with the private sector.

Information and its dissemination

- Organise information packaging and dissemination to suit different constituencies; e.g., the research community, public administrations, commercial and economic actors, and consumers.

Location and maintenance of collections

- Consider (partial) repatriation or relocation/centralisation of collections to Africa, with appropriate means for their maintenance.

Electronic communication

- Facilitate collaboration at national/regional/international levels by providing means for electronic communication.

Regional

- Consider the organisation of regional coordination of biodiversity activities in Africa (through regional recognition of a Centre).

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Annex 2 Programme

Thursday, 3/9/1998, EXPO

09:30-10:00	Registration			
10:00-10:30	Opening Session			
	Session 1 Introduction, Setting the Theme			Chair: Boris Fabres
10:30-10:45	The ACP-EU Fisheries Research Initiative			C. Nauen
10:45-11:15	***The Crisis of Aquatic Biodiversity***			D. McAllister
11:15-11:45	***The History of Aquatic Biodiversity***			R. Lowe-McConnell
11:45-12:15	***Current Approaches to the Sustainable Use of Biodiversity: Key implications for Fisheries Research***			J. McNeely
12:15-12:30	Discussion			
12:30-13:30	Lunch			
13:30-14:00	Bus transfer to IPIMAR			
	Sessions 2 + 3 Plenum			Chair: S. Wells
14:00-14:30	***The Challenge of Naming Life on Earth, keynote***			D.L. Hawksworth
14:30-15:00	***Analysis of Biodiversity Data: Drops from the Ocean, keynote***			A. Chapman
15:00-15:30	**Tea/Coffee**			
15:30-17:30	**Session 2** **Working Group: Naming Life on Earth** (Short presentations)	Chairs: F. Bisby / V.P. Canhos	**Session 3** **Working Group: Understanding Biodiversity: Data and Tools** (Short presentations)	Chair: R. Froese
	The Species 2000 approach	F. Bisby	Biodiversity Core Data	R. Froese
	The Brazilian experience in documenting species	V.P. Canhos	Coral Reef Fish Mapping	D. McAllister
	Identifying 1.75 million species: the ETI approach	P. Schalk	Gap Analysis in Biodiversity Studies	M. Araújo
			Mapping Biodiversity in the Indian Ocean	C. Sheppard
17:30-18:00	**Bus transfer to EXPO**			
18:00-20:00	**Cocktail in the VIP lounge of the EU Pavilion**			

Friday, 4/9/1998, IPIMAR

	Session 4 + 5 Plenum			Chair: R.S.V. Pullin
10:00-10:30	***Sustainable Use of Biodiversity, keynote***			B. Becker
10:30-11:00	***Ecosystem Management: a biological basis, keynote***			A. Jarre-Teichmann
11:00-11:30	**Tea/Coffee**			
11:30-13:00	**Session 4** **Working Group: Sustainable Aquaculture** (Short presentations)	Chairs: M. New / H. Kongkeo	**Session 5** **Working Group: Sustainable Fisheries** (Short presentations):	Chairs: A. Jarre-Teichmann /E. Abban
	Trends in aquaculture for the next century	M. New	Marine Fisheries as a selection factor in evolution.	A. Fonteneau
	Habitat monitoring and protection	A. Kamdem Toham	Use of Amazon Fish Biodiversity	V. Isaac
	The ecological footprint – concept and practical considerations for sustainable resource use and development limitations in aquaculture	N. Kautsky	Approaches on micro-level in dry parts of southern Africa.	F. Magagula
	Genetic research in support of sustainability	J.-F. Agnèse and R. Aman		
13:00-14:30	**Lunch**			
14:30-17:30	**Session 4 (cntd.)** **Working Group: Sustainable Aquaculture** (Short presentations)	Chairs: M. New / H. Kongkeo	**Session 5 (ctnd.)** **Working Group: Sustainable Fisheries** (Short presentations)	Chairs: A. Jarre-Teichmann /E. Abban
	Impact of Introductions on Biodiversity	D. Bartley	Marine Protected Areas as management Tool	A. Rijnsdorp
	Culture of Fish Larvae in Developing Countries: Information Needs	B. Ueberschär	Sustainable Use of Aquatic Biodiversity in Africa	J.C. Njock
	Sustainable Aquaculture in the Coastal Zone	M. Beveridge	Traditional Sustainable Use of Aquatic Resources in Guinea	I. Cissé

	Traditional semi-intensive aquaculture in Asia	Z. Basiao	Sustainable Use of Aquatic Biodiversity in the ICES Area	A. Jarre-Teichmann
	Small-scale aquaculture in Côte d'Ivoire	M. Oswald	Multidisciplinary Forecasting Monitoring of Marine Ecosystems and Fisheries	B. Trotsenko
	Aspects of environmental interactions: implications on sustainable aquaculture	M. Falcao, et al.	Artificial reefs: a tool to promote sustainable fisheries and biodiversity	M. Santos / C. Carlos Monteiro
	L'élevage du Tilapia en milieu saumâtre Ivoirien: Contraintes et perspectives	K.S. Da Costa	Octopus – finfish connection: fishery used or induced by biodiversity?	J. Pereira
17:30-19:00	**Snack at IPIMAR**			

Evening Session at IPIMAR

19:00-21:00	**Special Session : Demonstration of Biodiversity Tools**	Organisers: M. Vakily and C. Costa Monteiro
	ERIN System	A. Chapman
	FishBase	R. Froese
	ReefBase	M.L.D. Palomares
	EcoSim	A. Jarre-Teichmann
	WorldMap	NHM
	Species 2000	F. Bisby
	ETI Software	P.Schalk
	Reef Fish Mapping software	D. McAllister
	Aquatic Species Distribution Mapping, a Watershed Level Approach	G. Johnson

Saturday, 5/9/1998, IPIMAR

	Session 6 + 7 Plenum	Chair: H. Waibel
10:00-10:30	***The Economics of Aquatic Biodiversity, keynote***	A. Winnett
10:30-11:00	***Governance and Sustainable Use of Aquatic Biodiversity, keynote***	J. Kooiman
11:00-11:30	**Tea/Coffee**	

11:30-13:00	**Session 6** **Working Group: Economics of Biodiversity** (Short presentations)	Chairs: H. Waibel /B. Fabres	**Session 7** **Working Group: Institutions and Governance of Biodiversity** (Short presentations)	Chairs:J. Kooiman /D. Hounkonnou
	Economics of Shark Watching in the Maldives	C. Anderson	African Fish Biodiversity : Options and Strategies for Collaborative Research	E.K. Abban
	Economics of Biodiversity in the Caribbean	B. Fabres	European-African Collaboration on Biodiversity Collections	G. Teugels
	Fisheries recovery after break-down of all management	F. Turay	Institutions and Governance of Biodiversity in the Pacific Islands	T. Adams
	Economics and Sustainable Use of Aquarium Fishes	K. Davenport	Informed Decision-Making on Biodiversity	C. Carleton
	Economics of the Shell Trade	S. Wells	Developing Policies for Aquatic Biodiversity	R. Pullin
			Biodiversity Institutions in Germany/Europe	J.-W. Wägele
13:00-14:30	**Lunch**			
14:00-14:30	**Bus transfer to EXPO**			

Saturday, 5/9/1998, EXPO

	Session 8 Demonstration of Biodiversity Tools	Chairs:D. Hounkonnou / T. Viegas
14:30-16:00	Presentation and discussion of conclusions of sessions 2-7 – a strategy for sustainable use of aquatic biodiversity in the next century	Chairs of all previous sessions
16:00-16:30	**Coffee / Tea**	
	Closing of the Conference	Chairs: EC / ACP Secretariat
17:30-18:00	Summary and Closing Remarks	

Annex 3 The Crisis of Aquatic Biodiversity

by Don E. McAllister
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1. Introduction

Marine waters cover 71% of the planet's surface and represent 97.5% of its water supply. Of the marine waters, 5.4% lie over the continental shelves, 10.8% over the continental slopes, and 54.6% over the deep sea. Most of the world's freshwaters are locked up in ice and snow or exist as groundwater. Only 0.3% of freshwater is available on the surface: in lakes (99%) and streams and rivers (1%). Surface liquid freshwaters cover 0.8% of the Earth's surface. These freshwaters are also important intrinsically and as 'conveyer belts' of freshwater and its contents to the seas.

Human activities are stressing aquatic species and environment, as shown by the following examples of indicators:

- Over 20% of freshwater fishes are extinct, endangered or vulnerable;
- Alien ctenophores have shifted the ecological balance in the Black Sea;
- Elevated sea temperatures are causing bleaching of the world's coral reefs;
- The Aral Sea and Sudan's Sudd swamps are shrinking;
- Three billion metric tonnes of eroded soil are carried annually by the Ganges and Bramaputra rivers to benthic habitats in the Bay of Bengal;
- The 'dead zone', a mass of oxygen-deprived water, in 1998 covered 12,430 km^2 of the Gulf of Mexico off the mouth of the Mississippi River;
- The Atlantic cod on the east coast of Canada, has been classed as vulnerable and its fishery is essentially closed down.

2. Freshwater Biodiversity

Freshwaters are highly diverse in species and contain a considerable number of higher taxa. Surface freshwaters contain 2.4% of all known living species. Per unit area fresh waters are slightly richer in species than the land (3.0 vs. 2.7), and over ten times richer than the oceans (3.0 vs. 0.2). 41% of the approximate total of 25,000 known fish species occur in freshwaters. Reaka-Kudla (1997) estimated that all known freshwater species (animals, plants and micro-organisms) might total 44,000 species. Authors in McAllister *et al.* (1997), suggested that the number of known freshwater species might be much higher. Estimates of the known and unknown freshwater species, lie between 120,000 and 2.9 million. Clearly taxonomic research is needed to remove this impediment to ecological, biochemical and biotechnological studies; i.e., only about 3% of the freshwater biota have been described.

The most megadiverse countries with respect to freshwater fishes (i.e., those with the highest absolute count of species) are Brazil, Indonesia, China, Congo, Peru and the United States from data compiled mainly by Froese and Pauly (1996) with the most speciose first. If area is taken into account, the most speciose countries are then: Burundi, Malawi, Bangladesh, Malaysia, Sierra Leone and Cambodia. Better still is to locate biodiversity hotspots, not using diverse-sized geographic units, but an equal-area grid (see McAllister *et al.*, 1994).

Glimpses of what is happening to freshwater biodiversity can be provided by examining three of the better-known taxonomic groups. According to Baillie and Groombridge (1996), 734 species of fishes are critically endangered, endangered, or vulnerable. Another 93 are extinct or extinct in the wild, i.e., 8.1%

of freshwater fishes are 'threatened' or extinct, at least in the wild. Of course, there are many species whose status has not yet been evaluated. Estimates of all freshwater fishes which are threatened or extinct range from 20% to 35%, while 59% of freshwater mammals and 43% of crocodilians are threatened. Freshwater invertebrates are less well studied, but three-quarters of the freshwater mussel species in the U.S.A. are at risk. All this suggests that a high proportion of freshwater species is at risk. Commercial species are at risk too. The number of wild salmon returning to the Columbia River in the U.S. is now less than 10% of what it was before dams were built.

Rivers and lakes reflect to a large degree what is happening on the land; they are a barometer of the land's health. Of the Earth's land, 11% is used for crops and 26% for permanent pasture, together 37%. Widespread exposure of bare soil, high input of pesticides and fertilisers for monoculture crops of decreasing genetic diversity, as well as heavy grazing, lead to runoff which is toxic, and which induces eutrophication or siltation of benthic habitats.

Global freshwaters are becoming more and more dammed. Over 5,000 km^3 of waters were impounded by large dams by the end of the 1980s. Adding smaller reservoirs to this, gives a total for combined storage of as much as 10,000 km^3. China alone built 90,000 dams between 1950 and 1980, and is going ahead with one of the world's largest schemes, the Three Gorges hydroelectric project. Some dams provide water for agriculture and many are claimed to provide flood control. By the year 2000, 60% of the world's river flows will be regulated, affecting the ecology of more than 25 million km of rivers. Effects include a shift from riverine to lacustrine habitat; change of seasonal flow patterns and natural flooding important in fish life history; blockage of migrations; changes in temperature/turbidity; and the release of mercury into ecosystems. Flooded grounds in reservoirs release mercury into the food chain, and mercury levels may be biomagnified in the top predators.

Alien species are spreading beyond control on many continents; e.g., zebra mussels (*Dreissena polymorpha)* and purple loosestrife (*Lythrum salicaria*) in North America, water hyacinth (*Eichhornia crassipe*) in Africa, North American crayfish (*Pacifastacus leniusculus*) in Australia, Nile perch (*Lates niloticus*) in Lake Victoria, etc. Introductions come from a variety of sources including intentional fisheries introductions, escapes from aquaculture, disposal of aquarium fishes, and discharge of ballast water. International protocols, that require informed acceptance of neighbouring jurisdictions (with whom water basins are shared) before introductions are made, are lacking. Many other human activities affect freshwater biodiversity; e.g., aquaculture, fisheries, forestry, industry, municipalities, canals and diversions. The collision between the demands of humans for freshwater and the needs of nature is already here. Freshwater biodiversity is suffering at ecosystem, species/population and genetic levels.

3. Marine Biodiversity

Much of marine biodiversity is found on the continental shelves but awareness is growing that a considerable proportion of marine biodiversity lies on the continental slopes and in the deep sea. Much of marine biodiversity is benthic; less resides in the water column and at the surface, although the early life history stages of marine organisms often inhabit surface waters temporarily. Globally, much of marine biodiversity occurs in the tropics. Of the 33 animal phyla, 20 are dominantly or exclusively marine (Norse 1993); e.g., ctenophores, lamp shells and echinoderms. The coral reefs of the world contain about 25% of the marine fish species, even though they cover an area representing less than a tenth of one percent of the ocean's area. Many reef fish families as well as reef-building corals are most speciose in the triangle between the Indo-Australian Archipelago, Australia and the Philippines. There are exceptions. For example, among the algae, the kelps are most speciose in the temperate Northeast Pacific.

Until 1996, when the World Wildlife Fund and IUCN held a workshop in London, only a handful of marine fish species was considered threatened. The workshop helped raise the number of threatened species of marine fishes in the 1996 IUCN Red List (Baillie and Groombridge, 1996) to 117 exclusively marine species. This demonstrated that it was chiefly the lack of evaluation and resources which had limited the listing of marine fish species. The Coral Reef Fish Specialist Group of IUCN's Species

Survival Commission is well aware that there are many more marine fish species deserving of listing. A serious problem is deficiency of data.

A few statistics demonstrate the extent of the assault on marine ecosystem by humans: 58% of the world's reefs are potentially threatened (Bryant *et al.*, 1998); 50% of the mangrove forests of the world have been lost; at least 8% of the continental shelf has been damaged by trawling and 16% of that habitat has been fragmented (McAllister 1995), and there has been a 14% reduction in the Arctic sea ice habitat between 1978 and 1994. A first approximation suggests that 8% of seagrass beds of the world are lost or heavily degraded. The largest marine ecosystem area-wise, the neuston (tiny or small biota living on, at or just under the water's surface) is being affected oil slicks (10% of the total sea area is affected), increased UV radiation, persistent toxic chemicals, and flotsam (McAllister 1995, 1998). The neuston is the ocean's main biotic nursery. Eggs, embryos and larvae normally thrive here because of abundant sunshine, oxygen, phyto- and zooplankton. A stress on the neuston means an inevitable stress on ocean ecosystems, from the surface to the deep-sea. High productivity in the surface layers feeds the whole water column even to the deep-sea benthos, where falling plankton 'snow' from upper waters is an important energy source.

4. Root Causes

The primary root causes of aquatic biodiversity loss are:

- Growth in population and per caput consumption;
- The increased power of and control by transnational corporations over the policies and programs of democratically elected governments, with some exceptions;
- International organisations, like the World Trade Organization & International Monetary Fund, and legal instruments, like the North American Free Trade Agreement and the draft Multilateral Agreement on Investment, undermine environmental agreements, e.g. the Convention on Biological Diversity.
- Militarism consumes billions of dollars and wastes the talents of drafted young people, harming the environment and diminishing assets that could be used for the environment.

5. Solutions

There is a need for civil, egalitarian, knowledgeable and democratic societies to determine government priorities and to:

- Increase the status of women and foster civil societies;
- Achieve zero population growth and moderate consumption;
- Institute eco-agriculture, eco-forestry, and eco-fisheries - use ecosystem-based management, gear with low habitat impact and bycatch;
- Establish freshwater and marine/coastal protected area networks to conserve species, representative ecosystems, and fish stocks;
- Create ecolabelling systems so that consumers can choose environmentally friendly products;
- Foster bioregionalism instead of globalisation;
- Strengthen the capacity for taxonomic and ecological research and establish global hierarchical freshwater and marine/coastal ecosystem classifications;
- Sustain and (where necessary) restore civil and democratic processes;
- Ensure trade and investment agreements incorporate binding requirements to honour the Convention on Biological Diversity;
- Introduce taxes like the Tobin Tax, a surcharge on financial speculation in currencies and stocks, and use half of the proceeds for the environment.

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Annex 4 The History of Aquatic Biodiversity

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1. Introduction

Biodiversity was the term introduced in the mid-1980s for the total richness and variety of life on earth. Thereafter, concern for the environment led to the UN Convention on Biological Diversity at the Second Earth Summit in Rio, 1992. It is expressed as: species biodiversity, ecosystem biodiversity and now, with DNA studies, as genetic diversity within certain species. Key questions include: what is the role of biodiversity in maintaining sustainable aquatic ecosystems, in both freshwaters and the sea? How much does biodiversity affect ecosystem stability and resilience to changing physical conditions? In what circumstances does it matter if aquatic systems are greatly simplified (as they are fast becoming from anthropogenic impacts)? Which are the ‘keystone‘ species in a particular ecosystem without which ‘trophic cascades‘ occur, often with unexpected results? To explore these topics involves: collection and identification of species (taxonomy); field studies of their interrelationships and interactions (ecology and behaviour), including food webs and population dynamics; study of the limnological and oceanographical conditions affecting their life histories; and knowledge of evolutionary mechanisms and extinction rates, which help to explain the creation and loss of species.

Aquatic biodiversity evolves and increases with time as communities mature from pioneer to mature status. Interrelationships and behaviour become increasingly complex (involving use of space, breeding behaviour, cooperative feeding etc.). There are fewer dominant species and use of food resources is more specialised. Breeding is less seasonal, with fewer young at a time. The effect of perturbations is to reverse this succession. Intensive exploitation for food of very diverse communities with few dominants (such as coral reef systems) is likely to be unsustainable. The aesthetic value of biodiversity, and the value of tourism in maintaining it, should not be neglected. Biodiversity is being lost from nearly all aquatic ecosystems. What should be the priorities for conserving particular ecosystems or species?

This contribution looks at examples of marine and freshwater food webs in which biodiversity increases inversely with latitude (i.e., is highest in tropical waters), and directly with habitat structure (as in coral reefs and rocky shores). Case histories include changes in Lake Victoria and Lake Tanganyika.

2. The History of Aquatic Biodiversity

Long before the term biodiversity was introduced, the richness of species in different communities and ecosystems was being explored, together with what may have caused such differences: as discussed at the First International Congress of Ecology in the Hague 1974, (Van Dobben and Lowe-McConnell, 1975). In 1924, Hardy investigated the food webs supporting herring (*Clupea harengus*) in the North Sea, having invented an ingenious continuous plankton recorder which was towed behind commercial vessels to collect samples of their food; this showed a complex web and that herring feed at higher trophic levels as they grow. In the open oceans, food webs are based on small planktonic organisms and many trophic levels are involved in production of commercial fishes. When the International Biological Programme (IBP) in 1964-74 compared energy transfers from primary to tertiary production in lakes from many parts of the world, it was assumed that only 10% of the energy was passed from one trophic level to the next. For the oceans, estimates of primary production and trophic transfers were used to assess limits of tertiary production, indicating that this could never be much greater than 100-140 million tons (Cushing, 1975).

During the IBP studies, it was thought that ‘bottom up’ transfers of nutrients through primary and secondary producers to terminal ones, governed fish production (Le Cren and Lowe-McConnell, 1980).

Later studies in North American lakes have, however, shown that 'top down' effects, 'trophic cascades' from the removal or addition of top predators, also have important effects on ecosystem functioning at lower levels. In the sea, this was demonstrated when large 'man-eating' sharks were culled off Natal. This led, unexpectedly, to the decline of sport fish, as large sharks no longer controlled the number of smaller sharks which feed on sportfish.

Since the mid-1980s, the term 'biodiversity' has been used for the total richness and variety of life on earth. This is generally expressed as `species biodiversity`, the numbers of species of plants, animals or microbes within a site or habitat; or `ecosystem biodiversity based on numbers of species in an ecosystem. Since the advent of DNA molecular studies, `genetic diversity`, for genes as the units of evolution within a species, is also being considered in some groups.

3. Biodiversity Studies

Basic collection of species and their identifications, involving field and museum work (taxonomy) are essential. A report on the status of the earth`s living resources, including aquatic ecosystems, prepared for the Rio Summit (Groombridge, 1992), showed, for example, that of the then known fish species (total, about 22,000), about 40% lived in freshwaters. South America hosts the greatest freshwater fish diversity - well over 2000 species, mostly living in rivers, - followed by Africa with over 1800 species and with 'hot spots' of endemic species in the East African great lakes. North America has about 1500 species, compared with only 250 in Europe. The report estimated that about 20% of commercial freshwater fish species are now extinct or imperilled; the main threats being habitat degradation, introduction of alien species, overharvesting, pollution, and competition for water. In the sea, the greatest diversity is on coral reefs: over 2000 fish species are known from the Great Barrier reef (750 from Heron Island), 550 from Madagascan reefs, and around 220 on West Indian reefs. Field studies of ecology and behaviour are needed for analyses of food webs, population dynamics, breeding biology, migrations etc., and of the limnological or oceanographical conditions affecting life histories. For understanding the creation and loss of species, knowledge of evolutionary mechanisms, extinction rates and fossil records are also required.

SCUBA diving, enabling fish ecology and behaviour to be studied underwater, has revealed much about what governs species diversity and abundance on coral reefs. These represent 'hot spots' where numerous species of invertebrates and fishes share resources of food and living space. Whole families of fish are either primarily herbivorous, grazing or browsing on algae (surgeon and parrot fish), or carnivorous (for example, chaetodontids eating corals and their associated sessile invertebrates; wrasses eating numerous mobile invertebrates). Others are midwater planktivores, omnivores or piscivores; some feeding by day, others by night. Parties of mixed species travel over the reef, cooperative feeding helping them to obtain their food by disturbing invertebrates and overcoming defences of territorial species. There are also many commensal relationships between fish and invertebrates. Most reef fishes spawn throughout the year, casting eggs into the sea where many have pelagic larval stages. Recruitment to the reef is thus influenced by mortality of these and prevailing conditions for resettlement. How this affects the diversity and abundance of species on the reef has been much discussed (e.g., Longhurst and Pauly, 1987; Sale, 1991).

In freshwaters, communities are very much more biodiverse in tropical than temperate regions and have extremely complex interrelationships. For example, the food web in a North American lake has about four fish species, that in a Costa Rican stream 11 and that in a Venezuelan swamp over 50.

4. Case Histories

The African Great Lakes, with their spectacular flocks of cichlid species provide the best 'laboratories' in which to study the creation and loss of fish diversity: creation by very rapid speciation associated with trophic radiations within each lake, losses following environmental degradation and introductions of alien species (Lowe-McConnell 1996; Meyer *et al.*, 1994; Pitcher and Hart, 1995; Worthington and Lowe-McConnell, 1994).

Lake Victoria, a huge (69,000 km^2) equatorial lake has become notorious for the loss of an estimated 200 endemic cichlid fish species in the two decades following the explosive population growth of an introduced alien piscivore, the Nile perch *Lates niloticus* (Witte *et al*., 1992). This loss of fish biodiversity was accompanied with a fivefold rise in fish catches (100,000 $t.yr^{-1}$ to 500,000 $t.yr^{-1}$), though for how long this will be sustainable is not known, nor how long before *Lates* reaches a balance with the surviving fish fauna. An Ecopath model has suggested that the 'ecological efficiency' (from primary production to fish) has increased slightly (Moreau *et al.*, 1993). Recent research suggests that this lake dried out and refilled about 12,400 year ago. If so, this suggests that its cichlid taxa (about 500) have evolved more rapidly than in any other known locality. The whole ecology of the lake has now changed; bottom waters are now deoxygenated throughout the year and unavailable to the fish; eutrophication of the gulfs has increased with, since 1989, a serious invasion of water hyacinth. The huge bibliography (2000+ references) on Lake Victoria, demonstrates how difficult it is to disentangle the interacting causes of such changes. Limnological studies have shown that algal changes in bottom sediments (following land clearance) predated the *Lates* introduction and, together with a slight climatic change plus pollution in the gulfs (from human and cattle population increases), probably account for the limnological changes (Lehman, 1998).

Lake Tanganyika is a very old (10 million years) deep Rift valley lake, with a very high biodiversity of endemic invertebrates and fishes. Its cichlids represent seven ancient lineages: diverse and abundant, despite the presence of four endemic *Lates* species. Teams using SCUBA have investigated the littoral rocky shore communities for the last 20 years and found these to be very stable, with about 40 species (and up to 5000 fish) in their 20 x 20 m quadrats. They attribute this stability to the very complex interactions between the coexisting species (Hori *et al.*, 1993). Coexistence here depends on partitioning living space as well as food; there is intense intraspecific competition for species-specific territories for spawning and guarding their young (Kawanabe *et al.*, 1997).

5. Community Evolution

Biodiversity increases with time, from low diversity in pioneer communities (often comprising opportunist species adapted to use seasonal inflows of nutrients), to increasingly high diversity communities, with species specialised to utilise different foods and living space, many territorial, and spawning aseasonally throughout the year (Lowe-McConnell, 1987/1995). These diverse communities are not likely to produce as many food fishes as less diverse ones responding to seasonal influxes of nutrients; but the biodiverse communities, capable of high internal nutrient cycling, appear to have evolved to make the best use of ecosystems with little seasonal input of nutrients. Table 1 summarises these interrelationships. Intensive exploitation of fish for food from very diverse communities, which lack dominant species is often not likely to be economic, and may be highly damaging to these ecosystems.

The aesthetic value of biodiversity, and the value of tourism in maintaining it should not be neglected. Appreciation of the beauty of living organisms and wonder about how they evolved is of immense importance for the human spirit.

6. Conclusions

Biodiversity is being lost from nearly all aquatic ecosystems at an ever increasing rate, due mainly to the rising human population and anthropogenic changes to the environment: damming rivers has interrupted fish spawning runs (though opening up opportunities for new evolution), wetlands have been drained, introduced alien species have ousted native ones, in addition to pollution and overharvesting. How to choose what to conserve? For species which evolve and disappear rapidly, habitats and communities need to be conserved rather than emphasising individual species. A World Wildlife Fund for Nature 'Global 200' scheme, which attempts to integrate maintenance of species diversity with preservation of distinctive ecosystems and processes, has prepared a representative list of the earth's most valuable 'ecoregions' needing priority attention, a list on which many aquatic ecoregions are included (Olson, 1998).

Table 1. Attributes associated with biodiversity.

Creation of biodiversity		Loss of biodiversity
Speciation		Natural (e.g. climatic change)
		Anthroprogenic, environmental changes
Community Evolution		Overharvesting
		Pollution
		alien species
	Ecosystem maturation with time	
Pioneer →	**Biodiverse** →	**Mature**
low	Diversity	High
simple	Interrelationships	Complex
Generalists	use of food	Specialists
seasonal	Breeding	Aseasonal with complex behaviour and territories
Migrations	use of space	Territories
resilient	Stability	fragile? or stable?
suitable	For exploitation	Need conservation and careful management?
	Perturbations	
reverse this succession (but may provide new opportunities for evolution; e.g., in artificial lakes)		

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Annex 5 Current Approaches to the Sustainable Use of Biodiversity: Key Implications for Fisheries Research

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1. Introduction

The broadly-held concern that current rates of resource exploitation are not sustainable led the Brundtland Commission to advocate the rather loosely-defined concept of "sustainable development": development that enables this generation of people to meet their needs without compromising the ability of future generations to meet their needs (WCED, 1987). Numerous other definitions can also be found in the literature. The objectives of the Convention on Biological Diversity (CBD) "are the conservation of biological diversity, the *sustainable use of its components* (present author's emphasis), and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources" (CBD, 1994). Note that all three of these objectives are included in the same sentence, suggesting that governments felt that the three needed to be addressed together. While the idea of sustainable use is nothing new for fisheries biologists, the CBD provides an opportunity for placing sustainable use in a broader context and for building much broader support for its practical implementation.

Fisheries biology has been grappling with the challenges of sustainable use for decades, focused initially on the objective of maximum sustainable yield (MSY). However, it is also now widely recognised that this approach has not been adequate in achieving the objectives of the CBD, and indeed FAO has reported that 69% of the world's marine fish stocks are in urgent need of action to conserve them (FAO, 1995).

2. Are Current Fisheries Practices Sustainable?

It appears that no marine fish species have yet become extinct due to overfishing, but Casey and Myers (1998) present data from long-term research surveys that reveal that one of the largest skates in the Northwest Atlantic, the barndoor skate (*Raja laevis*) is close to extinction, at least partly because of a directed fishery for the skate initiated off the coast of Newfoundland and Nova Scotia that began in 1994. Several marine mammals have been driven to commercial extinction by overharvesting and two, Stellar's sea cow and the West Indian monk seal, have become extinct in the past 400 years (IUCN, 1996). In the Black Sea, 21 of 26 major fish species have become "commercially extinct"; i e., too few remain to be worth chasing. Already menaced by a string of ecological disasters around the Caspian Sea, the sturgeons that are exploited for caviar are rapidly becoming the latest victims of the collapse of the Soviet Union. In the early 1990s, four independent states and two autonomous regions appeared around the Caspian, which contains more than 90% of the world's sturgeon stocks. As a result, the tightly regulated caviar cartel formed by the USSR and Iran has collapsed, leading to a free-for-all in which poachers, organised crime bosses and bureaucrats muscle their way into this lucrative business (Dobbs, 1992). Experts believe that, within three or four years, sturgeon stocks will be completely depleted.

Commercial fishing can also seriously reduce the genetic diversity of wild fish. As just one example, the orange roughy (*Hoplostethus atlanticus*) is a medium-sized fish living in deep waters off the continental shelf of Australia and New Zealand, spawning around ancient sea mounts, where it forms enormous aggregations. When discovered in the late 1980s, these aggregations provided an economic bonanza, which reached its climax around 1989-90 when trawlers were landing 40,000 tons annually. But then fisheries biologists found that orange roughy can live for up to 150 years and may not breed until they are between 20 and 32 years old; clearly, they reproduce and grow very slowly, implying that this fishery is doomed without very strict regulation. Today the catch is around 38,000 tons and the total biomass of orange roughy in the New Zealand fishing grounds has been reduced by 60 to 70%, probably including the oldest and most genetically diverse portion of the population. This species has also the distinction of being one of best documented examples of a loss in genetic diversity through fishing (Smith, in press)

Modern biotechnology may pose a threat at the genetic level. Scientific research laboratories in China, Japan, Singapore, and Malaysia are working on transgenic fish, often in association with companies that expect to commercialize the genetically modified fish that grow faster than their wild or traditionally-bred aquaculture siblings. One problem is that transgenic fish are often created from eggs hatched from collections in the wild, so they are capable of mating with wild fish; this leads to concerns that the transgenic fish could escape to rivers or coastal areas where they could mate with wild fish and threaten the diversity of the wild population gene pool. They could also disrupt aquatic ecosystems by preying on and outcompeting native species, showing how genetic factors can have ecosystemic effects.

Overfishing can also have significant ecosystemic effects. The impact of fisheries on other species is well-known in the literature as "incidental take", involving impacts on dolphins, marine turtles, whales, seabirds, and so forth; this is one reason why the CBD focuses sustainable use on whole ecosystems rather than on individual species. Fishing also changes the trophic composition of fish communities, for example, by selectively harvesting predators. Pauly *et al*., (1998) found that the mean trophic level of the species groups reported in FAO Global Fisheries Statistics declined from 1950 to 1994, reflecting a gradual transition in landings from long-lived, high-trophic-level, piscivorous demersal fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish. This effect, also found to be occurring in inland fisheries, is most pronounced in the northern hemisphere. Fishing at lower trophic levels leads at first to increasing catches, then to stagnating or declining catches, indicating that present exploitation patterns are unsustainable.

Sea urchins eat kelp and other seaweeds, and with the decline of cod, a major predator on sea urchins in the North Atlantic, seaweeds have been so heavily grazed by sea urchins that they have been replaced by encrusting pink algae and a rocky bottom. This significantly reduces the habitat available to other species, thereby reducing the overall productivity of the habitat. Similarly, the reduction of sea otters in the North Pacific has allowed sea urchins to expand greatly their impact on kelp. Aronson (1990) reports archaeological evidence from aboriginal garbage dumps showing that the Aleuts living on Amchatka Island exterminated the local population of sea otters about 2,000 years ago. Sea urchins then underwent a population explosion and grew much larger as well, enabling them to wipe out the fleshy algae and kelp forests. Many of the fish that had sheltered within the kelp forest disappeared. So by killing the sea otters, the Aleuts destroyed their fishery too, forcing them to hunt further from their villages. This shows that the mismanagement of fisheries is not new, and indeed similar stories can be told about the Maoris of New Zealand, various other Pacific peoples, and many others.

Aquaculture also has some negative impacts on fisheries. For example, in 1995, prawn production in Thailand brought in about $2 billion in export earnings, 40% of the world market and the country's fifth-largest source of foreign revenue. On the downside, prawn farming has helped to clear about two-thirds of Thailand's 388,500 ha of coastal mangrove forests, essential nurseries for Thai fisheries.

Biodiversity in freshwaters is seriously threatened in many parts of the world, and indeed is probably where the threat of extinction is most grave. A survey in Malaysia found fewer than half of the 266 fish species previously known from the country (Mohsin and Ambak, 1983). In the south-eastern United States, 40-50% of freshwater snail species are now extinct or endangered due to the impoundment and channelisation of rivers, and one-third of native freshwater fish species are extinct or endangered to some degree (WRI/IUCN/UNEP, 1992). Over the past century, North American freshwater environments lost 21 of 297 mussel and clam species and 40 of the country's approximately 950 species of fish (Pimm *et al*., 1995).

Global transport can also cause biodiversity loss and threaten sustainable use. Many ocean-going ships carry ballast in the form of seawater that is taken on in port and released at subsequent ports of call. Transport of entire coastal planktonic assemblages across oceanic barriers to similar habitats renders bays, estuaries, and inland waters among the most threatened ecosystems in the world. The presence of taxonomically difficult or inconspicuous taxa in these samples suggests that ballast water invasions are already pervasive (Carleton and Geller, 1993).

In fisheries and aquaculture, the introduction and transfer of alien organisms has helped some local economies but sometimes at the expense of ecological stability. Garcia-Marin *et al*. (1998) obtained evidence of different degrees of genetic interaction of exogenous hatchery fish with native populations obtained from collections of brown trout (*Salmo trutta*) from four heavily fished areas and eight adjacent protected and unfished areas in north-eastern Spain.

3. What is Sustainable Use?

Costanza (1991) provides a useful definition of sustainability: the amount of consumption that can be continued indefinitely without degrading capital stocks. Natural capital, such as fish stocks, use primary inputs (notably sunlight) to produce a range of ecosystem services and physical natural resource flows. The limiting factor is no longer human-derived capital but remaining natural capital. The catch of fish is not limited by the number of fishing boats, but by the fish population. In terms of natural resources, sustainable use implies that the basic stock of natural capital should not decrease over time. Conservation biologists argue that sustainable use implies that a population does not decline to extinction. The CBD defines “sustainable use” as “the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations”. A complicating element is that sustainable use often depends very much on the perspective of the various users; different users have different perspectives on sustainable use that may be contradictory. For example, fisheries biologists have found that the annual runs of adult salmon in the Columbian river basin in the USA have declined by 75 to 85%. Groups with an interest in the policy response to this observed decline include electric utilities, environmental advocates, the barge industry, recreational boaters, agricultural irrigators, logging and mining companies, the aluminium industry, government agencies, conservation biologists, and commercial, sports, and tribal fishing groups (Hyman and Wernstedt, 1991). Thus, fisheries research is only part of a very complex determination of sustainable use.

Some have simplified the concept of sustainable use in financial terms as "living on the interest of biological wealth rather than on the capital", essentially skimming off the natural rate of increase, while realising that some levels of harvest can stimulate faster rates of growth. While fisheries biologists are actively debating whether such an ideal can ever be attained, few doubt that current practices leave enormous room for improvement. At the macroeconomic level, improvements may depend on: appropriate prices of biological resources in the marketplace, reflecting their total value; reflecting the benefits of marine protected areas in cost-benefit analyses; ensuring that those who benefit from exploiting fisheries resources pay the full social and economic costs of their actions; and adjusting discount rates used in economic planning systems to discourage the depletion of biological resources such as fisheries (McNeely, 1988).

4. How Marine Protected Areas Enhance the Sustainability of Fisheries

One of the major objectives of marine protected areas is to ensure the productivity of fisheries by protecting a portion of the spawning stock from exploitation. Eggs and larvae will then spread by oceanic currents to additional areas where they can be exploited (Roberts and Polunin, 1993). Some marine protected areas, such as Apo, Balicasag, and Pamalican in the Philippines, have shown significant increases in overall fish abundance after only one year of protection (Alcala, 1988). Mann *et al*., (1995) have argued that marine protected areas for fisheries purposes are highly beneficial when the local fishing pressure is especially high, because these areas provide a source of recruitment into habitat patches that have been fished out. Lauck *et al*. (1998) produced a model showing how the precautionary principle can be applied to fisheries management through the use of marine protected areas. They found that marine protected areas are far more effective than lowering the allowable catch level. A number of other benefits to fisheries arise from marine protected areas, including: protection of some fish from harvest to ensure an adequate quantity and genetic quality of offspring; dispersal of eggs and larvae from reserves to surrounding areas to maintain and improve fisheries yield; provision of essential genetic material for fish breeding operations and biotechnology involving fish; provision of opportunities for the recovery of important species that have become rare or that have been depleted because of their vulnerability to fishing; provision of insurance against the collapse of fish stocks; facilitation of scientific studies of harvested species, including such parameters as natural mortality that cannot be measured in an active fishery; protection of biodiversity and promotion of a natural balance free from direct human disturbance; reduction of user conflicts by separating incompatible activities; improvement of public awareness and understanding of natural systems; provision of sites for long-term monitoring of environmental changes, with the protected areas serving as baselines against which affected areas can be compared; and protection of sites of great interest for tourists (Bohnsack, 1994).

Protected areas for fisheries can lead to increased yield from fishing and/or value of the fisheries by producing larger, more desirable individuals or a greater diversity of fishes. Protected areas can be established for spawning grounds, nurseries, spawning migrations and other specific purposes. Kapetsky and Bartley (1995) further pointed out that: "Exploitation of fishery resources increases the overall value of the protected area ... providing a basis for quantifying the additional income, employment, and contribution to food security available due to fishing. In addition, by selling the resources to fishermen, the fishery may be a source of income to help defray the costs of the protected area". However, few examples are yet available of fisheries providing a significant income to a protected area.

The use of protected areas for supporting fisheries faces three key practical problems. Should reserves be permanent or rotated? How large should they be? Where should they be located? These questions cannot yet be answered with a sufficient degree of assurance. As Roberts and Polunin (1993) pointed out, if reserves do not contribute usefully to recruitment of fished areas, then benefits will be limited to increased population sizes and larger fishes within the protected areas. If fish do not emigrate out of the protected area, they will not be available for harvesting by fishermen. Protected areas appear, however, a more attractive option than dealing with a collapsed fishery or closing a fishery in order to rebuild stocks that have been depleted. The challenge remains how to link private sector fisheries operations to the benefits provided to fisheries by protected areas.

5. Conclusions

Fisheries biologists are already developing multi-species models and building recruitment processes from fisheries studies into improved management practices that go beyond managing stocks as separate entities. However, as Hall (1998) put it, the current management strategy "is to ignore the uncertainty … having made every possible effort to obtain the best estimate for a stock's current abundance and future trends, catch quotas are set with the best guess". Fisheries researchers are well aware of the complexity of the dynamics of fish populations, and most realise that adjusting fisheries quotas downward is politically very expensive; sometimes a collapse is required before a quota can be reduced. How can fisheries research best continue to contribute? Here are some suggestions:

- Identify spawning grounds and other areas critical to fish populations, and thus identify areas that need to be established as marine protected areas;
- Seek ways to minimise the destruction of habitat through various fishing technologies;
- Develop even better information on species and ecosystems, their relationships, and the uses to which they are subject;
- Carry out field studies to identify social, cultural, and economic factors which affect sustainable use;
- Continue and strengthen research on how to reduce incidental impact on non-target species;
- Develop a better understanding of the processes that drive the dynamics of aquatic ecosystems;
- Develop a better understanding of uncertainty as it affects fisheries; and
- Study linkages between biodiversity, climate change, and fisheries.

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Annex 6 The Challenge of Naming Life on Earth

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1. Introduction

The naming of Life on Earth ranks amongst the greatest remaining challenges to science. Smaller and ever smaller fundamental particles are discovered and named, stars more and more distant are not only detected and labelled but have key features documented, and the genomes of more and more organisms are fully sequenced. Yet the novelty in our backyards passes us by. Species new to science are to be found even in the grounds of Buckingham Palace in central London, let alone in virgin rainforests. In this paper, attention is drawn to the scale of the problem, its resource implications, nomenclatural impediments, and practical steps that could be or are starting to be taken to meet the challenge.

The consensus estimate is that there are about 1.7 million known species on Earth, although no unified catalogue of these exists: 291,000 (17%) of these live in freshwater or marine environments (McAllister *et al*., 1997). That may seem a daunting figure in itself, but it is the gap between the known and the unknown that is the greatest challenge. Estimates of the numbers of unnamed species vary widely, ranging from 112 million down to 3.6 million: an extraordinary span reflecting basic uncertainties. This means that we may know anywhere between 1.5% and 47% of the species with which we share the planet. As a working hypothesis in the face of such ignorance, the *Global Biodiversity Assessment* settled on 13.6 million, suggesting that only 13% of the species, with which we share the planet, have names (Hammond, 1995). This figure is subjective, and considered an overestimate by some (May, 1999). But even if it eventually proved to be 50% or even 100% in error, that would not detract from the fact that there is a major challenge to address.

The situation is strikingly different for different groups of organisms (Table 1). We probably know 84% of the plants and 90% of the vertebrates, but a mere 0.4% of the bacteria, 1% of the viruses, and 4.8% of the fungi. Fish, even in areas such as Sarawak, are considered 95% discovered. Yet it is the lesser studied, mainly microbial groups that are essential to the survival of all Life on Earth. The archaea, bacteria, microalgae and fungi drive fundamental ecological processes, and feature as keystones in all food chains, food webs and pyramids, including those in the soil and sea. Moreover, amongst the organisms still being discovered are ones which are important in global ecology. The photosynthetic bacterium *Prochlorococcus*, recognised in the last decade, may be the most abundant component of the phytoplankton in the sea, contributing up to 80% of total local primary production (Fuhrman and Campbell, 1998). The richness of the unique biota associated with mid-ocean deep sea vents has only been fully appreciated in the same period, and coral reefs have come to be recognised as rivalling tropical forests in species richness.

Many species are confined to particular hosts. On average each plant species can be expected to have 3 bacteria, 5 fungi, 10 insects, 1 virus, and in many cases 1 nematode unique to it (Hawksworth, 1998). This is not just an issue of associates of vascular plants; 52 collections of one species of a tropical leaf-inhabiting liverwort recently yielded 11 ascomycete fungi alone, of which 7 (including two new genera) were new to science (Döbbeler, 1998). In a parallel way, many corals have novel bacteria associated with them as symbionts; the sponge *Ceratoporella nicholsonii* yielded 80 bacteria, most as yet unculturable (Santavy, 1995).

Table 1. Known and estimated species numbers in selected kinds of organisms, compared with the numbers described each year and projected year of completion of the inventory (based on data in Hammond, 1992, 1995 and Hawksworth, 1995).

Organisms	Described (000's)	Estimated (000's)	% Described	Described per year	Number of authors	Years to completion
"Algae"	40	400	10	unknown	unknown	unknown
Animals	1,320	9,800	13.5	17,218	5,205	731
"insects"	1,025	8,750	11.7	7,200	unknown	1,073
Vertebrates	45	50	90	unknown	unknown	unknown
Bacteria	4	1,000	0.4	120	336	8,300
Fungi	72	1,500	4.8	1,800	498	892
"Protozoa"	40	200	20	unknown	unknown	unknown
Plants	270	320	84.4	1,705	875	29
Viruses	4	400	1	100	75	3,960
Total	**1,750**	**13,620**	**12.8**	**20,743+**	**6,989+**	**572+**

2. Resource implications

It has taken 250 years for taxonomists to describe almost 13% of the species on Earth. At present rates of species description, it will take another 572 years to complete the inventory – assuming that the entire taxonomic workforce is redeployed to tackle the most species rich groups (Table 1). Without any switching in the numbers of plant and vertebrate taxonomists, time scales for completion rise to 8,300 years for bacterial groups, 3,960 for viruses, and 892 for fungi. Fish species are currently described at the rate of about 230 each year. As some 24,618 fish species are now known, this equates to an annual growth in knowledge of just under 1%.

Human resources and how they are deployed are critical to more rapid progress. The first objective attempt to ascertain the extent of the current global workforce actively involved in the description of newly discovered species of all kinds was based on the numbers actually indexed in all major groups in a single year (Hawksworth, 1995). Almost 7,000 authors were involved, but were not distributed according to the knowledge gaps. Whereas, each plant taxonomist would have to describe 366 species to complete the world estimated total, each currently active mycologist would have to tackle 3,012. The redeployment of existing human resources remains an issue for debate and decision. At the end of his autobiography, the entomologist Wilson (1994) indicated that if he could relive his vision in the next century he would move into microbiology, with the aid of modern microscopy and molecular analysis. I wonder how many other taxonomists would contemplate such a shift. A consortium of systematists in the US estimated that it would take US$ 3 billion each year for 25 years to tackle the problem: six times the current global expenditure on systematics (Systematics Agenda 2000, 1994). If anything, I suspect that figure to be an underestimate in view of the costs of the molecular studies that we now recognize as necessary to elucidate uncultured archaea, bacteria, and viruses in particular.

Provision of the physical resources to house collections also has to be addressed. There are already about 2.5 billion specimens in museums and other institutions around the world (Hawksworth, 1995). These and newly discovered specimens need to be curated and made accessible to the world's scientific community. If representation was to be maintained at an equivalent level, storage for as many as 20 billion specimens would have to be planned for. There are equivalent resource implications for the various kinds of genetic resource collections, including aquaria, botanical gardens, microbial culture collections, seed banks, and zoos. The world's 482 microbial collections registered with the World Data Center on Micro-organisms (WDCM) hold collectively 786,328 strains (Sugawara *et al*., 1993), but this total is only a fraction of even the known species. An expansion in genetic resource collections of all kinds is needed, not least because, in some groups, comparative living material is required for identification and to fix the application of names.

Organizing even the existing data is a problem. There is still no overall checklist of the species we know, although this is fortunately starting to be addressed through the bold SPECIES 2000 programme (Bisby, CD-ROM with this volume). The specimen collection and other data that lie behind the names also has to be taken on board. This has been recognised by a proposal for a multi-million dollar 15 year programme to establish a Global Biodiversity Information Facility (GBIF) which is to be considered by ministers of the Organisation for Economic Cooperation and Development (OECD) in 1999 (Butler, 1998).

3. Nomenclatural impediments

The systems of naming Life on Earth also need to be addressed. We have to confront a nomenclatural impediment (Greuter, 1998). Name changes frustrate communication and effective research in all aspects of biology and conservation science. Those made responsibly, from new research that provides an improved understanding of the relationships between organisms, are to be welcomed, even if they sometimes appear irksome, as scientific advances. Those that result from our heritage of nomenclatural systems developed when the scale of the challenge before us was not appreciated, and user needs were regarded as secondary, are regrettable.

There are five different international Codes of nomenclature, each governing particular groups: the bacteriological, botanical, cultivated plant, virological, and zoological Codes. The application of the botanical and zoological Codes in particular is time consuming; on average this amounts to not less than about 10% of a taxonomist's research time (Hawksworth, 1994). Extrapolating this to the estimated 7,000 taxonomists actively describing new species, this implies a staggering 700 positions that could be directed into the core taxonomic activity of discovering and naming the Life. This insidious tax on taxonomy can scarcely be justified. Stimulated by long-standing concerns of the International Union of Biological Sciences (IUBS), and in collaboration with the International Union of Microbiological Societies (IUMS), an International Committee on Bionomenclature (ICB), comprising representatives of the different Codes, was established in 1995. The ICB aims to increase harmonisation between the existing Codes, to develop similar solutions to common problems, and to develop a unified approach to the future naming of organisms.

A particular problem is "noise" in the system, both synonyms for known species and names of uncertain application that may actually predate familiar names. It is envisaged that in due course there will be series of lists of names in current use that cannot be disrupted through the resurrection of long-forgotten names. In addition, advantages of a mandatory registration system for newly proposed names, as already occurs in bacteriology, have been recognised; a trial registration system for all botanical groups was initiated in 1998 (Borgen *et al*., 1998).

The ICB has also prepared a *Draft BioCode* (Greuter *et al*., 1998) which is currently under discussion. It is anticipated that this could be used for all kinds of organisms once basic lists of protected names and registration mechanisms are in place. The *BioCode* would relate to names proposed from a future date to be agreed by the various international bodies concerned, and not significantly affect names already in existence. The *BioCode* has the potential both to reduce materially the amount of non-productive time spent on nomenclatural matters by taxonomists, and to eliminate name changes purely for nomenclatural reasons.

4. *Practical steps*

Recognising the enormity of the overall task, what can pragmatically be done to meet the challenge? It is evident that the present piecemeal approach will have no significant impact for the foreseeable future. The issue is therefore what to name. Should the available human and financial resources be targeted to fully inventory certain groups, and if so how should they be selected? Priority might be given, for example, to species which people needed to communicate about, or ones which merit particular attention because of their roles in ecological processes and ecosystem structure or functioning, their value as bioindicators (including the use of macrophytes and invertebrates as bioindicators of water quality), and their relevance to food security and the sustainable use of natural resources. Systematics Agenda 2000 – International started to address this problem in November 1998.

Working practices will also need to be modified. Rapid ways of both documenting and disseminating information on newly discovered species will need to complement more streamlined approaches to the formal naming and registration of those newly discovered species. Systematists will also have to accept that in studies of species richness, Rapid Biodiversity Assessments based on collections sorted into unnamed "recognisable taxonomic units" will become the norm (Beattie, 1993).

Complementarity between systematists and systematic institutions can be enhanced in order to maximise the effectiveness of the taxonomic effort. National, regional and global networks are being developed to this end. For instance, BioNET-International (BI) was established in 1993 to develop regionally organized networks, primarily in developing countries, to enhance the skills base needed to support programmes on the conservation and sustainable use of biodiversity (Jones, 1997). In due course, the Global Taxonomic Initiative, launched by the Convention on Biological Diversity in 1997, is also expected to support the systematic infrastructure necessary for the implementation of the Convention.

With these steps, Internet database back-up through SPECIES 2000, and the Global Biodiversity Information Facility, practical steps to address the challenge before us are in train.

5. *Conclusions*

The challenge of naming Life on Earth is so great that there has been a tendency to dismiss it as an unrealisable goal. Yet to fail to provide the communication system necessary for the conservation and sustainable use of natural resources will be to fail humanity and our science. To address the problem requires pragmatic working practices and levels of cooperation that are not part of the taxonomic tradition. Difficult decisions over priorities and how taxonomists organise themselves and spend their time cannot be avoided. The message of the importance of their task as an underpinning world service must be communicated to and fully understood by the government departments and agencies that support taxonomic work and collections. The ascendant tendency to use taxonomists in revenue-generating projects rather than in taxonomic work *per se* also needs to be reversed. Living off taxonomic capital without adequate investment to replace and enhance that resource is unlikely to prove a successful long-term strategy in any institution. A sea change is starting to take place. There has been a welcome shift amongst taxonomists from over half a century of special pleading to redress declining support, to the development of major collaborative programmes that both excite systematists and are designed to meet user needs. The image of the isolated taxonomists amongst dusty specimens and books, oblivious of the excitement of the living world to explore, promises to pass into history as the challenge of naming Life on Earth is enthusiastically embraced.

6. *Acknowledgements*

I am grateful to Patricia A. Taylor-Hawksworth for assistance in researching data for this paper, and to the organisers of the meeting for facilitating my participation.

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Annex 7 Analysis of Biodiversity Data: Drops from the Ocean

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1. Introduction: From Oceans of Data come Rivers of Information, Streams of Knowledge and Drops of Wisdom

Environmental science is a science that is exploring an ocean of existing data in an attempt to find a few valuable drops that will lead to a better understanding of the environment in which we live, and thus to being able to make a difference, however small. This ocean of data is made up of myriad facts. Many of these facts, of course, have yet to be converted to data that is in a form that is of any use. There is a need to examine those masses of data in search of the few drops of wisdom or knowledge contained within them and that will allow us to make that difference.

It is not always obvious, when first dealing with an ocean of data what difference any one drop may make. Indeed no one drop alone is likely to make a difference, but it is the integration of many drops through analysis, their extension by modelling and their interpretation through the political process that will eventually lead to an accumulation of knowledge. At the beginning of this process, however, it is not always clear which drops will be of value in the long run but it is important to keep that long-term goal of "making a difference" in mind at all stages.

The process of reaching the final decision-making process is usually long. The first stage in that process - the identification, acquisition and gathering together of data - is one of the most underrated stages, but is the one that inevitably takes the longest time and more often than not, the most effort. It is also the stage that is mostly poorly carried out, but it is this stage that needs the most rigour to enable the following stages to be defendable and repeatable and to enable us to determine and understand the uncertainty within the final decisions. Recent improvements in data management allow us to find more easily the data we require in the masses of data available. This paper will expand on these issues and illustrate each stage, with examples from Australia and elsewhere.

2. Finding the Data

Metadata is a relatively new term that often turns people off when used in a forum like this. This should not be the case as, when used in the right way, good metadata will allow a user to find relevant datasets and to determine whether they are likely to be of use to them. It should also alert the user to constraints that may apply to the data, to information that will allow determination of its fitness for purpose, and to informing the potential user as to where and how the data may be acquired. There are a number of examples where metadata is being linked to analysis systems such as Geographic Information Systems (GIS) and to systems that allow the automatic download and availability of data to users over the Internet. Australia's Environment Department, through ERIN - the Environmental Resources Information Network, is linking metadata through an on line metadata system, the Environmental Data Directory (EDD) (EA 1998) to ArcView* GIS. A tool, known as AV-EDD (Symonds, 1998), allows staff of the Department to search for data (using the metadata information), to ascertain any conditions that apply to the use of the data, and to immediately load the data into the GIS. A second system developed in ERIN uses the

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metadata to develop an on-line licence system from information provided by a user using the internet along with information from the metadata and legal documents. Once the user agrees to the licence conditions, the licence agreement and a copy of the metadata are downloaded to the user along with the data itself (Freeman, 1997; Freeman *et al*., 1998).

Distributed database technologies are now being used to link metadata databases from around the world. Examples include GELOS (Global Environment Locator Service) developed by the G7 Environment and Natural Resource Management System (GELOS, 1997), Australian Spatial Data Directory (ASDI, 1998) and the Global Change Master Directory (Olsen, 1998). GELOS is a system which is using a mixture of hardware and software systems to retrieve environmental metadata from a range of agencies across the world. It uses the Z39.50 protocol (ISO, 1998) as the interchange standard. GELOS is built around two complimentary services, the GELOS Web-based information system which allows thousands of users to contribute resources to the Library, and the GELOS network of interoperable databases which is a platform that allows users to search across different databases and systems to retrieve information (ENRM, 1997; Chapman and Croft, in press). Prototypes have been developed, such as those by the Committee on Earth Observation (CEO) in Italy (GELOS, 1997), and by GELOS Search the European Environment Agency (EEA, 1997). The Australian Spatial Data Directory also uses the Z39.50 protocol to link nine distinct Commonwealth and State Government metadata sites in a common searchable interface (ASDI, 1998). NASA's Global Change Master Directory (GCMD) is a comprehensive directory of descriptions of data sets of relevance to global change research. The GCMD database includes descriptions of data sets covering climate change, the biosphere, hydrosphere and oceans, geology, geography, and human dimensions of global change (Olsen, 1998).

3. Determining Fitness for Use

Fitness for use or quality of a dataset is a key element in selecting a dataset for use in any project. A dataset cannot be regarded as high quality or low quality per se as it is the use to which the dataset is to be put that will determine whether it is of high or low quality for that particular use (Chapman, 1999). For example, a dataset that records presence or absence of plant or animal species by country may be perfectly suitable for someone preparing a species list of that particular country, but if someone wishes to prepare a species list by 10 minute grid square or to determine if a particular species occurs within a particular conservation reserve within the country, then the data has to be regarded as not fit for that purpose and consequently of low quality. Properly recorded metadata should provide the information necessary for a user to determine if the dataset is fit for the purpose to which it is to be put.

4. Modelling Across Data Gaps

There are many environmental models for modelling species distributions, especially in terrestrial areas. Most of these use environmental attributes such as rainfall, temperature, soils and geology along with known point localities to model predicted distributions. Some of these models, such as the Australian bioclimatic modelling software, BIOCLIM (e.g., Busby, 1991; Chapman and Busby, 1994) have been in widespread use for many years, especially for modelling at a small scale. Others such as Generalised Additive Models (GAM) and Generalised Linear Models (GLM) (Austin et al., 1995) have had better success at regional level, but rely on having both absence as well as presence data available for best use. More recently, Genetic Algorithms such as the Genetic Algorithm for Rule Production (GARP) (Stockwell, 1994; Boston and Stockwell, 1994) have begun to be used for environmental modelling. The success of Genetic Algorithms looks promising for large-scale modelling, but they have not been in use for environment modelling long enough for their worth to be properly assessed.

Many of these models should also be able to be applied to non-terrestrial environments, including marine environments. However, the environmental datasets for modelling have still to be fully developed (Margules and Redhead, 1995). In the marine environment, these include especially bathymetry, water temperature, salinity and turbidity. In addition, the number of reliable point-based biodiversity records available are generally too sparse to allow reliable modelling. This should, however, not stop the development and further testing of models in these environments.

5. Model Validation

Once a model has been produced, it needs to be validated against the known truth. This is not always easy and can prove extremely costly. For example, if a model predicts the likely occurrence of a species in a particular environment or geographic area, a survey can be conducted in an attempt to locate it. Depending upon the extent of the geographic area predicted, this may not be difficult, but more often than not, a species may be predicted over a wide area, and a fully effective survey may be beyond the resources available. An alternative method is to use expert opinion to validate the model. The Rapid Forests Assessment project being carried out in Australia has recently tested a number of these methodologies (e.g., Davies and McKenny, 1997; RFA Steering Committee, 1997). Models were prepared for a number of species using known localities and modelling these against a number of environmental variables such as climate, temperature, soils and habitat preferences. These models were then shown to an audience of experts for the area and feed back solicited. More often than not, these experts were able to refine the models based on their expert knowledge. For example, it might be shown that a particular species is known not to occur in one of the predicted areas due to a wrong geology, or ecosystem, etc., or to occur in an area where the model hasn't predicted (A. Taplin and D. Barrett, pers. com.). In this way the model can be refined. This may then reduce the area required for further survey and hence the cost of further verification of the model. In other cases, the refined model may prove sufficient for the purpose to which it is being put. At all stages, any modifications to the modelled areas are recorded, and can be verified or modified as further information becomes available.

6. Filling Data Gaps

The second use of models is to determine where to carry out future surveys most effectively. Limited resources do not allow continuation of unstructured random survey and exploration. The use of environmental models can assist the selection of survey sites in those environments that are undersurveyed compared to other areas. When one uses geography alone to determine survey locations, it is not always obvious where the real data gaps may be. By modelling survey locations against a range of environments (temperature, rainfall, salinity, etc.) it is easy to determine which classes within the various environments have been well surveyed and which under-surveyed. From this, more cost-effective surveys can be planned to fill the data gaps better (Neldner *et al.*, 1995).

Once the models are produced, further analysis using Geographic Information Systems can be carried out to overlay the models against other environmental attributes such as tenure, etc. This may place the predicted distributions, say for an endangered species, against protected areas, or migratory birds and fish against Ramsar wetland sites, etc.

7. Data Presentation

The presentation of analysis results to environmental decisionmakers must be in a manner such that they can understand what the information is telling them to allow them to make informed decisions. Maps and reports must be simple, use non-technical terms wherever possible, and not be over cluttered - i.e., not include extraneous information that detracts from the main objective. They should, however, include all information of relevance, including the sources of the information, map projections, clear legends, acknowledgements, etc.

The problem with much environmental analysis and especially environmental models are the high degree of uncertainty in those models. Too often, the results of environmental modelling, when transferred to maps, are looked on as fact when in reality, the mapped result is usually only one of a range of possibilities. For decisionmakers and managers to be best able to make truly informed decisions they should be aware of the uncertainty in the results and/or the range of uncertainties. The presentation of this uncertainty is not always easy. It may be represented on the maps themselves in one of a number of possible ways (e.g., Ehlschlaeger, 1998; van der Wel *et al.*, 1994), as animations (Ehlschlaeger and Goodchild, 1994; Ehlschlaeger *et al.*, 1997) or in associated reports (Hunter and Goodchild, 1995). The uncertainty in environmental models and outputs, should not however, be ignored any more than the error in the original data should be ignored. Uncertainty is seldom presented to policymakers – it should be!

8. Conclusions

Data – from their original selection and collection through to their presentation as analysed or modelled information in a report or map require diligence in tracking accuracy, quality and uncertainty. Errors in the original data will lead to great variations in the uncertainty in the final output and to even more uncertainty in the final outcome. The difference that those data will lead to may not be the difference required if the wrong data are chosen at the beginning, or if the models are run with the wrong assumptions. All these factors need to be taken into account in the determination of the uncertainty in the final results and presented to those who are making the decisions in a manner that they can understand and interpret. It is important that decision makers and environmental managers using the output of data analysis understand the full implication of the results they are using, and that includes the uncertainty inherent in those results.

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Annex 8 Sustainable Use of Biodiversity

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1. Introduction

This paper reflects the agronomy background of the author, and has no data and details on aquatic species or ecosystems and their conservation and use. It rather discusses general concepts which should be equally applicable to aquatic biodiversity, drawing on Pullin's (1997) suggestion to include 'useful comparisons from the field of agrobiodiversity' into ICLARM`s Internet database on aquatic resources (Froese and Pauly, 1998). The first part highlights some conceptual aspects of sustainability and its assessment in a time and space framework, with special reference to biodiversity as the resource to be sustained. The second part focuses on the application of the Convention on Biological Diversity (CBD) and its translation into economic terms to derive policies for the sustainable use of biodiversity.

2. Operationalizing the sustainability paradigm in the context of system theory

The objective of sustainable use of biodiversity was put forward in the context of UNCED 1992, where the CBD was put on the world agenda. In the aftermath of this conference, the sustainability paradigm, which dominated the preparation of UNCED and the CBD, was analysed in more detail. Some critical aspects of the sustainability paradigm relate to its vague definition and its subsequently difficult operationalisation. The basic definition of sustainability of the World Commission on Environment and Development (WCED, 1987) emphasised the temporal dimension of *inter*generational equity as complementing the conventional aspect of *intra*generational equity, i.e. the spatial and social dimension. Thus, for translating sustainability into measurable terms, the spatial and temporal dimensions of the system to be analysed need to be defined, and appropriate scales and time horizons have to be chosen.

The predictability of system behaviour is possible to only a limited extent (Dörner, 1989). In principle, such predictability requires knowledge of the dynamics of the entire life cycle of the observed components. This is, however, not always possible in *ex ante* analysis of long-term developments. The most relevant experiences with respect to ecosystem management have been gained in fisheries. Ludwig *et al.* (1993) reviewed the concept of 'maximum sustained yield' (MSY) for fisheries management based on analysis of historical statistics. They concluded that this concept encouraged overexploitation of a fluctuating resource due to a 'ratchet effect': the lack of limits on investment during good periods, but strong pressure not to disinvest during poor periods. They concluded that predictions of future events, in particular the effects of atmospheric changes, are extremely difficult because the time scales involved are so long that observational studies are unlikely to provide timely indications of required actions or to highlight the consequences of failing to take remedial actions.

Wissel (1995) showed the potential of ecological modelling for predicting system behaviour. In particular, he pointed out that modelling forces one to define clearly which system component or property is to be sustained and which timeframe and spatial scale is to be used as a reference.

In ecosystem theory it is generally agreed that systems may exist in any one of several stable states, depending on environmental conditions (multiple stability). As a consequence, small changes in factors that influence the system may lead to sudden and strong changes or even collapse of the system. Such sudden changes have been experienced in fisheries when slight increase in the harvest rate has led to the destruction of the fish resource (Wissel, 1995). Thus, recognising threshold levels of factors that may cause undesirable irreversible changes to an ecosystem is the greatest challenge in sustainability assessment. This requires the detection of hidden stress before it translates in yield decline or before the system is irreversibly damaged. Thus, to anticipate changes that are not yet apparent in yield decline, yield trend analysis must be complemented by indirect measures of the ecosystem's capacity to respond to stress; e.g., by observing symptoms of change not directly linked to the yield trend, such as species composition or rates of flow and turnover (Becker, 1995; Dalsgaard *et al.*, 1995).

Wissel (1995) concluded that modelling, under clearly defined conditions and assumptions, can be used to predict system behaviour, not as a deterministic prognosis but to indicate the level of probability of a system behaving in a particular way. This provides a way to assess the remaining risk of failure at applying certain strategies or policies.

Such risk assessment has become common practice in Environmental Impact Analysis over the last decade. However, predictability is limited not only by probability assumptions which can be estimated in more or less exact and reliable figures. Often, one is also confronted with uncertainty, i.e. unpredictable events whose effects cannot be assessed, either in quality or in intensity. Going beyond risk and uncertainty, Dovers (1995) included ignorance in designing sustainability policies. Ignorance refers to unprecedented effects that cannot even be recognised.

Despite these shortcomings, system theory has proven valuable for sustainability assessment. First, it contributes to clarifying the conditions of sustainability. By definition, system theory forces one to define the boundaries of the system under consideration and the hierarchy of aggregation levels. By identifying the system hierarchy, externalities between levels and trade-offs among components can be traced and explicitly taken into consideration. This is particularly necessary for operationalising the spatial and social aspects of sustainability; i.e., for reconciling local and global needs and interests.

In this way, the 'tragedy of the commons', (i.e. individual use of common resources), can be analysed adequately only by considering the higher system level to find proper policies for sustainable use; e.g., in the case of marine fisheries in international territories. Such conflicting interests among different groups - or hierarchical levels of the system - is a typical problem in sustainability strategies. Problem analysis is greatly facilitated by system theory to derive alternative scenarios of future development, depending on the policy chosen.

3. Operationalizing sustainability in space and time

Figure 1 situates selected sustainability indicators in a space/time frame; a logarithmic scale was chosen so that the entire range of local to global dimensions and of short to long durations can be shown. Although short time spans (i.e., hours or less) are relevant for biological and physical processes, sustainability assessment is focussed on longer time periods. Thus, these fast processes are not covered by this diagram, although they may enter into the modelling of system components.

The diagram shows that yield trends and Total Factor Productivity (TFP) as the two approaches central to the assessment of agroecosystem sustainability are very limited in scale and scope. In particular, they cover time spans of only one or two decades. Thus, they do not assess intergenerational changes, which, according to the WCED definition, is the principal criterion for sustainability. Similarly, policy measures have a temporal scope of at most one or two decades, but generally much less. The most prominent approach derived from the concept of intergenerational equity is to calculate and valorise resource depletion or absorption capacities for pollution. This concept can be applied for trend assessment of abiotic, physical, and terrestrial resources and to the assumed sink capacity of aquatic, terrestrial, and atmospheric systems over intergenerational time periods.

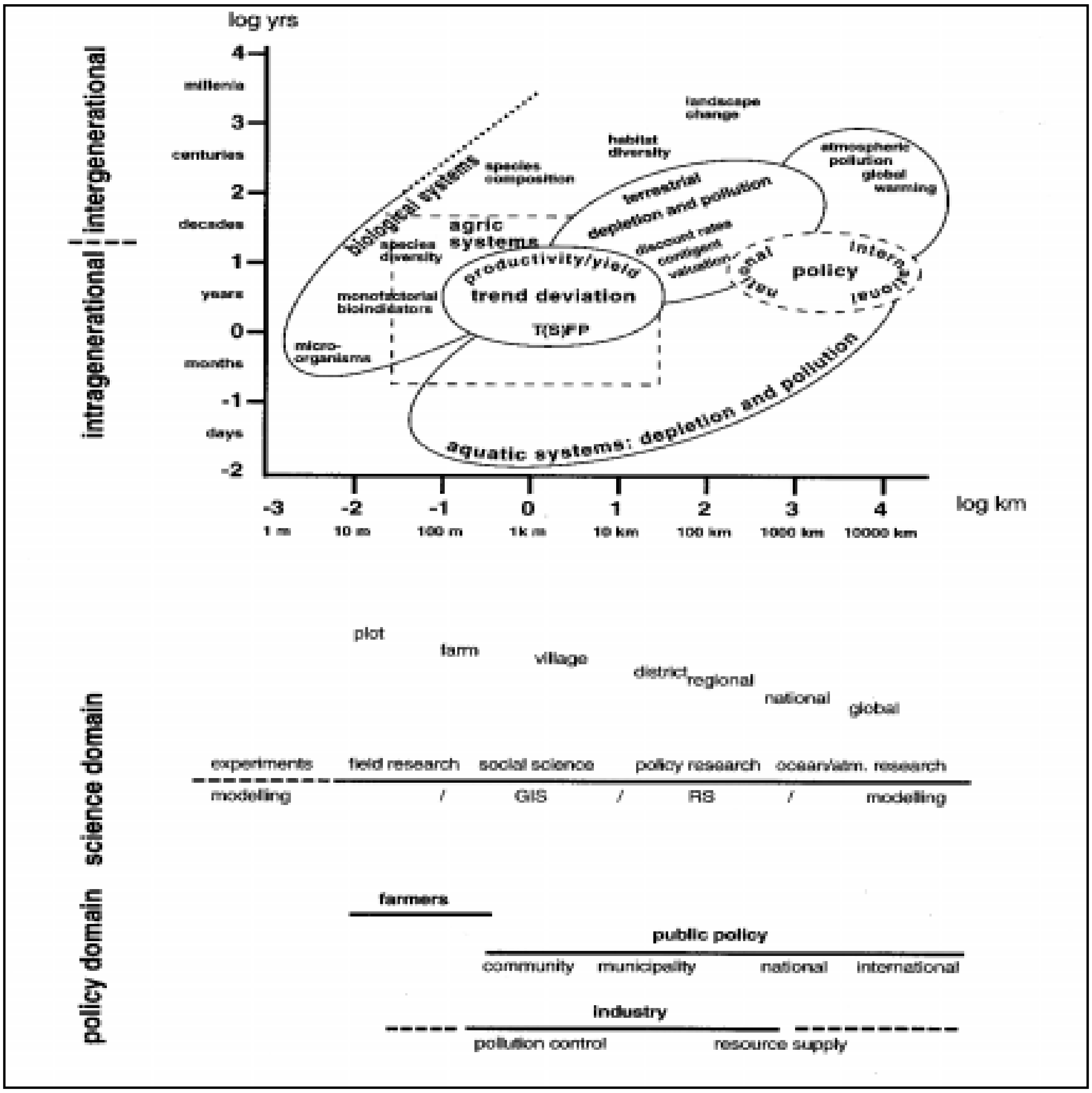

Figure 1: Space and time matrix for sustainability assessment: source, Becker (1997).

While resource endowment and sink capacity are dynamic system properties with regard to supply and absorption over time, they are also site-specific spatially differentiated system properties. This includes the total amount of resources, as well as the dynamics of biological activity and the genetic potential of biodiversity, as well as the transfer of resources from one site to another (Haber, 1994). Just as resource flow results in spatially unequal depletion and consumption of resources, waste transfer leads to unbalanced pollution, in particular of aquatic ecosystems.

Considering the threat of irreversible extinction, the conservation of biodiversity is the greatest challenge for sustainability strategies with the longest-term implications. In Figure 1, it is assumed that extinct species are unsubstitutable ('hard' sustainability), leading to time horizons on the order of magnitude of evolutionary processes. If substitutability of the value of species were assumed ('soft' sustainability), the temporal scope for their replacement would depend on the creativity of humans, i.e., on technical progress.

4. *Use and valuation of biodiversity*

The first part of this paper highlighted the complex operationalization of sustainability. The second part focuses on the complex valuation of using biodiversity. These considerations are based on a classification proposed in the context of ecological economics for the monetary valuation of biodiversity (see *inter alia*, Braun and Virchow, 1996; Pearce and Moran, 1994). The use of biodiversity comprises its direct, indirect and future use. The direct use can be further subdivided into consumptive and non-consumptive use. Going one step further from use categories to economic categories, the total economic value of biodiversity assets is the sum of its use value with the above mentioned components, and of its non-use value, consisting of the existence and the bequest value.

Traditionally, material direct use value has been the only biodiversity component with an economic value attached to it. Even for this component, it may be difficult to assign the appropriate monetary value; e.g., depending on whether a genetic resource being used in a subsistence economy or on local or global markets. Using the example of non-wood forest products (NWFP) in tropical forests, estimates of the value of this genetic resource range from <1 to 420 US$ $ha^{-1}yr^{-1}$ (Godoy *et al.*, 1993), with a median of 50 US$ $ha^{-1}yr^{-1}$. If an accurate estimate of the material direct use value is so difficult, assessing the indirect use value and non-use value components of biodiversity is even more difficult in quantitative terms. Non-use values require an elevated degree of informed judgement rather than precise monetary calculations. As shown for sustainability assessment, consideration of the proper time and space scales is essential for economic biodiversity assessment. Pearce and Moran (1994) reviewed available literature with estimates of the economic value of biodiversity and related the results of case studies to categories of biodiversity values.

At the local level, the wealth of biodiversity for direct use as food, medicine, raw material, etc. has always been known to indigenous populations, whether a monetary value was attached to it or not. At the global level, awareness of these riches has gained increasing importance over the last few years. Under the label of 'bioprospecting', private companies claim property rights for the 'discovery' and subsequent use of substances derived from living organisms for use in pharmacy, cosmetics, or for industrial purposes. In particular, marine organisms have become the target of extensive bioprospecting (Mooney, 1997; Glowka *et al.*, 1998). This policy adequately takes into account the genetic diversity of the target ecosystems. However, the benefits derived from bioprospecting largely go to the private companies and not to the local communities of whose territories these substances and organisms are extracted - possibly even making use of their collective traditional knowledge.

5. *Conclusions*

Scientific analysis of sustainability is a necessary and useful tool for defining problems, but its role in the derivation of specific policies is limited. Dovers (1995) recognised a gradient for response-framing from micro-level to a macro-levels. 'Micro-problems' may be solved by 'applied science', meso-issues by 'professional consultancy', whereas 'macro-issues' require 'post-normal science' - as Dovers coined it -, reflecting a gradient of increasing system uncertainty and increasing decision stakes. Consequently, with increasing scale, policy decisions are more and more normative and value-guided, possibly even irrational, rather than based on 'hard' scientific facts.

Translating the sustainability principle of intergenerational equity into policy requires the definition of priorities between short and long-term goals, the choice of realistic time horizons, and dealing with risk, uncertainty, and ignorance. In modern society, policy decisions generally have short time horizons, in the order of years rather than decades. Yet the impact of such decisions may have much longer effects. In the case of long-term environmental damage, Ludwig *et al.* (1993) pointed out that: "Scientific certainty and consensus in itself would not prevent overexploitation and destruction of resources. Many practices continue even in cases where there is abundant scientific evidence that they are ultimately destructive".

The complementary sustainability principle of intragenerational equity refers to decisions that span the local and global levels, and their reconciliation, under the CBD objective of benefit sharing. Examples of economic values attached to biodiversity assets of tropical rain forests reveal that the relative proportions of direct and indirect use values at local and global level and the respective beneficiaries are highly incongruent. In view of the increasing dominance of globalisation, strong advocacy is needed for giving due consideration of the local value of biodiversity to the indigenous populations when negotiating policies to achieve the CBD objectives: conservation and sustainable use of biodiversity, and the fair and equitable benefit sharing arising out of the utilisation of genetic resources.

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Annex 9 Ecosystem management: a biological basis

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1. Introduction

The awareness that fish, or more generally 'living aquatic resources', are an integral part of their ecosystem is certainly not new (e.g., Hardy, 1924). However, and especially for marine areas, exploitation of living resources has been handled on a species-by-species basis. In the past, more generalised concepts may have been limited largely by practicalities; e.g., the lack of computational facilities to adequately handle a multitude of highly non-linear interactions of populations with their abiotic and biotic environment. However, modern hard- and software technology make it possible to quantify the conceptual understanding of ecosystem functioning, and it is a particular challenge to scientists to translate this increased understanding into more holistic concepts of the management for exploitation of aquatic ecosystems.

2. The traditional approach: single species based advice for fisheries management

Traditional single-species management is still practised widely (e.g., ICES, 1998a). Following Russell (1931), it builds on the classical estimates of fish population dynamics, namely stock size, growth, mortality and recruitment, which can be derived using standard software packages such as the FAO-ICLARM Stock Assessment Tools (FiSAT; Gayanilo *et al*., 1995). Results of this kind of assessment are stock-recruitment curves, yield-per-recruit estimates and estimates of the maximum sustainable yield. For the North Atlantic and adjacent seas, this standard analysis has recently been extended by estimating target and limit reference points (e.g., ICES, 1998b), perceived to be consistent with the precautionary approach behind the FAO Code of Conduct for Responsible Fishing (FAO, 1995).

Hydrographical observations, such as preferred temperature (Csirke, 1980), optimal recruitment window (Cury and Roy, 1989), or other habitat considerations may find their way into improved stock-recruitment curves (e.g., Jarre-Teichmann *et al*., in press), but do not necessarily find their way into scientific advice for fisheries management.

3. Four steps towards ecosystem management:

3.1 Incorporating ecology into single-species models, with emphasis on fish

Predator-prey interactions among fish species, such as accounted for in Multispecies Virtual Population Analysis (Sparre, 1991; Pope, 1991), have increased insights into the interspecific dependencies of fish production and led to more realistic estimates of natural mortality rates, notably for the younger age groups of a given fish population. However, it is only those improved natural mortality rates which have been used in producing scientific advice for fisheries management – estimates of interdependencies of species population dynamics have largely been ignored (Brugge and Holden, 1991).

3.2 Incorporating ecology into single-species models, with focus on the ecosystem

Trophic flow models, such as mass-balance models constructed using the Ecopath software (Polovina, 1984; Jarre *et al*., 1991; Christensen and Pauly, 1992, 1995), allow the inclusion of all components of an ecosystem in a model, notably the various links from primary producers to herbivorous or detritivorous invertebrates that build the basis for fish production. Starting off as static models, they give a picture of the trophic flows in an ecosystem during a period of time with certain well-defined properties; e.g., a decade with high abundance of a target fish species, typical seasonal conditions, or a period with a climatic anomaly. Higher-level analysis of the properties of the system analysed can subsequently be performed; e.g., investigation of the trophic structure by Lindeman's (1942) discrete trophic levels, mass cycling analysis (Finn, 1976), Odum´s (1969) theory of system maturity, or ascendancy theory (Ulanowicz, 1986). Such summary statistics also give insight into common properties or distinct features among ecosystems, and therefore allow for comparison (Jarre-Teichmann, 1998; Pauly *et al.*, 1998).

3.3. Simulating trophic interactions in an ecosystem

Recent work (Walters *et al.*, 1997) has made it possible to simulate changes in an ecosystem based on a mass-balance model of, for example, the Ecopath family. As a typical application, such a simulation allows assessment of the consequences for an ecosystem of a change in fishing pressure (e.g., Shannon and Jarre-Teichmann, 1998), taking into account direct impacts and indirect consequences of this change on all system components. As a further extension, economic analysis can be linked to this biological assessment (Sumaila, 1998).

3.4 Ecosystem modelling for ecosystem management

Ecosystem management requires spatially-explicit management decisions, which in turn require spatially-explicit ecosystem modelling. Partially or fully coupled, two or three dimensional biological-physical simulation models, although generating most interesting scientific insights, require computational facilities beyond the reach of many scientists in the world, as well as highly specialised expertise. As an alternative, a spatial component of the EcoSim approach is under development (Walters *et al.*, in press) which does not provide the link to highly variable physical conditions, but allows for spatial simulation based on the "average" conditions mentioned above.

4. A step beyond trophic interactions: habitat concepts for ecosystem management

An important basis of spatially explicit simulations are the requirements of the different components of an ecosystem with respect to their habitat . In this respect, the habitat concept applies to a geographical range (species occurrence, distribution), but should also be understood in a wider sense as physiochemical habitat (e.g., waterbodies with suitable temperature and oxygen conditions), or the habitat provided by biogenic structures (coral reefs, sponge aggregations) which, in a further step, link in with community requirements and biological diversity (Fig. 1). Furthermore, different life stages of an ecosystem component may have different habitat requirements (e.g., the presence of seagrass beds for the development of juveniles, and an intact deeper-water ecosystem for the adult populations), and these habitats need to be linked in space and time (e.g., Cross *et al.*, 1997).
Consequently, habitat quality assessment (Fig. 2) is a complex task that is to be carried out outside an ecosystem model primarily based on trophic interactions. However, the results of such analysis can well be re-incorporated into ecosystem approaches using the existing tools. Using radioactive pollution as an example, Dalsgaard *et al.* (1998) simulated the distribution of persistent pollutants in the food webs of a tropical coral reef and a temperate shelf ecosystem, respectively.

In conclusion, and without trying to claim exclusiveness, the modelling tools presented here provide an important step towards the biological basis of genuine ecosystem management. They are straightforward to use – and as a tool to assess the impact of changes in fishing policy, species habitat, or, for that matter, biological diversity, they allow to test hypotheses on the outcome of such change in a situation where real-world experiments usually cannot be carried out.

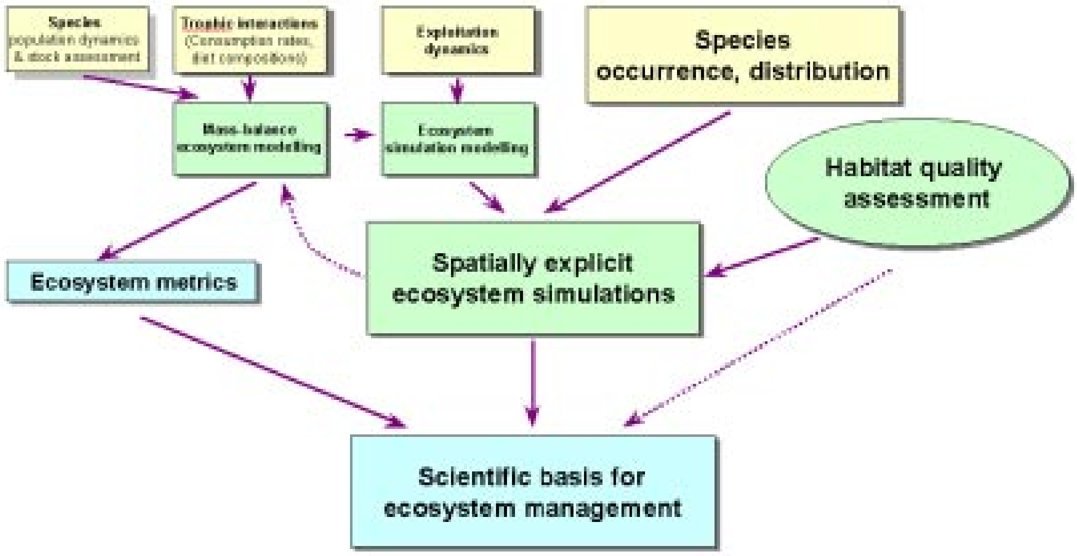

Figure 1. Components of the scientific basis for ecosystem management.

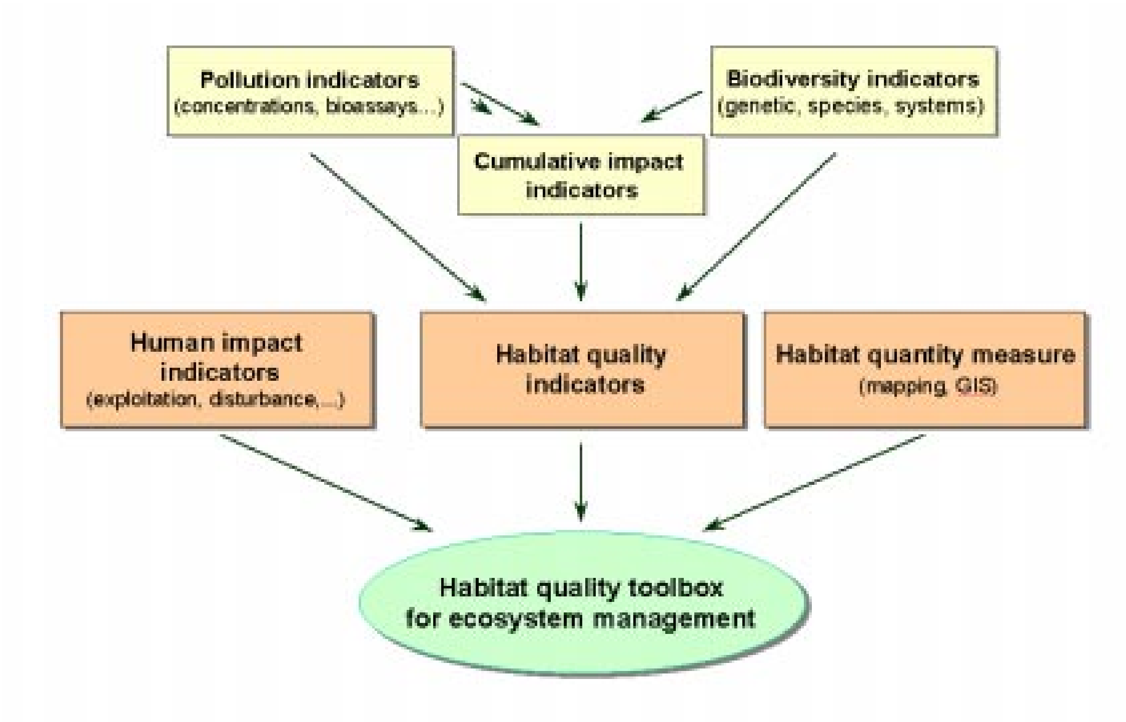

Figure 2. Habitat concepts for ecosystem management: development of a toolbox for habitat quality assessment, e.g. for input into ecosystem models.

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Annex 10 The Economics of Aquatic Biodiversity

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1. The economics of biodiversity

The economics of biodiversity is essentially a specialised application of two of the main areas of research in environmental and natural resource economics: the appropriate *valuation* of environmental assets and the *incentives* to invest in maintaining stocks of those assets. These are obviously closely related: if decisionmakers value inappropriately the assets for which they are responsible, they will then make inappropriate investment decisions. But it is important to distinguish cases where the decision to disinvest in assets, such as the extent of biodiversity, is *efficient* from those where it is *inefficient*. One of the difficulties that non-economists sometimes have is in accepting that the former can be a possible outcome, though this simply follows from the anthropocentric viewpoint of classical economics. If a different viewpoint is taken, then there may be interest in conserving a wider range or different types of biodiversity, but it will still be essential to understand the economic mechanisms at work in reducing biodiversity.

1.1. Valuing biodiversity

The conceptual and practical difficulties of biodiversity valuation are immense. It is important to emphasise that the *total economic value* of an environmental asset encompasses potentially a wide range of attributes. Some of the difficulties that non-economists sometimes have (with notions such as efficient disinvestment) flow from a failure to appreciate this. A primary distinction is between *use* values and *non-use* values. The former include benefits from *direct* consumption of and production from biological resources, and from their *indirect* contributions to supporting consumption and production. One of the difficulties in establishing even these more straightforward valuations is that the relationships, especially quantitative relationships, between the biological products (which are directly consumed or used as productive inputs) and biodiversity is not clear in most cases. The same is true of the indirect support, often identified as ecosystem services, which biodiversity contributes to consumption or production. In popular discussions, too hasty identifications are sometimes made between the productivity of biological resources, ecosystem services and biodiversity; possibly leading, at this level, to overvaluation of the last. Indeed, some increases in the productivity of biological resources over time have been strongly associated with declines in biodiversity; suggesting that the real causes for concern are more subtle and are to do with sustaining the productivity of biological resources over very long time horizons and with their resilience to shocks.

Valuation questions carry high levels of *uncertainty*, flowing from a lack of knowledge of the processes involved as well as from the fact that these processes are often intrinsically stochastic or chaotic. This is compounded by the assumed *irreversibility* of declines in biodiversity. Thus there is a need to impute an *option* value to biodiversity to reflect aversion to the risk of making irreversible decisions and a *quasi-option* value to reflect the possible gains from learning about biodiversity over time. Moreover, the *existence* of biodiversity can be valued for moral, aesthetic or other reasons, independently of any direct or indirect contribution to consumption or production. Moreover, existence value needs to be distinguished from so-called non-consumptive use values, such as tourism, which arise from observing stocks of biological assets rather than consuming them or using them in production. The distinction between this and non-anthropocentric valuation is philosophically subtle. Again, the potentially wide scope of economic valuation should be emphasised.

1.2 Externalities from biodiversity

Moving down the list, from direct use value to existence value, means moving progressively away from values which are likely to be of interest to resource appropriators, and especially of appropriators whose interest is in the marketability of resource products. Thus, there is likely to be a disjuncture between the *private* and *social* valuation of natural resource stocks and of the biodiversity embedded in or underpinning them, and this is likely to become more pronounced as more natural resources are traded more impersonally. This classic *externality* problem is one reason for supposing that biodiversity is undervalued by many decisionmakers and that there is insufficient investment in maintaining it, especially by non-traditional appropriators.

1.3 Efficiency and equity in biodiversity conservation

For this reason, and for others discussed below, inefficiently low levels of investment in maintaining biodiversity would be expected. An important issue is the extent to which attempts to ameliorate disinvestment in biodiversity have distributional implications; that is, effects on the incomes of resource appropriators. If these effects are inequitable and cannot be properly compensated for, then attempts to raise investment in biodiversity are likely to be difficult to implement (and, of course, such effects are important in their own right).

Equity has two dimensions: the distribution of incomes among those with current interests in biodiversity and the distribution of incomes among those with interests in the biodiversity at different times. The latter problem is especially severe when different generations are involved, partly because compensation is even more difficult to implement than it is among those currently alive, and given the long time horizons involved in biodiversity management this is highly likely. These distributional dimensions are termed *intragenerational* and *intergenerational*. In terms of the productivity of biological resources, it could be argued that there are short-term gains from reducing biodiversity and longer-term, more uncertain gains from lower rates of reduction. Further, biodiversity is often greater in poorer parts of the world, partly because of the foregoing but also for underlying ecosystem reasons. Thus, the burden of attempts to slow biodiversity decline are likely to fall in the first instance on the incomes of poorer people who are alive now, in the interests not only of their descendants but also of the descendants of the better-off; and these gains are relatively uncertain. There is potential for serious inequities and of distributional conflict if attempts are made to arrange compensatory transfers. There have been experiments with instruments such as debt-for-nature swaps, particularly for tropical rainforests, but these have been very limited in scope. In essence, this is the problem which has already been confronted in attempts to ameliorate global warming.

1.4 The economics of species extinction

In *static* models of sustainable catch, extinction may result from attempting to operate at maximum sustainable yield and misidentifying this or not allowing for stochastic effects in the stock. Alternatively, if there is a failure to manage effort levels and if costs per unit of effort are sufficiently low relative to revenue, then stocks may become biologically unstable. Costs per unit of effort are compounded from the technical efficiency of fishing and input costs. Though poor, traditional fishing communities have low input costs, they also generally have inefficient techniques, partly because of financial constraints. In modern fisheries, input costs may be higher, but techniques are more efficient, and, more important, there are high levels of innovation in techniques, increasing the probability of biological instability over time.

In *dynamic* models, the critical consideration is the relationship between the marginal biological productivity of the stock (the effect on growth of the stock as stock sizes alter), adjusted for valuation effects as stock sizes alter, and the risk-adjusted rate of return on competing assets. The need to earn a positive rate of return on investment in a fishery itself biases stock size downwards, risking biological instability; hence, the antipathy of many conservationists to the use of positive discount rates in making natural resource investment decisions. If the competing rate of return exceeds the adjusted biological marginal productivity of the stock even at critical minimum levels, then the stock becomes extinct (at least in terms of its commercial availability), unless costs per unit of effort relative to revenue rise sufficiently rapidly at very low stock sizes. This is important since it suggests that what is essentially a single species model of extinction may mislead in multispecies models which offer the opportunity for switching effort among species (Wilson, 1982). In terms of biodiversity, this has important policy implications, since some commonly used policy instruments used to control overfishing, such as quotas on catches of particular species, may dampen down switching and thus damage diversity unless they are carefully designed

If the rate of return on competing assets is socially efficient, then this generates the well-known model of *optimal extinction*. Even leaving aside wider issues to do with evaluating the social efficiency of discount rates, there are familiar arguments for supposing that resource appropriators may demand excessively high rates of return. First, in situations of extreme poverty and if, for example, natural resource stocks have become seriously depleted through some environmental shock, it may appear rational to consume the remaining resource stock: since survival into future periods only has a positive probability if the present period is survived. Second, resource appropriators, especially if they are poor or live in socially isolated communities, may be faced with highly imperfect financial markets imposing usurious interest rates. Both of these arguments link poverty to resource depletion. However, traditional communities may well have stronger intergenerational commitments, perhaps embodied in customary norms that emphasise the need to maintain natural resources.

Third, failure to control access to fish stocks (and thus effort levels in their exploitation) are equivalent to excessively high discount rates, since there is an incentive to catch before others do. *Open access* has long been widely regarded as one of the leading causes of depletion of many natural resource stocks (Gordon, 1954), especially of fish, and thus of biodiversity. However, there was for a long time a tendency, especially among economists, to conflate open access with *common property*. It is now recognised that many common property regimes involve sophisticated methods of communal effort management and that a simple contrast between open access and private property is therefore misleading (Ostrom, 1990).

1.5 The economics of habitat conversion

Models of species extinction have for some time dominated the economic analysis of biodiversity loss. They are undoubtedly appropriate to the context in which they were first developed, that of deep sea fisheries, with the caveat that care is needed in extending them to multispecies contexts. However, in looking at coastal and especially inland fisheries, one must be alert not only to the nature of local common property management regimes, but also to the existence of possible alternative uses of the supporting habitat. Biologists have long recognised this a major factor in explaining biodiversity loss, and it has major implications for the choice of policy instruments. The optimal rotation interval of a stand of a timber is shorter the higher the worth of the land in the next best alternative use. In effect, timber has to be felled at an earlier date so as to generate a higher rate of return to justify maintaining the present use of the land. When this can no longer be achieved, the land is switched. Exactly the same would be true of a waterbody which had alternative uses. The usual assumption is that this reduces biodiversity. This is not necessarily the case: for example, the switch may be into ecotourism, and this may be linked with decisionmakers putting a proper valuation on biodiversity, as discussed above. Notice that if the use of the waterbody as a capture fishery, is degraded by, say, pollution from high intensity aquaculture, this then increases the probability of switching. Thus environmental degradation as a cause of biodiversity loss can be analysed within this framework.

The important policy implication is that simple species protection, for example, restrictions on trade in products from endangered species, may be counterproductive if it depresses the value of the habitat on which they depend, leading to switching. As Swanson (1994) has pointed out, it is possible to view investment in a species, in their habitat and in a management regime as component parts of a general model of investment in biodiversity, thus integrating much of the relevant analysis into a common framework.

2. A Case Study: South East Asian floodplains

An interdisciplinary research project has studied floodplain capture fisheries in Bangladesh (Hail Haor in Sylhet province), Indonesia (the Lempuing River, Sumatra) and Thailand (Thale Noi lake and its associated swamp, the Phru, in Phattalung province) (Heady and Winnett, in preparation). The main objective was to explore the sustainability of biodiverse small-scale inland fisheries. At all three sites, there are artisanal peasant fisheries, each exploited predominantly on a household basis. Mechanisation is restricted to simple outboard motors but this should not suggest a 'subsistence' type of activity. All the fisheries are well integrated into complex and modern trading networks and fish caught in each may be traded commercially, often over quite large distances and even internationally.

The project built up a detailed profile of the exploited fish stocks (their composition by species and age, and their mortality rates from catches by different sorts of fishing gear) and the formal and informal regimes under which the fisheries are managed, and the markets in which fishing households operate. This information was used to construct a formal, computable model, but there are many important aspects of such fisheries which cannot be captured in models of this sort. In particular, an emphasis on overfishing as a result of failure to control access has informed many management decisions, but can mislead and even exacerbate problems, by leading to inequitable outcomes which are not acceptable to the community. This can undermine local management regimes which have been probably quite supportive of biodiversity for long periods of time. This is the central conclusion of these studies.

2.1 Characteristics of floodplain fisheries

There is a close link between access to such floodplain fisheries and distribution of income, both among those who work the fishery directly and between them and other claimants on the income (including the agencies and agents of the state). This is always the case, though the socio-economic complexity of the fisheries studied here makes this access-distributional nexus especially complicated and constraining. However, received wisdom sees the solution to overfishing as an efficiency gain to be traded-off against the disruption of the pattern of income distribution which would result from a tighter restriction on access; (and a disruption which, if thought undesirable, could be handled by compensatory policies: for example, by adjusting tax burdens to redistribute income). The underlying assumption is that there is a reasonable sensitivity of catch to effort. But if the aggregate catch is relatively insensitive to variations in effort over wide ranges, there may be little efficiency gain to be found, and all that is left is the distributional disruption.

These arguments should not be taken to as suggestions that there is never likely to be a problem of long-term sustainability in the type of fisheries studied here. Rather, if there is a problem, it is more likely to come from pressures external to the fishery, than from the inadequate management of fishing effort within the community. These may be pressures which adversely shift the whole catch-effort relationship or disrupt the legitimacy of the pattern of distributional claims on the fishery. The first may affect sustainability directly but, by undermining the customary access-distribution nexus, both may set in motion moves to altogether different modes of exploitation, which may not be sustainable.

2.2 Modelling catch and effort in floodplain fisheries

In all three fisheries studied, there are large numbers (thirty to forty) of species caught by equally extensive ranges of active and passive fishing gears, which vary in their selectivity among species, according to factors such as location, time of use, and mesh size. Most of the fish species have high rates of reproduction, growth, and mortality, and depleted species are quickly replaced by others. All of this reflects adaptation to the high fertility and variability of the floodplain environment. The project was able to capture much of this complexity by adapting and extending FAO's BEAM 4 model (Sparrre and Willman, 1991). The key result was that aggregate weight and value of catches were found to be quite insensitive to all but the most extreme restrictions on fishing activity, and indeed that they sometimes suggested *under*fishing. For example, reducing effort on all gears by half *reduced* the weight of catch by

17% in Bangladesh and by 4% in Thailand and Indonesia. The latter orders of magnitude are typical: the scenarios generally have only a small effect on either the total weight of fish caught or the total catch value. At Hail Haor, the only restrictive scenarios that increased the catch and by very small amounts were one gear ban and one (selective) closed season.

These results are not consistent with the view that the fishery is generally overexploited. Given the usual perceptions of resource use in Bangladesh, this is surprising. Indeed, small increases in total yield are generated by increases in fishing effort. Similarly, the Lempuing fishery showed no substantial yield increases from more restrictive management. It can be safely concluded only that there is no evidence of serious general overfishing in any of these three study sites, although there is overfishing of some species and some life-history stages. Moreover, some guilds are overfished; e.g., carps and predators in Hail Haor, predators in the Lempuing River and snakeheads in Thale Noi/Phru. Others are underfished, in the sense of being below the maximum yield; e.g., medium and small fish and shrimps in Hail Haor; blackfish, whitefish and shrimps in the Lempuing River. In most cases, the changes of catch for individual fish types that resulted from changed effort levels were substantial. On the (perhaps questionable) rule of thumb that fishing down the food chain is indicative of problems with sustaining biodiversity this appears to suggest that such problems may be developing or, indeed, already be present.

2.3 Access and income distribution in the fishing community

Very large changes in labour time, beyond anything that could be regarded as realistic, are necessary to produce anything more than small changes in the value of catch. Consider the fishery as under the control of a rent-receiving owner. The main effect of the owner restricting access would be to restrict employment and the labour incomes of fisherfolk at the expense of rent. There would be very little effect on the total value of catch, but much distributional disruption.

In Bangladesh and for Thale Noi in Thailand, the households that derived a significant income from fishing comprised three groups: high income, middle income and poorest. The short-run effects of various scenarios on the *average* income of each of these groups is only slightly larger than their effects on the total catch value. In contrast (and this is the important point) there are very often large distributional effects *within* each group. For example, a seine net ban on Hail Haor caused the poorest households, on average, a 1% fall in income, with the worst-off household suffering a drop of 36% and the best-off an increase of 8%. Thus, concealed within fairly stable aggregates and averages are large potential shifts in income at the microlevel: attempts to change levels patterns of fishing activity could have serious distributional effects.

2.4 Communities and sustainability

The fisheries literature has tended to focus on overfishing as the problem to be addressed. Such a view is based essentially on, so to speak, the internal dynamics of the fishery. The conclusion here is, rather, that the sustainability problems of the fishery are better understood as part of the wider problems of the economy, society, and polity of which it forms a part. Threats to biological sustainability are most likely to arise from environmental degradation, particularly if this leads to recruitment failures. However, pressures on the viability of the local management regime are most likely to arise from external pressures on the system of income entitlements within the fishery, and this has been relatively neglected in conventional economics. Rural overcrowding and outward migration can disrupt rural fishing communities in terms of shifts in the size and structure of population which then feed through into patterns of income distribution. Further, both rural overcrowding and outward migration share some common causes with environmental degradation, when related to the wider contexts of extreme population pressure and rapid, unbalanced economic growth, respectively. Thus any attempts to intervene in the management of the fishery, in the belief, say, that these interventions are necessary to maintain biological sustainability (which, as we have seen, in these fisheries is linked to a high level of diversity), have to be alert to the capacity of the local management regime to absorb distributional shocks and to whether the best solution lies within the fishery at all.

3. *Conclusions : future research issues*

Fisheries research has been the province of specialised groups of biologists and economists. It is generally true to say that the elaboration of models on the biological side has not been matched by comparable elaboration on the economic side, and *vice versa*. However, there is an important interaction between complexity in the biological structure of the fish stock, with multiplicity of species and maturities, and complexity in the adaptations of effort available to fisherfolk, along dimensions which include selection of gear types and of location and time of fishing. Thus it is necessary to go beyond simple homogenous measures of fish stock and fishing effort, and this will require more extensive collaboration and understanding between biologists and economists, continuing a process which we began in the project reported. Against this background, obvious candidates for further research include: application of this modelling strategy to other types of aquatic ecosystem; collection of information on the relative valuation of habitats for biodiverse fishing and other uses, and how this is affected by environmental change; collection of information on the impacts of technical and economic change (especially in labour markets) on fishing costs and gear choice; and integration of all such information into the model.

4. *Acknowledgements*

This paper was prepared with the assistance of Professor Anil Markandya. It draws on material prepared jointly with Professor Christopher J. Heady and Dr J. Allister McGregor as part of UK Overseas Development Administration project R4791 on floodplain fisheries; biological sampling and modelling was carried out by the Marine Resources Advisory Group associated with Imperial College, London (Heady and Winnett, in preparation).

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Annex 11 Governance and Sustainable Use of Aquatic Biodiversity

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1. Introduction

For this conference, the governance approach can be looked upon as a framework in which questions can be phrased or issues raised, which are of relevance for the way in which the conservation and sustainable use of aquatic biodiversity can be 'governed' in an effective and legitimate manner. These questions and issues can be seen as 'modern' expressions of broadly acceptable norms for how humans want this governance to look and to take place. As with all norms, they are debatable and give room for different translations into action. However, they might be a workable start applicable to the aims of this Conference. The paper has a broad conceptual character and does not attempt to address directly the governance and sustainable use of aquatic biodiversity. The concept of 'social-political governance' is considered to be: those arrangements in which public as well as private actors participate, that are aimed at solving societal problems or creating societal opportunities and at caring for the societal institutions within which these governing activities take place (Kooiman, 1993, 1999; Kooiman *et al.*, 1999).

2. Societal trends and changing governing relations

Governance, as a concept is receiving a lot of attention these days. The basis for this lies in societal developments and in particular in growing or changing societal interdepencies, at many levels and in many directions. Most governance concepts highlight aspects of this awareness. One might say that this common element expresses itself quite well in the notion of long-term societal trends such as processes of differentiation and integration. These processes result in lengthening chains of interdependence or, phrased more dynamically, in lengthening chains of interaction (Kaufmann *et al.*, 1986). These chains become increasingly institutionalised, with multilevel and multisectoral dimensions. Such lengthening chains of interaction cause and require a multiplication of the number of parties participating in them, while also the number of interactions among these parties multiplies. Not only multilevel but also intersectoral patterns of integration take place. These might be seen as answers to changing needs for collective action; collective in the sense of public and private interactions, and not just of public responsibilities alone.

As a consequence, the dividing lines between public and private sectors are becoming blurred. Interests generally are not just public or private, they are frequently shared. Responsibilities are becoming diffused among various societal actors and their relationships are changing. It is generally more appropriate to speak of shifting roles of government than of shrinking roles of government, as part of such changing relationships. A reshuffling of government tasks and a greater awareness of the need to cooperate with other societal actors does not render traditional government interventions obsolete. It merely implies a growing awareness of the limitations of traditional public command-and-control mechanisms. Responses to societal problems require broader sets of instruments. These instruments have been partly borrowed and incorporated from market actors and from civil society parties.

3. Coping with diversity, dynamics and complexity of societal situations

The conceptualisation of societal tendencies mentioned above, emphasises three basic characteristics of modern societies which form a basis for further theoretical refinement: diversity, dynamics and complexity. All three are important and all three have their particular problems and opportunities as subjects of governance. To illustrate diversity, dynamics and complexity, some ideas are borrowed here from systems thinking: a system being a whole of entities which show more interrelations among themselves than with other entities which form the environment of the system. Diversity, according to this perspective, is a characteristic of the entities which form the system and points at the nature and measure in which they differ from each other. Complexity is an indicator for the architecture of the relations between the parts of a system, between the parts and the whole and between the system and its environment. Dynamics applies to the tensions within a system and between systems.

The starting point of this governance conceptualisation is that social-political phenomena and their governing, in terms of interactions further explained below, should be placed in the context of the diversity, dynamics and complexity of societies all over the world. These societies derive their strength from these characteristics. In other words, they present these societies continuously with opportunities. But they also present them with problems. These opportunities and problems are themselves also complex, dynamic and diverse. After all, they reflect the strong and the weak sides of these societies. This also applies, without doubt, to the conditions under which opportunities are created and used and problems formulated and solved. Therefore the methods of governing should also be complex, dynamic and diverse. If not, their success will be a matter of chance rather than purpose.

4. Interactions and governance

There seems to be a shift away from more traditional patterns in which governing was basically seen as "one-way traffic" from those governing to those governed, towards a "two-way traffic" model in which aspects, qualities, problems and opportunities of both the governing system and the system to be governed are taken into consideration. This is termed ‘social-political governance’, based upon broad and systematic interactions between those who are governing and those who are governed, and this applies to public-public as well as public-private interactions and the way they are governed. Often, these interactions are based on the recognition of (inter)dependencies. No single actor, public or private, has all the knowledge and information required to solve complex, dynamic and diversified problems; no actor has an overview sufficient to make the application of needed instruments effective; no single actor has sufficient action potential to dominate unilaterally in a particular governing model.

Interactions can be considered as mutually influencing relations between two or more entities. Within systems of interactions, some forces are at work with a tendency to maintain existing relations and others are at work to change them. In these tensions, the dynamics of an interaction are implied. In the characteristics of the entities among which the interactions occur, the diversity of real life comes into being. In the mutual cohesion between these many interactions, the complexity of the governing world is realised. Interactions can take place at many societal levels: from interactions among individual actors to those among nation states. They can take many different forms: from cooperation and bargaining to competition and conflict.

5. Modes of governance

Three modes of governance are recognised here, self-governance, heterarchical governance and hierarchical governance. The most 'chaotic' and fluid forms of social-political interactions, expressed in governing terms, are those of a *self-governing* character. In modern societies, sectors certainly govern themselves up to a certain point. It could not be otherwise. There are, however, major differences between different sectors in the character and scope of this self-governing or, in juridical terms, ‘self-regulation’. By comparison, *‘co’* forms of governing, are *heterarchical*; i.e., different forms of horizontal and vertical relations are mixed and can follow each other in the course of time; although modes of horizontal structures still dominate. There is more equality in such structures, within which participating entities relate to each other. Autonomy of those entities remains an important characteristic of interplays; relinquishing autonomy is always only partial and involves mutual agreements, common rights and duties. *Hierarchical* modes of governance are the most formalised forms of governing interactions, but interactions they remain. Rights and duties are organised according to superordinate and subordinate responsibilities and tasks. In particular, the positive and negative sanctions attached to interventions have a highly formalised character and are surrounded by all kinds of political and juridical guarantees.

From the perspective of governing, the three modes are looked upon in general terms; separate from a particular governance situation. So, for the purpose of getting insight in modes of governing, the questions to be asked are more in terms of: what can self-governing interactions do as systems? What kinds of effects can they be expected to have? What kinds of problems might arise in what kinds of situations? The same applies to 'co' modes of governing and hierachical governing. There may also be social-political considerations in terms of certain 'ideological' or 'methodological' preferences. In the late 80s and in the early 90s, self-governing became 'ideologically popular', whereas interactive governing became popular from a more methodological point of view. From the mid-90s, there seems to have been a come-back of hierarchical forms, such as the perceived need for a 'strong state': one starts speaking here of 're-regulation'.

Social-political (collective) problem solving and collective opportunity creation in complex, dynamic and diverse situations are public as well as a private, governmental as well as market challenges, and profit-seeking as well as non-profit activities. At one time, one party takes the lead; in another situation, it is another one. A growing number of social-political challenges call for shared responsibilities and 'co-arrangements'. For solving social-political problems and (preferably) creating social-political opportunities, thorough and combined public and private insight into the diversity, dynamics and complexity of social-political questions and the conditions in which these questions arise is indispensable. All this expresses itself in different mixes of public, public-private and private forms of interactions, organised in the three modes distinguished above. Little is known about their qualities or faults. In the context of this paper, it is really suggested that, on the basis of analyses so far, the mix of self- and co-governing has hardly been explored, whereas the mix of co- and hierarchical mix between self and hierarchical governing have been somewhat more explored. An analytical grip on the mix of all three is still at a very early stage.

6. Governing orders

Recognising different orders of governance facilitates, hopefully, the 'linking' of different levels of aggregation with different levels of analysis, in terms of the action-structure level of governing interactions. *First-order* governing aims to solve problems directly, at a particular level. *Second-order* governing aims to influence the conditions under which first order problem-solving or opportunity creation takes place. In fact, second-order governing applies to the structural conditions of first-order governing. But, if we take this structural level as our primary governing level, such governing becomes first order, and so on. In addition to these two 'orders' there is a third, *meta*; i.e., *third-order* governing. Basically, in meta governing the question is being asked: 'who or what ultimately governs the governors'? In itself, this is a simple question but, in practice, the answer is far from simple (see below).

6.1 Problem-solving or opportunity creation as first-order governing

The great challenges in modern societies are not only finding solutions to collective problems, but also creating collective opportunities. The 'classical' (routine) distinction of turning to government for problem-solving, and to the private sector and the market for creating opportunities is an inappropriate and ineffective point of view in modern societies. Collective problem-solving and collective opportunity creation, in complex, dynamic and diverse situations, are a public as well as private tasks, and are governmental as well as a market and civil society challenges. At one time one party takes the lead, in another situation it is another one; and there seems to be a growing number of social-political challenges that call for shared responsibilities and 'co-arrangements'.

6.2 Institution building: second-order governing

Recent interest in the role of institutions in influencing behaviour of actors (and thus their willingness or ability to enter into interactions) has given insight into factors which may be of importance in this context (Hall and Taylor, 1996). In the first place, it is becoming clear that one can identify institutional influences on 'behaviour' of actors. Governing actors such as politicians, but also private sector and non-profit sector leaders trying to maximise the attainment of certain specific goals, will be influenced by institutions; as these help or hinder them by providing or withholding insight into the behaviour of other actors. Information such as that concerning enforcement mechanisms for agreements and penalties for non-compliance plays a crucial role here.

However, not all behaviour can be expected to be of such a goal-maximising nature. Individuals are also accustomed to established routines or familiar patterns of behaviour that satisfy rather than maximise. Institutions provide the frameworks for such routines, which filter alternative views and behaviour patterns.

6.3 Meta: third -order governing

The above serve as building-blocks for social-political governing, but a building has not yet been fabricated. This can be done by developing 'mortar' between the building blocks which should be able to keep the whole construction together. This mortar consists of political and managerial norms and criteria. In other words, in addition to all the analytical distinctions made so far, a more norm-oriented framework, which binds together what the analysis has 'taken apart', has to be developed.

Here, the governing rabbit is conjured out of the systems-theoretical hat. And to continue the image, the magic is more than adding the rabbit to the hat. The whole is more than the sum of the constituent parts. This again, is one of the foundations of the systems paradigm. Governing is not just things governors do or do not do, or things that the governed do or do not do.

This systems quality is best expressed by the term *governability*. The governability of a system expresses not only how the system governs itself (as a whole) but also how it wants to govern itself (as a whole). Somewhere in the conception, the matching of the empirical and the normative must take place, and here, through the concept of governability, is where this can be done most explicitly. Governability, in particular, aligns the three 'orders' with normative content. In first-order governing, day-to-day problems are tackled; in second-order governing, the conditions for first-order governing are formulated. But, of course, a lot of differences, clashes, conflicts, risks and uncertainties remain unsolved. What to do then? These are the kinds of dilemmas that, belong to the domain of meta governing. Basically these have to do with normative qualities of 'governability': how legitimately do we handle problems that seem insoluble? What kinds of effectiveness conditions for governing do we find acceptable or unacceptable? The basic normative rules of the game can be said to guide its governing quality. In other words, the quality of governing is governability, or the question of 'good governance'.

7. Conclusions

This paper has explored the utility of the governance concept as an instrument to conceptualise problems and opportunities and their contexts on the borderline between the social and the political: in current terminology, the borderline between state, market and civil society. These issues cannot be handled by each of these 'realms' in isolation. Their character and nature is such that they 'trespass' over the more traditional boundaries separating them. By taking diversity, dynamics and complexity and their mutual relations as a starting point, a governance model comes into being in which social systems and the entities forming them can be interrelated consciously, explicitly and purposefully. This governance theory starts with diversity, dynamics and complexity of the societies to be governed and governing themselves. These societies need order, but nothing can change without dynamics. They need similarity to enable communication, but diversity to gain new insights. They need standards to reduce uncertainty and risk, but complexity to solve problems and to create opportunities. So, theorising on governance aims to be diverse but consistent, complex but elegant, and dynamic but orderly. The 'and-and' not the 'either-or' is a main characteristic of this exploration. This, it is hoped, could serve as a stimulating and useful framework for thinking about governance of sustainable use of aquatic biodiversity.

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Titles of Related Interest

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The ACP-EU Fisheries Research Initiative

The ACP-EU Fisheries Research Initiative was requested by the ACP-EU Joint Assembly, composed of Members of the European Parliament and Representatives of African, Caribbean and Pacific (ACP) Countries, in a Resolution on Fisheries in the Context of ACP-EEC Cooperation, adopted in October 1993. A series of dialogue sessions was conducted between ACP and European aquatic resources researchers, managers and senior representatives of European cooperation, using a draft baseline paper for the Initiative produced by intra-European consultation.

The Initiative aims at promoting sustainable economic and social benefits to resource users and other stakeholders, while preventing or reducing environmental degradation. It has set an agenda for voluntary collaborative research based on mutual responsibility and benefits. It promotes commitment to addressing the most crucial problems of rehabilitating complex resource systems and their ecological and economic productivity with the objective of informing and supporting more directly economic and political decision making, through pro-active and high quality research.

Suitable instruments to fund such research are, among others, the European Development Fund (EDF), International Science Cooperation (INCO-Dev) as part of the EU 5th Science Framework Programme, European Member States bilateral research and cooperation programmes and ACP institutions' own resources.