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Report of Working Group 19 on Ecosystem-based Management Science and its Application to the North Pacific

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Abbreviations and Acronyms

ABC	Allowable biological catch
ACC	Area Coordinating Committees, Japan
ADFG	Alaska Department Fish and Game
AMD	Acid mine drainage
ANN	Artificial neural network
As	Arsenic
BAEP	Basic Act of Environment Policy, Korea
BCCDC	British Columbia Conservation Data Centre
BOD	Biological oxygen demand
BRP	Biological reference point
BSAI	Bering Sea and Aleutian Islands
CCA	Cowcod Conservation Area, U.S.A.
CCIMA	Central Coast Integrated Management Area, Canada
CCLCRMP	Central Coast Land and Coastal Resource Management Plan, Canada
CCME	Canadian Council of Ministers of the Environment
Cd	Cadmium
CEAA	Canadian Environmental Assessment Agency
CEC	Commission for Environmental Cooperation of North America
CEDP	Community Economic Development Program
CEPA	Canadian Environmental Protection Act
CFIA	Canadian Food Inspection Agency
CITES	Convention on International Trade in Endangered Species
CN	Cyanide
CNY	Chinese yuan
COD	Chemical oxygen demand
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPS	Coastal pelagic species
CSSP	Canadian Shellfish Sanitation Program
CWS	Canada-wide Standard
CZMA	Coastal Zone Management Act, U.S.A.
DEPOMOD	Particle tracking model used in aquaculture waste modelling
DFO	Department of Fisheries and Oceans, or Fisheries and Oceans Canada
DO	Dissolved oxygen
DPSIR	Driver-Pressure-State-Impact-Response
EAM	Ecosystem approach to management
EBFM	Ecosystem-based fisheries management
EBM	Ecosystem-based management
EBS	Eastern Bering Sea
EBSA	Ecologically and Biologically Significant Area
Ecopath/Ecosim	Ecological/Ecosystem modelling software
EEZ	Exclusive Economic Zone
EFH	Essential fish habitat
EIA	Environmental impact assessment
EIS	Environmental Impact Statement
EL	Equilibrium line
EMA	Environmental Management Act, British Columbia
ENSO	El Niño–Southern Oscillation

EO	Ecosystem objective
EOA	Ecosystem Overview Assessment
EPA	Environmental Protection Agency, U.S.A.
ESA	Endangered Species Act, U.S.A.
ESS	Ecologically significant species
ESSCP	Ecologically significant species and community properties
ESSIM	Eastern Scotian Shelf Integrated Management, Canada
FAO	Food and Agriculture Organization, UN
FCA	Fisheries Cooperative Association, Japan
FIS	Fishery Science Committee, PICES
FMO	Fishery Management Organization, Japan
FMP	Fishery Management Plan, U.S.A.
FMR	Fisheries Management Region, Russia
FTA	Free Trade Agreement
FUTURE	Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems program, PICES
FWS	Fish and Wildlife Service, U.S.A.
GBAP	Georgia Basin Action Plan, Canada
GEF	Global Environmental Fund
GLOBEC	Global Ocean Ecosystem Dynamics Programme
GOA	Gulf of Alaska
GS	General Status of Wildlife in Canada
GVRD	Greater Vancouver Regional District, British Columbia
HAB	Harmful algal bloom
HADD	Harmful alteration, disruption or destruction
HAPC	Habitat areas of special concern
Hg	Mercury
HMP	Habitat Management Plan, Canada
HMS	Highly migratory species
EIM	Integrated ecosystem management
IFQ	Individual fishing quota
IM	Integrated Management
IMO	International Maritime Organization, UN
IPHC	International Pacific Halibut Commission
IPMA	Integrated Pest Management Act, British Columbia
IR/IU	Improved retention/improved utilization
IUCN	International Union for Conservation of Nature and Natural Resources
IVQ	Individual vessel quota
JPOI	Johannesburg Plan of Implementation
LME	Large marine ecosystem
LOMA	Large Ocean Management Area
MAFF	Ministry of Agriculture, Forestry and Fisheries, Japan
MARPOL	Marine Plastic Pollution Research and Control Act, U.S.A.
MBTA	Migratory Bird Treaty Act, U.S.A.
MEOW	Marine Ecoregions of the World
MEQ	Marine Environmental Quality (also Marine Environmental Quality Committee, PICES)
MIFAFF	Ministry of Food, Agriculture, Forest and Fisheries, Korea
MMPA	Marine Mammal Protection Act, U.S.A.
MOE	Ministry of Environment, British Columbia
MOMAF	Ministry of Maritime Affairs and Fisheries, Korea
MPA	Canada's Oceans Act-legislated marine protected area
mpa	Marine protected areas in general, *i.e.*, legislated by *Acts* other than Canada's Oceans Act
MRA	Maximum retention allowance
MRB	Maximum retainable bycatch

MSE	Management strategy evaluation
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act, U.S.A.
MSST	Minimum stock size threshold
MSVPA	Multispecies virtual population analysis
MSY	Maximum sustainable yield
NEPA	National Environmental Policy Act, U.S.A.
NFRDI	National Fisheries Research and Development Institute, Korea
NMFS	National Marine Fisheries Service, U.S.A.
NOAA	National Oceanic and Atmospheric Administration, U.S.A.
NPESR	North Pacific Ecosystem Status Report, PICES
NPFMC	North Pacific Fishery Management Council, U.S.A.
NWFSC	Northwest Fisheries Science Center, NOAA
OAP	Ocean Action Plan, Canada
OECD	Organisation for Economic Co-operation and Development
OFL	Overfishing level
OY	Optimum yield
PA	Precautionary approach
PBR	Potential biological removal
PCA	Principal components analysis
PCB	Polychlorinated biphenyl
PCPA	Pest Control Products Act, Canada
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fishery Management Council, U.S.A.
PICES	North Pacific Marine Science Organization
PMRA	Pest Management Regulatory Agency, Canada
PNCIMA	Pacific North Coast Integrated Management Area, Canada
PULSE	*PICES Understanding, Linking and Synthesis of Ecosystems*
RCA	Rockfish Conservation Area, U.S.A.
RFCC	Regional Fisheries Coordinating Committees, Japan
ROV	Remotely operated vehicle
SAFE	Stock Assessment and Fishery Evaluation documents
SAIP	Stock Assessment Improvement Plan, U.S.A.
SakhNIRO	Sakhalin Research Institute of Fisheries and Oceanography, Russia
SARA	Species at Risk Act
SCOR	Scientific Committee on Oceanic Research
SEP	Salmonid Enhancement Program
SOA	State Oceanic Administration, China
SSB	Spawning stock biomass
SSC	Science and Statistical Committee, NPFMC
TAC	Total allowable catch
TAE	Total allowable effort
TINRO-Center	Pacific Research Institute of Fisheries and Oceanography, Russia
TMDL	Total maximum daily load
UNCED	UN Conference on Environment and Development
UNCLOS	UN Convention on the Law of the Sea
USSR	Union of Soviet Socialist Republics
VMS	Vessel monitoring system
WGEO	Working Group on Ecosystem Objectives
WMA	Waste Management Act, British Columbia
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization
WWTP	Municiple wastewater treatment plant
YRCA	Yelloweye Rockfish Conservation Area, U.S.A.

Executive Summary

In October 2004, PICES Working Group on *Ecosystem-based Management Science and its Application to the North Pacific* (WG 19) was established, under the direction of the Marine Environmental Quality Committee (MEQ) and Fishery Science Committee (FIS), with the following terms of reference:

1. Describe and implement a standard reporting format for Ecosystem-based Management (EBM) initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem based management objectives of each country.
2. Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges.
3. Evaluate the indicators from the 2004 Symposium on "*Quantitative Ecosystem Indicators for Fisheries Management*" for usefulness and application to the North Pacific.
4. Review existing definitions of "ecoregions" and identify criteria that could be used for defining ecological boundaries relevant to PICES.
5. Hold an inter-sessional workshop in Year 2 or 3 of the WG's mandate that addresses the status and progress of EBM science efforts in the PICES region, with the deliverable being either a special journal issue or a review article.
6. Recommend to PICES further issues and activities that address the achievement of EBM in the Pacific.

The second term of reference above was never addressed, as it was later realized that no PICES country was advanced enough in EBM applications to be at the stage where it was monitoring and actively practicing EBM.

This Working Group report builds on the earlier Study Group on *Ecosystem-based Management Science and its Application to the North Pacific* report (Jamieson and Zhang, 2005), which documented that:

1. EBM challenges are different in China, Japan and Republic of Korea compared with Canada, Russia, and the United States because of differences in coastal population sizes and their different exploitation histories for most harvestable renewable resources. For the former three countries, EBM is, initially at least, focused on (a) minimizing existing impacts, (b) rebuilding depleted stocks to more acceptable levels, and (c) minimizing, in nearshore areas in particular, widespread impacts in the marine environment from land runoff from both industrial and urban developments. In contrast, human coastal populations and urban development in the latter three countries were generally much less, with fishing impacts and offshore oil and gas development and transport identified as the major impacts. In many instances, relatively unaffected habitat and biological communities still exist, and so the challenges there are often how to maintain them while permitting appropriate new economic activities to occur; and
2. While there are many human activity impacts on the marine environment *(e.g.*, fishing, mariculture, oil and gas exploration and development, pollution from land-based activities, disruption of freshwater discharges by urbanization, *etc.*), a relative lack of comprehensive databases has meant that reporting of ecosystem impacts has mostly focused on documenting and addressing only fishery impacts.

To date, management of human activities in the marine environment has been primarily sector-focused. For instance, fisheries have targeted commercially important species, without explicit consideration of non-commercial species and broader ecosystem impacts. There is an increasing international awareness of the cumulative impacts of sector-based activities on the ecosystem and the need to take a more holistic or EBM approach to ensure the sustainability of marine ecosystems. In this report, we track progress toward developing ecosystem approaches by PICES member countries in the North Pacific. The primary focus is on fisheries as one of the most common economically and socially beneficial uses of the North Pacific ecosystem. However, fisheries can be a significant driver of ecosystem change. Still, as is discussed herein, there are many other activities of importance to countries in the North Pacific and these, too, are increasingly becoming part of the forward looking evaluation of ecosystem approaches to management (EAM). The diversity in approaches taken by the different PICES member countries is seen positively as experimenting with the concept of EAM/EBM consistent with each country's experience and circumstances. Through the process of documenting this diversity, it can be discerned about what works and does not work under particular circumstances. We therefore, also look beyond fisheries applications and suggest what a fully integrated EAM might entail as a long-term goal of management.

This report provides a summary of the emerging consensus on indicators of marine ecosystems, and makes recommendations applicable to North Pacific waters of PICES interest. In addition, it attempts to take a broader view of indicators for EBM of marine systems rather than the narrower application to fisheries management (even though most research to date has focussed on this narrower application). Specific recommendations relating to indicators include that PICES should:

1. explore the use of a consensus suite of indicators in each of its regions to develop a common set of indicators to be included in each iteration of the PICES North Pacific Ecosystem Status Report;
2. use the WG 19 Ocean Management Activity reports and FIS and MEQ committee inputs to help identify region-specific drivers of change and pressure measurements in order to interpret relevant status indicators;
3. establish collaborations with social scientists to develop indicators which describe the coupled marine social-ecological system and expand the understanding of human behaviors and responses to environmental forcing from the marine sector; and
4. recommend a research activity to explore the use of additional indicators for marine ecosystem-based management in each of its regions, building from those outlined here and elsewhere.

Accounting for spatially explicit trends, processes and relationships is a main component of EBM, and so the identification of spatial characteristics and the relevant spatial scales of marine ecosystems is important to provide a context for identifying stakeholders, defining objectives, conducting research, and implementing policies focused on sustainable management of species, goods and services. The Working Group found broad consistency in the criteria used to define and delineate marine ecosystems in the territories of PICES member countries, even though the member countries approached the issue in several different ways. All PICES countries also acknowledged cases where ecosystems extend beyond their Exclusive Economic Zone (EEZ), either into another nation's EEZ or into international waters. However, National Summaries contain less information about waters that lie beyond continental slopes and outside of their EEZs, even in cases where those waters are deemed part of the same ecosystem as (and are thus thought to be ecologically linked to) waters lying nearer to shore. PICES member countries varied widely in the formality of their approaches and the extent of their progress with respect to ecosystem delineation and sub-regionalization. Finally, at least two major challenges remain for formal delineation of ecosystems and subregions in the PICES area. First, PICES member countries need to determine the priority of developing, defining and implementing a standardized template for ecosystem delineation. This is relevant because many suggested ecoregions extend beyond national boundaries. Currently, such a template does not exist and its priority, both within individual nations and within PICES, remains unclear. Second, the delineation schemes described above were largely prepared by fisheries ecologists and likely reflect biases inherent to this sector. The limitations and consequences of those biases would need to be addressed, likely through inclusion of a broader number of disciplines.

The PICES EBM topic sessions and workshops held in association with Annual Meetings in Vladivostok, Russia (2005, Session 8 on "*Ecosystem indicators and models*"); in Yokahama, Japan (2006, Workshop W3 on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*") and in Victoria, Canada (2007 Worskhop W3 on "*Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation*") made progress in highlighting the above issues with respect to implementation of EBM in PICES member countries. From the presentations, especially at the 2007 workshop, it was clear that member countries are in different stages of implementation with respect to EBM. Some countries are still working on incorporating an ecosystem approach to fisheries management while others have national legislation that provides a mechanism for implementing a cross-sectoral approach to the management of marine activities to ensure environmental protection. The degree of advancement might be partly related to the nature of the different human pressures being exerted on the marine environment. Even some of the countries that appeared to be more advanced in their implementation mentioned problems in actually making cross-sectoral management work in marine ecosystems. Particularly, the need for overarching legislation that requires action may be needed. It was clear that more than one agency was involved in EBM activities in each country and a challenge is to get agencies to work together in implementation. It was also noted that the main type of legislation in most nations that forced this cross-sectoral implementation was species-at-risk legislation.

Data requirements for EBM were discussed to some extent. The Australian experience demonstrated that implementation could involve both highly quantitative approaches and models if data are available but the framework could also include methods to evaluate ecosystem status and potential impacts even in qualitative ways. The ICES experience demonstrated how highly evolved data gathering for EBM advice could be, although it was noted that highly evolved advice did not necessarily translate into the political will to follow such advice. The PICES Technical Committee on Monitoring (MONITOR) outlined some of the data requirements that would require its involvement along with the involvement of all the PICES Committees. The 2007 workshop particularly noted the lack of socio-economic data to aid in decision-making in an EBM context.

Analytical tools being developed to aid in EBM frameworks included the highly structured risk assessment framework of Australia that allows for both quantitative and qualitative evaluation of risks and defining when actions are needed. The PICES MODEL Task Team described the suite of modeling tools that might be used to understand impacts of climate variability on marine ecosystems. Models such as Atlantis, used in the evaluation of management strategies, seem to be important tools in EBM decision-making.

Communicating results of EBM activities is ongoing in PICES member countries. Some are using highly structured reporting instruments such as ecosystem assessment documents. ICES advisory structure for communicating EBM advice in a tactical way is highly evolved although reporting its success in implementing EBM might not be so advanced. Reporting of ecosystem status is important but it was also recognized that identification and reporting of ecosystem pressures and ecosystem responses to management are important pieces of communication of EBM progress. Communicating measures of human health was noted as important in this regard. The PICES role in communicating EBM was seen to be more of a strategic one. There are a variety of potential scales useful in reporting results.

A major outstanding research gap is the need for inclusion of social science indicators and information. The advancement of risk assessment frameworks and tools also seemed particularly important.

Looking Beyond WG 19

We discussed how the findings and work of WG 19 could best be integrated and built upon within PICES in years ahead, particularly within the context of the new PICES integrative science program on **F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems (FUTURE). Development of EBM is still very much in its early stages in each of the PICES member countries, and so we recommend that PICES continue to actively monitor progress into the foreseeable future. To provide a long-term forum for this process, we concluded that the issues addressed by WG 19 might justify the establishment of a new group, with emphasis on developing an integrative, science-based, ecosystem-scale understanding of the human dimension (across a diversity of sectors). This group will be closely associated with FUTURE's Advisory Panel on *Anthropogenic Influences in Coastal Ecosystems* (AICE). We suggest the new group be called *"**P**ICES **U**nderstanding, **L**inking and **S**ynthesis of **E**cosystems"* (PULSE). Below is a draft proposal on the objective, terms of reference and membership recommendations for PULSE:

Objective

To monitor and synthesize regional and basin-wide ecosystem-based management (EBM) studies and initiatives (ecosystem health) and to provide a forum for the integration of FUTURE-related EBM practices and their implementation.

Draft Terms of Reference

1. PULSE (*PICES Understanding, Linking and Synthesis of Ecosystems*) is the scientific body responsible for the promotion, coordination, integration and synthesis of research activities related to the implementation of EBM among PICES member nations. This goal would be accomplished by convening meetings, periodic scientific symposia or workshops, and by distributing information designed to foster cooperation and integration among existing or developing PICES programs, and possibly between and/or within member nations.
2. PULSE will provide the scientific body to identify and improve indicators to measure progress in the achievement of EBM. It will provide the forum to discuss the needs, impacts and responses of coastal communities in a changing marine environment, and to enhance the use of this information by governments and society at large. It will also provide a forum for the connection of ecosystem monitoring and status reporting of both environmental and social indicators (through linkage with MONITOR), and the subsequent implementation and adaptation of EBM.
3. Scientific collaboration and coordination with other international agencies, bodies and societies that are engaged in either EBM or human activities that are relevant to the achievement of EBM will be undertaken. This will engage expertise not previously active in PICES, such as social-scientists and policy makers.
4. PULSE will encourage establishment of other component activities, such as developing the basis for coupled human science-natural science models, and emerging approaches as needed to facilitate synthesis of the FUTURE Program.

Membership

We recommend a membership that will ensure core connection with PICES Committees, key expertise from the various disciplines involved in studying ecosystem approaches to management, and national representation. We advocate a nomination process that will closely connect PULSE to PICES Scientific Committees, such as ensuring that a member or designate from each Committee and perhaps from the current Study Group on *PICES Communications* in PULSE. There is also perhaps merit in having member participation from different sectors besides fishing (*e.g.*, mariculture) and ecoregions.

Advice on the Structure and Content of Future North Pacific Ecosystem Status Reports

WG 19 also considered advice on the structure and content of future North Pacific Ecosystem Status Reports (NPESRs), and specifically the inclusion of EBM-related topics in status reports. An incremental improvement version of NPESR is being recommended by Science Board, and we recommend that enhanced information on pollution and socio-economics be considered for inclusion. We discussed the need to identify key pressures in each region, and how indicators on status and trends describing human well-being should be determined, and concluded that further review on these topics is needed. Establishment of a PICES Study Group on *Indicators of Human Well-Being: Benefits and Health* is recommended to assist in this effort. Terms of reference for such a group might include:

1. Identify potential indicators of human-well being and human impacts in relation to the PICES report on marine ecosystem status and trends; evaluate the Millennium Ecosystem Report indicators for their appropriateness.
2. Review how these measures might be quantified and standardized across member countries, and if the data are available to quantify these.
3. Review how these measures can be used in ecosystem models and management strategy evaluation frameworks.

4. Identify longer-term issues that might be covered by a working group on this topic (governance structures for implementation, *etc.*).

Criteria for selection of membership should include natural and social scientists, including in the latter those with strong economic, sociological and anthropologic expertise who are working on questions relating to marine ecosystem approaches and management issues.

Ecosystem-based Management in International Waters

In the above, all details and discussion presented have been focused on initiatives being undertaken within the EEZs of PICES member countries. While significant progress is being made in these regions to address issues related to EBM, the reality is that many species have spatial distributions in the Pacific Ocean that extend well beyond national jurisdictions. For these species, effective EBM can only be realized if national efforts to achieve EBM are harmonized with similar multinational efforts in international waters. To this end, many of the initiatives to determine appropriate EBM steps in national waters, such as identifying ecoregions (spatial areas with a basically similar mix of species and environment) and within them, ecologically and biologically significant areas and species, need to be undertaken in offshore international waters of the PICES region.

1 Introduction

Jamieson and Zhang (2005) noted that under the overarching objective of conservation of species and habitat, ecosystem-based management (EBM) is the implementation of defined objectives related to maintaining and monitoring biodiversity, productivity and physical and chemical properties of an ecosystem. EBM worldwide is now recognized as both timely and necessary because 1) in many environments, individual ecosystem components are presently being utilized, harvested or impacted with limited attention paid to the maintenance of the integrity of the overall ecosystem, and 2) the scale of these impacts is now so large that there is real danger of overall negative ecosystem change to the detriment of human society. Following recommendations of the PICES Study Group on *Ecosystem-based Management Science and its Application to the North Pacific* (Jamieson and Zhang, 2005), a working group was formed (Appendices 1 and 6) to deal with these issues, and this report builds on that initiative.

In October 2004, the PICES Working Group on *Ecosystem-based Management Science and its Application to the North Pacific* (WG 19) was established, under the direction of the Marine Environmental Quality Committee (MEQ) and Fishery Science Committee (FIS), with the following terms of reference:

1. Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem based management objectives of each country.
2. Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges.
3. Evaluate the indicators from the 2004 Symposium on "Quantitative Ecosystem Indicators for Fisheries Management" for usefulness and application to the North Pacific.
4. Review existing definitions of "ecoregions" and identify criteria that could be used for defining ecological boundaries relevant to PICES.
5. Hold an inter-sessional workshop in Year 2 or 3 of the WG's mandate that addresses the status and progress of EBM science efforts in the PICES region, with the deliverable being either a special journal issue or a review article.
6. Recommend to PICES further issues and activities that address the achievement of EBM in the Pacific.

The second term of reference above was never addressed, as it was later realized that no PICES country was advanced enough in EBM applications to be at the stage where it was monitoring and actively practicing EBM.

This is the final report of WG 19. It should be noted, though, that establishment of ecosystem-based approaches to management of human activities in the marine environment is very dynamic, and in the three years that this report has been in preparation, numerous changes have ocurred in each of the PICES member countries. While attempts have been made to provide the most relevant and recent data at the time of report completion, there are likely many instances where, by the time this report is published, some elements may be somewhat dated. Nevertheless, this report does provide a snapshot in time in documenting where the different PICES countries are in their progress towards their achievement of EBM. Implementation of EBM is best viewed as an incremental adaptive approach, and thus countries should be considered to be in a constant process of adaptation toward achieving an agreed upon ecosystem approach to management.

This report is structured to first provide an overview of why EBM is relevant today, the incentives that are making its implementation such a high priority in each PICES member country, and how EBM is being approached by each of the six member countries in the North Pacific. Section 2 tracks the progress toward developing ecosystem approaches, and while the primary focus is on fisheries as one of the most common economically and socially beneficial uses of the North Pacific ecosystem and one that may be a significant driver in ecosystem change, there are many other relevant human activities of importance to

PICES countries in the North Pacific. These too are becoming part of the forward-looking evaluation of EBM.

The next section of this report focuses on the development and utility of marine ecosystem indicators, which is currently an active research topic worldwide. This is connected with the increased interest in moving forward with EBM of marine resources, and recognition of the need to index and summarize the state of marine ecosystems.

Section 4 focuses on identifying the spatial characteristics of North Pacific ecosystems, and how the different PICES member countries have incorporated these features into their management regimes. Because accounting for spatially explicit trends, processes and relationships is a main component of EBM, it follows that the spatial characteristics of marine ecosystems need to be identified in order to provide a context for identifying stakeholders, defining objectives, conducting research, and implementing policies focused on sustainable management of species, goods and services.

The report concludes by presenting a brief overview summary of regional approaches to EBM, and their implications, and suggests relevant actions for PICES in the future, *i.e.*, beyond the end of WG 19. It addresses the fact that while all EBM activities to date in the North Pacific are occurring within the Exclusive Economic Zones (EEZs) of member countries, *i.e.*, from the edge of each country's territorial sea (up to 12 nautical miles (22 km)) out to 200 nautical miles (370 km) from its coast, recent international conventions are beginning to focus development of EBM in international waters, *i.e.*, beyond the EEZs.

Finally, the PICES EBM topic sessions and workshops held in association with Annual Meetings in Vladivostok, Russia (2005, Session S8 on "*Ecosystem indicators and models*"); in Yokahama, Japan (2006, Workshop W3 on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*") and in Victoria, Canada (2007 Worskhop W3 on "*Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation*"); see Appendix 5) made progress in highlighting the above issues with respect to implementation of EBM in PICES member countries. From the presentations, especially at the 2007 workshop, it was clear that member countries are in different stages of implementation with respect to EBM. Some countries are still working on incorporating an ecosystem approach to fisheries management while others have national legislation that provides a mechanism for implementing a cross-sectoral approach to the management of marine activities to ensure environmental protection. The degree of advancement might be partly related to the nature of the different human pressures being exerted on the marine environment. Even some of the countries that appeared to be more advanced in their implementation mentioned problems in actually making cross-sectoral management work in marine ecosystems. Particularly, the need for overarching legislation that requires action may be needed. It was clear that more than one agency was involved in EBM activities in each country and a challenge is to get agencies to work together in implementation. It was also noted that the main type of legislation in most nations that forced this cross-sectoral implementation was species-at-risk legislation.

1.1 Reference

Jamieson, G. and Zhang, C.-I. (Eds.) 2005. Report of the Study Group on Ecosystem-Based Management Science and its Application to the North Pacific. PICES Sci. Rep. No. 29, 77 pp.

2 Developing an Ecosystem-based Approach for Ocean Management in the PICES Region

David Fluharty, Chris Harvey, Glen Jamieson, Xianshi Jin, Patricia Livingston, Mitsutaku Makino, Vladimir Radchenko and Chang-Ik Zhang

2.1 Introduction

This section is an effort to identify the efforts of PICES member countries in moving toward adoption of an EBM approach for fisheries and other sectors. Member countries were asked to confirm their commitments to, or incorporation of ecosystem-based management (EBM) actions or principles, into current fisheries and ocean management. As reported below, there is a wide range of effort in this regard, with considerable variation in approach and with respect to how comprehesive management actions turn out to be. The PICES Working Group on *Ecosystem-based Management Science and its Application to the North Pacific* (WG 19) regards these efforts as indicative of the progress toward EBM – especially with respect to fisheries from which we can compare experience and gain knowledge. None of the PICES member countries can be seen as fully implementing an ecosystem-based approach even for the fisheries sector, yet it is apparent that each member is seeking to employ and learn from the experience of implementing EBM. It is the hope of WG 19 that these experiences will be expanded upon and that as an EBM approach encompassing multiple sectors is developed among PICES countries, PICES will provide a significant focal point for documenting, synthesizing and comparing national experiences.

Since the industrial revolution, man's impact on the oceans has increased dramatically, this being especially true in recent years. In nearshore coastal areas, human population growth has led to increasing pollution and habitat modification. Fishing effects have become increasingly severe, with many, if not most, traditionally harvested populations now either fully exploited or over-fished (Garcia and Moreno, 2003). Thus far, management of these activities in the North Pacific has been primarily sector-focused. Fisheries, for example, have generally been managed in isolation of the effects of other influencing factors and have targeted commercially important species, without explicit consideration of non-commercial species and broader ecosystem impacts. There is an increasing international awareness of the cumulative impacts of sector-based activities on the ecosystem (Jennings and Kaiser, 1998; Kaiser and de Groot, 2000) and the need to take a more holistic or Ecosystem-Based Management approach (Anon., 1999; Link, 2002; Kabuta and Laane, 2003) to ensure the sustainability of marine ecosystems. Globally, there is an emerging paradigm shift in our approach to ocean management and usage (Sinclair and Valdimarsson, 2003) that is quite broad for which the term Ecosystem Approach to Management (EAM) applies.

The roots of this change can be found in the 1972 UN Conference on the Human Environment, and the 1992 UN Conference on Environment and Development (UNCED) in Rio, itself emanating from the 1973 UN Conference on the Law of the Sea which, in turn, resulted in the 1982 UN Convention on the Law of the Sea (UNCLOS). UNCED highlighted the need to consider resource management in a broader biological, socio-economic and institutional context. This led to follow-up conferences and conventions such as the 1993 Convention on Biological Diversity, the 1995 Agreement for the implementation of provisions of the UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN Fish Stock Agreement), and the 1995 FAO Code of Conduct for Responsible Fisheries, to name a few. FAO has put in place International Plans of Action to meet UNCED objectives, progress against which was reviewed in Johannesburg at the RIO +10 meeting in August, 2002. At the World Summit on Sustainable Development (WSSD), governments obligated themselves to an ambitious time frame for implementing EBM in marine waters. Thus, there is a growing body of international agreements in support of EBM. (See Table 2.1.1 for some examples of the involvement of North Pacific nations.) In addition, the transboundary nature of marine resource use and management for fisheries, oil and gas, maritime transportation, and pollution control make it imperative that countries cooperate scientifically to observe and understand these activities and their interactions. In Table 2.1.2 we provide some examples of North Pacific multilateral regional agreements and bilateral agreements that recognize the transboundary nature of the ocean environment and cooperation needed to take the ecosystem into account.

The focus of this portion of the WG 19 report is to track the progress toward developing ecosystem approaches by PICES member countries in the North Pacific. The primary focus is on fisheries not only as one of the most common economically and socially beneficial uses of the North Pacific ecosystem, but one that may be a significant driver in ecosystem change. Scientific research that enables better understanding of the conditions affecting fishery management and the role of fisheries in an ecosystem is critical. Still, as is discussed herein, there are many other activities of importance to countries in the North Pacific and these, too, can become part of the forward looking evaluation of EAM.

Table 2.1.1 Examples of international conventions to which PICES member countries are parties. Note that UNCED and WSSD were conferences, not conventions. However, these meetings did produce some important exhortatory documents that have helped popularize and give commitment to sustainable development concepts, including ecosystem-based management and integrated management. Those documents were Agenda 21 and the Johannesburg Plan of Implementation (JPOI). Both were negotiated and adopted by consensus by States, and represent outcomes of conferences.

Convention	Canada	Japan	P.R. China	R. Korea	Russia	U.S.A.
UN Convention on the Law of the Sea (UNCLOS), 1982	Signed 1982; ratified 2003	x	Signed and ratified 1996	x	Signed and ratified 1997	Not signed
UN Conference on Environment and Development (UNCED), 1992	x	x	x	x	x	–
UN Convention on Biodiversity, 1993	x	x	x	x	x	x
Conservation and Management of Straddling Fish Stocks and Highly Migratory Species, 1995 [Implementation of UNCLOS]	x	x	x	x	x	–
Ramsar Convention, 1976 [wetlands]	Signed 1981	x	x	x	x	x
World Summit on Sustainable Development (WSSD), 2005	x	x	x	x	–	–
Code of Conduct for Responsible Fisheries, 1995	x	x	x	x	x	–
Convention on International Trade in Endangered Species (CITES)	Signed July 1975	x	x	x	x	–
IMO Convention for the Control and Management of Ballast Water and Sediments, 2004	Signed but not yet ratified (as of 2008)	Not signed	–	–	–	–

x = participant

Table 2.1.2 Examples of North Pacific transboundary ecosystem approach to management (EAM) treaties.

Treaty	Parties	Provisions
Regional/ Multilateral		
Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea, February 11, 1994	Japan, People's Republic of China, Poland, Republic of Korea, Russia, USA	Manages fishery in the international zone of the Bering Sea
Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean, February 11, 1992	Canada, Japan, Republic of Korea, Russia, USA	Allows anadromous fisheries on the high seas
UN Moratorium on High Seas Driftnet Fishing, 1993	UN Moratorium	Closes North Pacific high seas to drift net fisheries
Convention for a North Pacific Marine Science Organization (PICES), 1991	Canada, Japan, People's Republic of China, Republic of Korea, Russia, USA	Establishes basis for broad scientific cooperation among signatory nations
Yellow Sea and East China Sea Fisheries Agreements	Japan, People's Republic of China, Republic of Korea	Allows fisheries in transboundary areas
Bilateral		
Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean, 1923	Canada, USA	Conservation of Pacific halibut
Pacific Salmon Treaty, 1985	Canada, USA	Conservation of Pacific salmonids
Memorandum On Four Islands Waters Agreement	Japan, Russia	Allows fisheries in the Russian zone by the Japanese fleet
Salmon/All Other Species–Commission on the Fisheries	Japan, Russia	Allows fisheries in each zone and fisheries under exchange agreement – joint research [5–6 cruises previously]; now mostly exchange of data due to strict border regulations
Amur River Fisheries	People's Republic of China, Russia	Allows Chinese fishing in Russian waters and Amur River considerations
Republic of Korea Fishing in Russian waters	Republic of Korea, Russia	Allows Republic of Korea fishing in Russian waters
Japan/Republic of Korea transboundary areas	Japan, Republic of Korea	Allows fisheries in transboundary areas
Joint oil and gas development zone	Japan, Republic of Korea	Operation assignment protocol

In order to have a common language and definition of EBM/EAM, we developed a typology (Table 2.1.3) that served to discipline our Working Group's discourse on this topic. Further, we have elected to construct Country Profiles of efforts to implement EAM. The template for these profiles is in Appendix 2.

The reports provided by each country in the following sections demonstrate a high level of interest and a diversity of approaches. This diversity is seen positively as experimenting with the concept of EAM/EBM, consistent with each country's experience and circumstances. Through the efforts of WG 19, approaches being tried under particular circumstances are shown.

Although we have looked primarily at fisheries applications, we hope the approach discussed here will guide PICES in its further research and deliberations on EAM in the context of the new PICES scientific program, FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems).

2.1.1 Ecosystem-based Management/ Ecosystem Approach to Management Typology

It is useful to agree to a common typology of ecosystem approaches to management for purposes of discussion because it helps us more rigorously evaluate the progress toward EBM, or as its sometimes referred to, an Ecosystem Approach to Management (EAM). The typology found in Table 2.1.3 starts with recognition that even traditional management approaches that focus on single sectors or species, in the case of fisheries, do take considerable ecosystem information into account. The more factors and species that are taken into account in management decisions, the greater the progress toward EAM, *e.g.*, sectoral and ultimately integrated management in an ecosystem context.

2.1.2 Country Profiles

Country profiles have been constructed to provide background information of how each PICES member country has begun to recognize an EBM/EAM in its scientific research in support of management decisions and societal goals. We present the country reports in alphabetical order. Each report brings very interesting and valuable contributions to our learning about how EAM can be applied. Each country has attempted to respond to a systematic set of descriptors, listed below:

1. Definition of EAM objectives/purposes and goals
2. Agencies involved
3. Legislative mandates related to EAM.
4. Current implementation
5. Future implementation

For current and future work, we developed a template (Appendix 2) for assessing concrete progress toward developing and implementing EAM in fisheries, and provide illustrations by Canada of how it might be used. While there is some deviation from this format because of national experience and circumstances, this template serves well to organize each of the presentations.

Table 2.1.3 Typology of ecosystem approaches to management.

EBM component	**I. Traditional single factor management**	**II. Sectoral Management in an Ecosystem Context**	**III. Integrated Management in an Ecosystem Context**
Species	Considers only the factor or species being used	Considers prey, dependent predators and food supply, and impacts on ecosystem	Considers impacts of other activities on the status of the species being used and across the ecosystem
Physical habitats	Only considered if a surrogate for population parameters	Considers productive capacity and impacts of activity on the habitat	Accommodates spatial needs and habitat impacts of other activities
Environmental conditions	Not considered	Considers productivity regime and forcing	Considers direct and indirect effects
Biodiversity	Not considered	Considers impacts on species not being used directly	Considers status of communities and resilience of the community/system
Other components	Not considered	Considers other components as they affect the particular sector	Considers all components and all sectors and the interactions among them relative to agreed ecosystem management goals

Describing and documenting EBM is a complex enterprise and one that does not fit into a single pattern. Each member country profile presented here addresses those components that are part of that country's approach to management. It is not expected that each component may necessarily be discussed in each profile. In fact, diversity in approaches is expected and adds to the potential for learning from alternative approaches. Critical to understanding the process of implementing EBM is that current efforts are seen as building blocks toward eventual fully implemented EBM.

2.1.3 References

Anon. 1999. Sustaining Marine Fisheries. Committee on Ecosystem Management for Sustainable Marine Fisheries. Oceans Studies Board, Commission on Geosciences, Environment, and Resources, NRC, National Academy of Sciences, 164 pp.

Garcia, S. and Moreno, I. 2003. Global overview of marine fisheries. pp. 1–24 *in* Responsible Fisheries in the Marine Ecosystem *edited by* M. Sinclair and G. Valdimarsson, FAO & CABI Publishing, 426 pp.

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Link, J. 2002. What does ecosystem-based fisheries management mean? *Fisheries* **27**: 18–21.

Sinclair, M. and Valdimarsson, G. (Eds.). 2003. Responsible Fisheries in the Marine Ecosystem. FAO & CABI Publishing, 426 pp.

2.2 Canada

2.2.1 Objectives/Purposes, Goals and Legislative Mandates for Ecosystem-based Management

In Canada, the *Fisheries Act*, first enacted in 1857, has been to date, the prime legislative vehicle governing ocean usage, particularly fishing. It regulates the capture, holding and possession of all marine life, and makes unlawful the harmful alteration, disruption or destruction of fish habitat. While it is periodically revised (most recently in 1991), the focus of the *Act* has been the conservation and protection of commercially exploited species and their habitat. Similarly, the *Coastal Fisheries Protection Act* regulates the presence of foreign fishing vessels in Canadian fisheries waters and since 1977 there have been no unauthorised foreign vessels in Canadian Exclusive Economic Zones (EEZs) fisheries. Responding to both international legislative changes, as well as to concerns for the impacts of human activities on its marine ecosystems, Canada enacted the *Oceans Act* in 1997. This *Act* outlined a new approach to managing oceans and their resources, based on the premise that oceans must be managed as a collaborative effort among all stakeholders using the oceans, and that new management tools and approaches are required. While fishery management plans under the *Fisheries Act* continue to focus on target species, the *Oceans Act* has changed the legislative basis for management and now requires consideration of the impacts of all human activities on Canada's ecosystems in marine resource management plans.

While Canada's Department of Fisheries and Oceans (DFO; also referred to as Fisheries and Oceans Canada) had been active in addressing habitat impact issues (*e.g.*, oil and gas resource development in Atlantic Canada), the *Oceans Act* has provided a new tool in Canada's development of an EBM approach. As a consequence, since 1997 there have been a number of initiatives through which Canada's approach to EBM is beginning to emerge. In 2002, Canada's Oceans Strategy was published (Anon., 2002a), a key element of it being a nationally coordinated Integrated Management (IM) program in which interested stakeholders and regulators will work together to decide on how to best manage designated geographic areas (Anon., 2002b). In support of the IM program, DFO has established a national coordinating body, termed the Working Group on Ecosystem Objectives (WGEO), to facilitate the development of best practices for IM and oversee regional pilot projects designed to test implementation of the concepts. In 1998, a pilot project was established in DFO's Maritime Region to facilitate EBM in the Atlantic Ocean on the eastern Scotian Shelf, with a Strategic Planning Framework recently produced (Anon., 2003). Similarly, DFO's Pacific Region joined the Province of British Columbia in initiating the Central Coast Land and Coastal Resource Management Plan (CCLCRMP) process, and has established the pilot Central Coast Integrated Management (CCIM) project in another IM approach. The WGEO was instrumental in planning a national workshop (Jamieson *et al.* (2001), termed herein as the Sidney workshop) in 2001 to outline the objectives to guide EBM and, more recently, has initiated an exercise to define scientifically-based ecoregion boundaries within which ecosystem objectives (EOs) will be established. Human activities will be managed in Large Ocean Management Areas (LOMAs) in a manner that will allow the conceptual ecological objectives for the ecoregion a specific LOMA is in to be met.

2.2.2 Current Implementation

When the *Oceans Act* was proclaimed in 1997, there was little concept in Canada as to what IM actually meant in practical terms, not unlike the situation in other countries. Much of the dialogue had been at a higher policy level, with little linkage to implementation. Since then, there has been much discussion on implementation both in Canada and elsewhere, with various approaches starting to emerge (*e.g.*, Garcia and Staples, 2000; Pajak, 2000; Sainsbury and Sumaila, 2003). Here, we summarize the Canadian perspective on IM, based on our experiences with EBM in Canada (O'Boyle and Jamieson, 2006).

IM has been defined in Canada as "a commitment to planning and managing human activities in a comprehensive manner while considering all factors necessary for the conservation and sustainable use of marine resources and the shared use of ocean spaces" (Anon., 2002a). IM acknowledges the inter-relationships that exist among different uses and the environments they potentially affect (Anon., 2002b). It will thus involve many facets relating to both what activities are undertaken and to how these are undertaken when it is finally implemented.

It should be pointed out here that the *Oceans Act* refers to Marine Environmental Quality (MEQ) objectives, which are to be incorporated in IM plans to facilitate implementation of an ecosystem approach. MEQ objectives are functionally synonymous with the definition of operational objectives. Operational objectives are the strategies by which conceptual objectives are actually implemented. They make the link between conceptual and management control. Jamieson *et al.* (2001) considered that an operational objective consists of a verb (*e.g.*, maintain), a specific measurable indicator (*e.g.*, biomass from a population analysis), and a reference point (*e.g.*, 50,000 t for a specific species or stock), thus allowing an action statement for management (*e.g.*, maintain biomass of a given forage species greater than 50,000 t biomass). While others might differ on the details of what defines an operational objective (*e.g.*, FAO, 2003; Sainsbury and Sumaila, 2003), there is consensus on the need for indicators and reference points in operational objectives. In this PICES WG 19 report, we will use the terms 'conceptual' and 'operational', as they are more in line with usage in the literature.

How the conceptual and operational levels of objectives are linked is a critical issue. Jamieson *et al.* (2001) considered components and sub-components associated with the high-level conceptual objectives, thus creating a 'branched tree' of conceptual objectives. They stated, for example, that diversity and productivity are components of the 'conservation objective', and under diversity there are sub-components at the community, species and population level. For each component and sub-component, a conceptual sub-objective is stated (*e.g.*, for the diversity component, conserve population diversity so that it does not deviate outside the limits of natural variability). Jamieson *et al.* (2001) then provided example operational objectives (verb, indicator and reference point, as described above) linked to each conceptual objective. These were primarily included to indicate the intent of the associated conceptual objective.

Jamieson *et al.* (2001) translated each of the sub-objectives into operational objectives through a process termed 'unpacking', which involves breaking the objectives completed into their component parts (Table 2.2.1). Unpacking involves considering each conceptual objective associated with a component/sub-component and determining whether or not a final operational objective can be stated. In other words, how best can a measurable indicator and reference point (see Appendix 3 for definitions) be associated with that sub-objective? This requires an understanding of what knowledge and information is available upon which indicators and reference points can be based. If this information is available, then the unpacking process stops and the final operational objective associated with that conceptual objective is considered defined. Otherwise, a further unpacking occurs which is again tested for it being a final operational objective. The unpacking stops when all conceptual objectives have been addressed. As mentioned above, Canada's Oceans Strategy (Anon., 2002b) refers to MEQ objectives. Both of these terms are synonymous with the operational objectives that would go in management plans.

Table 2.2.1 Link between conceptual objectives and operational objectives (Anon., 2002b).

Conceptual objectives		**Operational objectives**
Objective	Maintain productivity	Consists of a verb, indicator and reference point
Sub-objective	Trophic transfers	
…	Forage species	
	Target escapement	
	(Maintain) biomass	Maintain biomass of forage species > 50,000 t

With 'maintenance of productivity' as an example conceptual objective, beginning to unpack it creates the statements as maintaining trophic transfers and interactions within the foodweb. However, while this restatement is a more tractable concept than maintenance of productivity, it is still far from what managers can deal with practically. Therefore, the concept of 'trophic transfers' is further unpacked. This produces a more specific statement on the maintenance of forage species, and then, in turn, of target escapement. A point is finally reached where some component of the ecosystem is associated with a particular measure or indicator, and at this point, the objective can be termed 'operational'.

Before IM can be implemented in Canada, concepts and approaches need to be tested in pilot-scale initiatives. Only through a nationally coordinated system of pilot studies would the challenges, opportunities and utility of different approaches be operationally evaluated for consideration in the development of a national approach. Such exercises would need to include:

- Synthesis, either through Delphic (see Appendix 3 definition) or more quantitative approaches, of all currently available information including socio-economic data,
- Practical experience in compiling ecosystem-level data and their utilization in ecosystem function measurements to allow comparison of experiences from different situations,
- Practical experience with regional 'unpacking' exercises to break down conceptual objectives to operational ones, and
- An assessment of the costs of conducting required ecosystem monitoring.

Since the Sidney workshop, many of the above recommendations have been or are in the process of being acted upon. Pilot IM projects have been established to test the concepts discussed at the workshop, including the unpacking exercises (*e.g.*, Jamieson *et al.*, 2003; O'Boyle and Keizer, 2003; Jamieson and McCorquodale, 2004) to test the efficacy of the objectives' structure and the unpacking process reported above. These pilots involve consideration of how best to engage managers, clients and scientists in consultation and decision making. It will take time for results of these pilots to be realized and to determine how the concepts and approaches discussed by Jamieson *et al.* (2001) can be implemented over the long term.

Canada's IM planning is at the heart of new, modern oceans governance and management. It is a comprehensive way of planning and managing human activities so that they do not conflict with one another and so that all factors are considered for the conservation and sustainable use of marine resources and shared use of oceans spaces. IM is:

- an open, collaborative and transparent process that is premised on an ecosystem approach;
- involves planning and management of natural systems rather than solely political or administrative arrangements;
- is founded on sound science that can provide the basis for the establishment of ecosystem management objectives.

Canada's Oceans Strategy calls for the Minister of DFO to lead the development and implementation of plans for the IM of all activities affecting estuaries, and coastal and marine waters.

In the Oceans Action Plan (http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/oap-pao/pdf/oap_e.pdf), DFO identified ecoregions nationally and named five priority LOMAs across the country in which it will coordinate IM efforts. In the Pacific Region, the priority area was the Queen Charlotte Basin, which is the Pacific Northern Shelf Ecoregion (see section 4.2, Figure 4.2.8). This area is also now referred to as the Pacific North Coast Integrated Management Area (PNCIMA), and includes the previously identified Central Coast Integrated Management Area (CCIMA). The earlier CCIMA work laid the foundation for later PNCIMA development.

In initial attempts to develop operation objectives from higher-lever conceptual objectives, referred to above, it was quickly realized that a solely top-down approach could not prioritize objectives, and so a combined top-down:bottom-up approach was developed. This involves the identification of Ecologically and Biologically Significant Areas (EBSAs; DFO, 2004; Clarke and Jamieson, 2006a,b), Ecologically Significant Species (ESSs; DFO, 2006), Depleted Species, and Degraded Areas, and through consideration and weighting of these data, first identifications of highest priority science-based conservation objectives (DFO, 2007) will be proposed. This latter process is currently on-going for PNCIMA, and is now beginning to be undertaken for the other parts of Canada's Pacific Coast.

2.2.3 Future Implementation

Integrated Management is still in its initial stages in Canada. While progress has been made in some areas, much remains to be done. In the short term, Canada has stalled implementation of IM nationally – while the science process to develop appropriate conservation objectives has advanced, the complementary consultative process to develop appropriate socio-economic objectives has yet to commence, at least in Canada's Pacific Region. Jamieson *et al.* (2001) summarized three main recommended next steps to achieving IM in Canada, which are still relevant today:

1. Objectives, Indicators and Reference Points
There is a need to develop objectives for the other dimensions of sustainability (social, economic, and cultural) through workshops involving the appropriate experts. Whereas biology is relatively well circumscribed and objective, these other dimensions of sustainability tend to be driven by regional and local issues, and can be politically charged.

2. Assessment Approaches
A technical review of ecosystem assessment approaches is required, considering their performance and sensitivity through simulation exercises using existing and simulated data.

3. Research Directions for the Future
There is a continuing need for research to define indicators and reference points related to each objective, including consideration of their practicality, the extent to which measurements can separate real change from background variability, cost of measurement, *etc*. The direction of this research would greatly benefit from unpacking case study exercises to identify appropriate indicators and reference points for management, which would identify gaps in our knowledge to supply this information. This research needs to build on international initiatives such as the SCOR WG 119 workshop on *Quantitative Ecosystem Indicators for Fisheries Management* (Cury and Christensen, 2005).

Also, relatively little effort has been put into how one would use suites of indicators to meet the totality of objectives defined under operational resource management plans. Such an exercise has begun on the Eastern Scotian Shelf (O'Boyle *et al.*, 2005) where a number of ocean sectors – fishing, oil and gas exploration, transport, defence – utilize the area, typical of situations both in Canada and elsewhere in the world. A standardized operational framework for integrated management will thus be of global interest. The suite of national conceptual ecosystem-level objectives has been unpacked to a regional level for the Eastern Scotian Shelf Integrated Management (ESSIM) area to address biodiversity, productivity and habitat issues. Operational objectives, which identify an indicator and reference point associated with each conceptual objective, are being considered. Utilizing Canada's conceptual objectives unpacking protocol, individual ocean sector management plans and activities are beginning to be reviewed in a consistent manner to determine how they might be influenced by the conservation objectives for the area. Issues of spatial scale and cumulative impacts are beginning to be addressed, as required, and evaluated as to how progress against the suite of objectives could be reported.

Based on these experiences, it is suggested that the following sequential steps be required to effectively make the linkage between the high level, national objectives and operational objectives necessary for implementation of IM:

1. Identification of the conservation issues and threats relevant to the IM area,
2. Identification of the ecosystem science components (EBSAs, ESSs, Depleted Species and Degraded Areas) to be conserved, and the associated conservation objectives (Figs. 2.2.1 and 2.2.2),
3. Determination of the appropriate socio-economic (desirable) objectives (Figs. 2.2.1 and 2.2.2),
4. Definition of operational objectives for the IM area,
5. Definition of operational objectives for each ocean sector (fishing, oil and gas, transportation, *etc.*).

Once the operational objectives are available, monitoring programs can be designed to provide the indicators and reference points needed for assessment and decision making.

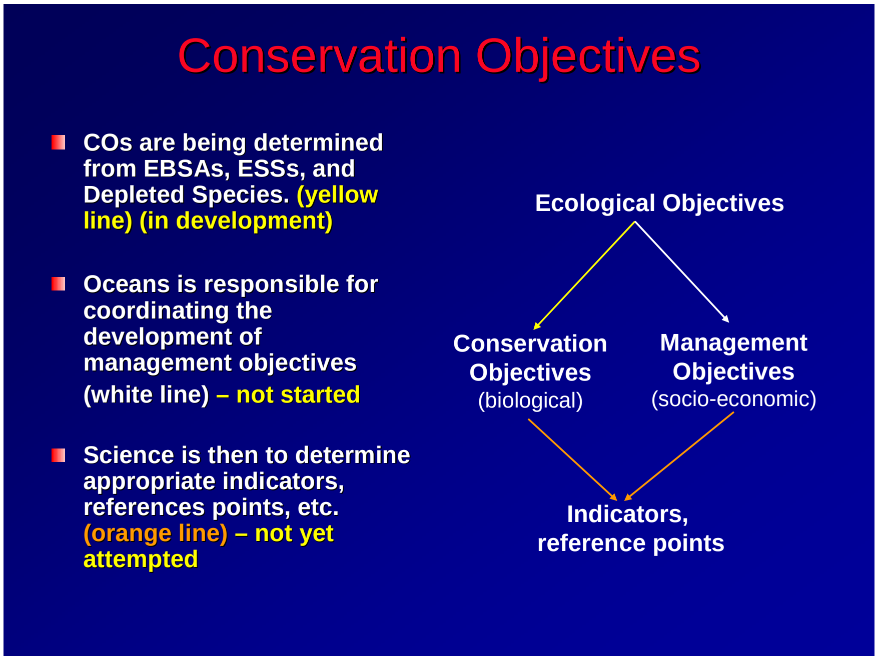

Fig. 2.2.1 Sector processes leading to the the determination of both conservation and desirable thresholds.

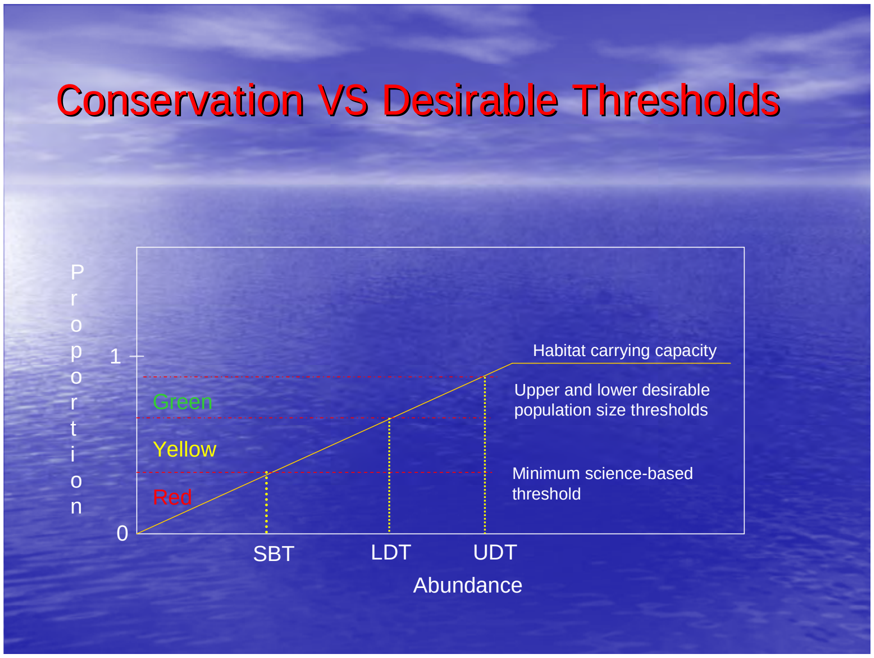

Fig. 2.2.2 Conceptual relationship between minimum science-based threshold (conservation objectives) and desirable thresholds.

2.2.4 Canadian Template of Ocean Management Activities

Ecoregion

In 2004, DFO conducted a workshop (Powles *et al.*, 2004) to identify Canadian marine ecoregions to be used as a basis for integrated oceans management, using criteria that fell into three broad categories: geological properties, physical oceanographic properties and biological properties. The workshop resulted in the identification of 17 marine ecoregions for Canada's three oceans: four in the Pacific (see section 4.2, Figure 4.2.8), six in the Arctic and seven in the Atlantic. Here, we describe ocean management activities in the PNCIMA, a LOMA whose boundaries exactly match one of the identified Pacific ecoregions, the Pacific Northern Shelf (Fig. 4.2.8). Its characteristics are represented in the following:

1. *Geographic features:* It is bounded to the south by Brooks Peninsula and extends northward into U.S. Alaskan waters. A distinctive geological feature in this ecoregion is the shallow water area in Hecate Strait located between the Queen Charlotte Islands (officially renamed Hiada Gwai in 2009) and the mainland coast.

2. *Physical Oceanographic Properties:* The shallow water area east of the Queen Charlotte Islands results in a warm water front and strong mixing, and is considered to be a weak boundary within the ecoregion.

3. *Biological Properties:* The Northern Shelf is one of 17 ecoregions in the Canadian Pacific, Arctic and Atlantic oceans identified by experts within, and external to, DFO in 2004. Four ecoregions identified in the Pacific Region are the Strait of Georgia (part of the officially named Salish Sea (2010) that also includes Juan de Fuca Strait and Puget Sound), the Southern Shelf (West Coast of Vancouver Island), the Northern Shelf, and Offshore. The Southern Shelf extends from Brooks Peninsula on the northwest coast of Vancouver Island, south into U.S. waters. The Northern Shelf extends north from Brooks Peninsula into Alaskan waters. Many fish populations in the Northern Shelf area are managed separately from other populations of the same species. North Coast herring, several rockfish and flatfish species, and some other groundfish species, for example, are considered discrete populations based on biological traits, tagging studies which indicate minimal migration between geographic zones, and observed variation in trends in abundance indicators over time.

General Description of the Oceanographic and Biological Setting

The Pacific Northern Shelf is the continental shelf portion in the transition zone where the eastward-flowing trans-North Pacific Current divides into the southward flowing California Current and the northward-flowing Alaska Current. It is included in the description of the Gulf of Alaska in PICES (2004). Strong seasonality in storm intensity and frequency cause strong seasonality in coastal current forcing. During the winter, intense southeasterly alongshore winds support northward-flowing currents, while in the summer, the Eastern Pacific High Pressure system expands into the Gulf of Alaska and the associated, generally northwesterly winds create southward-flowing currents. Freshwater input varies seasonally with maximum discharge in the fall and minimum discharge in winter, when much of the precipitation is stored as snow. Water density in coastal waters is primarily driven by variations in salinity from freshwater input which, along with wind mixing, determines the onset and the strength of stratification in the spring and summer, with important implications for ocean productivity.

The Gulf of Alaska shelf is highly productive and supports a number of commercially important fisheries such as walleye pollock, salmon, Pacific halibut, other flatfish, Pacific herring, crab, and shrimp. The nearshore areas serve as important spawning grounds and as nursery grounds for juveniles of numerous demersal and pelagic species, including salmon, walleye pollock, Pacific cod, crab, and over 20 species of flatfishes.

Relevant Management Plan, Policy and Legislation

DFO is the Department within the government of Canada that is responsible for the management and safety of waters under federal jurisdiction. The Department mandate is largely focused on the conservation and allotment of quotas for saltwater fisheries on the Atlantic, Pacific and Arctic coasts of Canada. To address the need for conservation, DFO has an extensive science branch, with research institutes in various locations across the country.

Typically, the science branch provides evidence for the need of conservation of various species, which are then regulated by the Department. DFO maintains a large enforcement branch, with peace officers (known as Fishery Officers) used to combat poaching and foreign overfishing within Canada's EEZ. The Department is also responsible for several organizations, including the Canadian Coast Guard and the Canadian Hydrographic Service.

The *Fisheries Act*, passed in 1887 and last modified in 1985, is the main legislation under which marine resources have been managed. It is focused primarily on the management of commercial species, but does have some habitat conservation provisions. It prohibits the deposit of deleterious substances that would alter or degrade water quality, such that it would harm fish or fish habitat, into waters frequented by fish, such as oceans, rivers, lakes, creeks, and streams, or into storm drains that lead to such waters.

DFO, through the *Fisheries Act*, has authority over all marine animals and plants, but this *Act* does not allow for the establishment of marine protected areas (MPAs). Where MPAs have been established by other federal legislation (*e.g.*, *National Park Act*), fishing may still occur unless specifically closed by *Fisheries Act* regulation.

Provincial land in British Columbia is all land between 'headland to headland', and while this is accepted by the federal government, there is a difference of legal opinion as to what constitutes a headland. However, to date, this lack of clarification has not resulted in serious jurisdictional problems. Thus, in some nearshore waters, seafloor habitat is managed by the province but all marine animals present are managed federally by DFO. This means that in provincial MPAs, fishing may still occur, unless specifically closed there by *Fisheries Act* regulation.

Canada's *Oceans Act*, passed in 1997, states that "conservation, based on an ecosystem approach, is of fundamental importance to maintaining biological diversity and productivity in the marine environment". EBM is a guiding principle for implementing oceans management and preserving the health of oceans under Canada's Oceans Action Plan. EBM is the management of human activities so that ecosystems, their structure (*e.g.*, diversity of species), function (*e.g.*, productivity) and overall marine environmental quality are maintained. This ecosystem approach to oceans management recognizes that activities must be managed in consideration of the interrelationships between organisms, their habitats and the physical environment.

The *Oceans Act* calls for: 1) implementation of IM plans, 2) development of a national system of MPAs, and 3) establishment of MEQ guidelines, objectives and criteria. However, DFO is still determining how best to implement IM, and because the other two components are in reality a part of IM, progress in their implementation is also stalled. The PNCIMA is one of five pilot areas in Canada (the other four are in Atlantic Canada) where establishment of IM is currently being focused, and as of April 2009, only initial draft ecological objectives (EOs) in support of IM have been developed. EOs are determined from both science (conservation) objectives and socio-economic (desirable) objectives, as illustrated in Figure 2.2.1. The threshold relationship between conservation and desirable objectives is shown in Figure 2.2.2. Development of the draft EOs is ongoing and will be the culmination of a lengthy process which involves the completion of an Ecosystem Overview Assessment (EOA; Appendix 4) for the PNCIMA. The EOA is a technical document to provide IM partners and stakeholders with relevant information on marine and coastal ecosystems, including regional status and trends, an impact assessment and recommendations to management – based on the best science and knowledge available – in order to support IM planning and further decision making. The EOA contains two main parts:

1. A LOMA-scale ecosystem description that reports on ecosystem status and trends, and the basic information necessary to inventory key properties and components of ecosystems and describe ecosystem relationships and key elements. This part consists of different sections to report on influencing systems:
   a. geological systems (*e.g.*, sedimentology),
   b. oceanographic systems (*e.g.*, physical oceanography),
   c. biological systems (*e.g.*, flora and fauna).

2. Based on the above background information, the second part of the EOA document, "Assessment and Conclusions", provides managers with:
   a. an assessment that:
      i. reviews threats and human activities which have – or are suspected to have – significant impacts at the ecosystem scale;

ii. assesses and reports on the impacts of human activities on ecosystem structure and function, and overall marine environmental quality; and
iii. identifies ecologically and biologically significant areas (EBSAs) (Clarke and Jamieson, 2006a,b), ecologically significant species and community properties (ESSCPs), and Depleted Species and Degraded Areas;

b. recommendations for science managers to support planning and management actions in the IM area, *i.e.*, in terms of knowledge gaps identification, science research planning and the use of monitoring programs – be they existing or specifically designed – to effectively support oceans management in future.

Overall Ecosystem-based Management Objective

- *How will the objectives be achieved?*
- *What is the timeframe to implement objectives and meet goals?*

In 2002, DFO held a national workshop (Jamieson *et al.*, 2003) which identified national ecosystem-level objectives, with associated indicators and reference points, that could be used in managing ocean activities. Under the overarching objective of conservation of species and habitat, the workshop defined objectives related to biodiversity, productivity and the physical and chemical properties of the ecosystem. Under each of these, further nested components were defined, along with an unpacking process to link these conceptual objectives to those suitable for operational management (see Table 2.2.1). For each nested component, a suite of biological properties or characteristics was developed that further described the objective. Example indicators and reference points were also developed by operational objective, although further work on these at both a national and regional level was required. Assessment frameworks that evaluated progress against all objectives were discussed simultaneously and their potential uses investigated. A major achievement of the workshop was development, at a national level, of the concepts and terms related to EBM.

Two broad overarching general goals for EBM were accepted:

- the sustainability of human usage of environmental resources, and
- the conservation of species and habitats, including those other ecosystem components that may not be utilized by humans.

Discussion at the workshop was extensive and focused on objectives under the conservation goal; for more detail, refer to Jamieson *et al.* (2003). Initial conceptual objectives relating to biodiversity, productivity and the physical and chemical properties of the ecosystem were developed to:

1. conserve enough components (ecosystems, species, populations, *etc.*) so as to maintain the natural resilience of the ecosystem,
2. conserve each component of the ecosystem so that it can play its historic role in the foodweb (*i.e.*, not cause any component of the ecosystem to be altered to such an extent that it ceases to play its historical role in a higher order component),
3. conserve the physical and chemical properties of the system.

The first conceptual objective, biodiversity, has the following nested components:

1. to maintain communities within bounds of natural variability,
2. to maintain species within bounds of natural variability,
3. to maintain populations within bounds of natural variability.

Current activities in relation to endangered and threatened species would be addressed under the species component, which thus provides a link to national and international species at risk acts, accords and legislation.

The second conceptual objective relates to the productivity of the ecosystem, with nested components being:

1. to maintain primary production within historic bounds of natural variability,
2. to maintain trophic structure so that individual species/stage can play their historical role in the foodweb,
3. to maintain mean generation times of populations within bounds of natural variability.

Current work under the *Fisheries Act* relates primarily to these three components.

The third conservation objective is intended to safeguard the physical and chemical structures within which the ecosystem resides, with nested components being:

1. to conserve critical landscape and bottomscape features,
2. to conserve water column properties,
3. to conserve water quality,
4. to conserve biota quality.

Example indicators and reference points were also developed for some of these objectives. It is expected that specific situations within particular ecosystems, while starting from the same set of conceptual objectives, may produce different operational objectives through the unpacking exercise.

O'Boyle and Jamieson (2006) summarized a number of initiatives undertaken to explore the structure and function of this approach in Canada, in both the Atlantic and Pacific, since the 2001 Sidney workshop. These include not only the objectives of management, both at the conceptual and operational levels, but also issues relating to assessment, regulations and governance. They thus span the full complexity of what is termed IM.

O'Boyle and Jamieson (2006) also considered activities undertaken as part of management (functions) separate from the organization of how management is achieved (structures) (O'Boyle, 1993). Functions involve both goal setting (what one hopes to achieve, *i.e.*, objective definition) and control activities (how goals are achieved), the latter involving both regulation of human activity and the monitoring and assessment of the scale and nature of impacts. Structures include what it is that is being managed (*e.g.*, determination of ecosystem boundaries) and the organization of mandated management institutions (decision-makers and technical bodies). Much of their paper was focused on IM functions, particularly the determination of objectives, with some consideration of IM structure.

A number of lessons were learned (Jamieson *et al.*, 2003; O'Boyle and Keizer, 2003; DFO, 2004) from these exercises. Having an objectives tree that outlines the desired conceptual objectives and that formally links these to operational objectives used in everyday management forced consideration of why a particular indicator should be, or is being, measured. There was a tendency to use data availability to define the objective, rather than the converse. There will be occasions when documented scientific support for use of a particular indicator and reference point is not available. In these cases, expert judgement (Delphic approach) is appropriate.

O'Boyle and Jamieson's (2006) conclusions were that IM on Canada's East and West coasts is still in its initial stages. While progress has been made, development of IM will be a long-term, ongoing, adaptive process that will involve the testing of many alternative approaches to determine which approach works best and is most cost-effective. Incorporation of conceptual objectives for the dimensions of sustainability (social, economic and cultural), technical review of ecosystem monitoring approaches, and the continuing need for research on appropriate indicators and reference points are just some of the major IM challenges ahead. Progress to date has been substantial though, and the broad outline of what is required to implement IM is starting to emerge, as presented in the following.

1. Fishery Management

- General approach to management for target and non-target species in fisheries

Canadian fishery management is still either species or gear-type focused. Management plans for target species, available for Canada's Pacific Coast as a whole, are listed in Table 2.2.2. Ecological objectives are just beginning to be incorporated into management plans. Non-target species are typically not specifically managed, although regulated area closures and catch limits exist in some management plans for some species/gear types to avoid incidental capture of some species (depleted species, or species that are targeted by another gear type) or damage to fragile species, such as sponges. Examples are regulated sponge reef closures and sub-area closures to address shellfish interception and shallow water habitat concerns in the groundfish trawl fishery (http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans10/Groundfish_2010_june28.pdf; appendix 8, section 5.1) and shrimp trawl fishery (http://www.dfo-mpo.gc.ca/Library/336240.pdf; section 1.13 and appendix 6).

- *How is the ecosystem taken into consideration when managing fisheries?*

Initial EOs in support of EBM have only been established since April 2007, and their incorporation into management plans is an on-going adaptive management process, with EOs being refined in both number and detail as a gradual shift to effective EBM is achieved. An example of their inclusion to date is shown in the shrimp trawl management plan

Table 2.2.2 Canadian fishery management regulations by species, species group or gear type for Canada's Pacific Coast.

	Fishery regulation									
Species	**Closed season**	**Gear size limit**	**Area closure**	**TAC**	**IVQ**	**Species closure***	**Minimum size limit**	**Minimum mesh size**	**Escape ring**	**Bycatch**
Groundfish										
Trawl	x	x	x	x	x	x	–	x	–	Yes
Hook and line rockfish	x	–	x	x	x	–	x	–	–	Yes
Halibut	x	–	x	x	x	–	x	–	–	Yes
Sablefish	x	–	x	x	x	–	x	–	x	–
Hake	x	x	x	–	x	–	–	x	–	Yes
Pelagics										
Roe herring	x	x	x	–	–	–	–	x	–	No
Roe on kelp	x	–	x	–	–	–	–	–	–	No
Food and bait herring	x	x	x	x	x	–	–	–	–	Yes
Sardine	x	x	x	x	–	–	–	–	–	Yes
Invertebrates										
Intertidal clam	x	–	x	x	–	–	x	–	–	No
Crab		–	x	–	–	–	x	–	x	Yes
Geoduck and horse clam	x	–	x	–	–	–	x	–	–	No
Euphausiid	x	–	x	x	–	–	–	–	–	Yes
Prawn and shrimp	x	–	x	–	–	x	x	–	x	Yes
Sea cucumber	x	–	x	–	x	–	–	–	–	No
Sea urchin	x	–	x	–	x	x	x	–	–	No
Shrimp trawl	x	x	x	–	–	x	–	–	–	Yes
Opal squid	x	x	x	–	–	–	–	–	–	Yes
Scallop trawl	x	x	x	x	–	–	x	–	–	Yes
Scallop dive	x	–	x	x	–	–	x	–	–	No
Octopus dive	x	–	x	–	–	–	x	–	–	No
North Coast Salmon	x	x	x	x	–	x	x	x	–	Yes

*Species closure: fishery may be closed if bycatch of other species is excessive.
TAC = total allowable catch, IVQ = individual vessel quota

(http://www.dfo-mpo.gc.ca/Library/336240.pdf; section 8), which discusses Canada's efforts to date in identifying areas and species that require protection or other conservation measures.

- *How selective is the gear (e.g., bottom trawl, midwater trawl, purse seine, long line and trap, gillnet and other gear) for the target species?*

Selectivity for target species varies by gear type, as does the options available to minimize bycatch. Spatial and temporal closures to avoid bycatch are sometimes effective and design features of the gear can help minimize bycatch of either non-target species or undersirable sized individuals such as juveniles of target species. Groundfish trawl bycatchs have not been well analyzed, particularly with respect to their ecosystem impact implications but since 1996, every groundfish trawl vessel has been required to have an observer onboard to document bycatch by species and weight. Jamieson and Davies (2004) document both the nature and quantity of bycatch in the groundfish trawl fishery in PNCIMA. Bycatches for other fishing gears are not as well documented, as observers are typically not present, and data have not been analyzed in detail. An example of a selectivity device is in the shrimp trawl fishery management plan (http://www.dfo-mpo.gc.ca/Library/336240.pdf; appendix 1, section 6), which typically targets pink shrimp (*Pandalus borealis eous* and *P. jordani*). Voluntary plastic lattice panels are recommended to be installed in all otter trawl nets to reduce eulachon (*Thaleichtys pacificus*, an osmerid that currently has a reduced abundance) bycatch.

- *Does fishery gear target certain sizes or life-history stage(s)?*

Mesh sizes and trap escape rings regulations are, in some instances, used to target specific sizes and life-history stages by allowing the escape of undesired animals.

- *Is the fishery spatially concentrated?*
- *Is the fishery year-round?*

Because of the wide diversity in fisheries in PNCIMA, there is a whole range of fishing strategies being used for different species. Some species are year-round with a minimum size limit (*e.g.*, Dungeness crab); others are year-round with individual vessel quotas (IVQs), or have specific closed periods, and many have spatial restrictions, either as to where fishing can occur or to limit the amount of fishing activity (*e.g.*, number of vessels) that can occur in an area. Management plan features are summarized in Table 2.2.3.

- *Are certain geographic areas excluded from the fishery? Explain reason for the exclusion.*

In some cases, yes, for the following alternative reasons:

1. to avoid bycatch and/or to conserve biogenic habitat (*e.g.*, sponge reef closures),
2. to protect spawning stock and/or habitat and hopefully, to enhance recruitment (*e.g.*, rockfish conservation areas),
3. to protect communities in MPAs, which can be established for a variety of reasons (see Jamieson and Lessard, 2000).

- *Are there catch limits on non-target species?*

Not usually, but they do occur for some depleted species (*e.g.*, eulachon 'action levels', in shrimp trawl fisheries) when the species is normally fished by another gear type (*e.g.*, prawns (normally trapped) in a shrimp trawl fishery), or when different quotas exist for species caught by the same gear (*e.g.*, salmon species). When a certain biomass of eulachon (action level) is caught, the fishery may be closed. Likewise, no more than 100 prawns (all prawns caught must be retained) are allowed on a vessel while fishing. If prawn catch levels become too high, the area is closed to shrimp trawling.

- *Is the catch of non-target species recorded and accounted for?*

The groundfish trawl fishery has had 100% observe reporting of all bycatch since 1996. The shrimp trawl fishery requires estimates of bycatch to be provided for certain species. Other fisheries do not as of yet require bycatch reporting, which creates difficulties in the gathering of necessary inputs for EBFM.

- *What is the environmental variability (e.g., physical disturbance regime; El Niño, typhoon, changes in current strength) and how do species respond, if known?*

Periodic North Pacific regime shifts and El Niño events have an impact on the Pacific North Coast ecoregion. Water temperatures, in particular, may vary, which can impact some species. Migrating salmon seem to be particularly impacted, as in colder water periods, most salmon migrate to the Fraser

Table 2.2.3 Canadian species with Pacific management plans (obtainable from http://www-ops2.pac.dfo-mpo.gc.ca/xnet/xIndex.cfm?pg=xnet_main_menu&expand=107).

Groundfish	o Groundfish trawl o Hook and line o Halibut o Sablefish
Pelagics and minor finfish	o Roe herring o Spawn on kelp o Food and bait herring o Eulachon o Sardine o Albacore tuna
Shellfish	o Clam o Crab o Euphausiid o Geoduck o Octopus o Prawn o Scallop o Sea cucumber o Sea urchin o Shrimp o Squid
Salmon	o Salmon

River from the outside of Vancouver Island, while in warmer water periods, most migrate through Johnstone Strait (see section 4.2, Figure 4.2.8) which, because of tidal mixing with deeper colder waters, is cooler. Because this region is also in the transition zone between many southern and northern species, ranges and relative abundance of different species may consequently vary. In El Niño years, for example, more southern species occur in abundance farther north (*e.g.*, hake in Queen Charlotte Sound). The relative copepod species proportions between southern and northern species can also change significantly.

- *What is the spatial distribution of the fishery compared to the distribution of the target species?*

With so many regional fisheries, this is difficult to answer. Many fisheries target mobile species when they are concentrated in abundance, such as spawning or feeding aggregations, or when they are concentrated by topography while migrating (*e.g.*, salmon in the confines of Johnstone Strait. With relatively sedentary nearshore invertebrate species like sea urchins, crabs and clams, fisheries occur where high abundances of these species occur, which are often dependent on substrate characteristics. Figure 2.2.3 shows the spatial distribution of commercial trawl effort in recent years for the northern British Columbia (BC) coast.

2. Management of Threatened or Protected Species and Communities

- General approach to management of threatened or protected species and communities

Oceans Act

Under the *Oceans Act*, the main deliverable for Phase I of the Ocean Action Plan (OAP) for the Pacific Region is the establishment of a LOMA planning process for the North and Central coasts called the Pacific North Coast Integrated Management Area (PNCIMA). PNCIMA will: 1) focus on addressing management needs and priorities related to multiple ocean uses, 2) be a collaborative planning and management process and 3) augment and consolidate decision making processes in the Queen Charlotte Basin.

The aim of the Plan is to augment and consolidate decision making processes and link sector planning and management to an overarching set of management objectives and targets. Regulatory authorities will continue to remain responsible and accountable for implementing management policies and measures within their mandates and jurisdictions. Rather than build an entirely separate process, the goal of the PNCIMA plan is to build references and linkages to existing management strategies and actions. DFO is currently preparing the background documentation required to inform this process. Part of this documentaion is the identification of EBSAs (DFO, 2004), ESSCPs (DFO, 2006), and Depleted Species and Degraded Areas which, as a first effort for PNCIMA, was completed for EBSAs (Clarke and Jamieson, 2006a,b). These will be used to determine conservation objectives (DFO, 2007).

Species at Risk Act (SARA)

The *Species at Risk Act* (SARA) was created to protect wildlife species from becoming extinct by: 1) providing for the recovery of species at risk due to human activity and 2) ensuring, through sound management, that species of special concern do not become endangered or threatened. The *Act* became law in June 2003. It includes prohibitions against

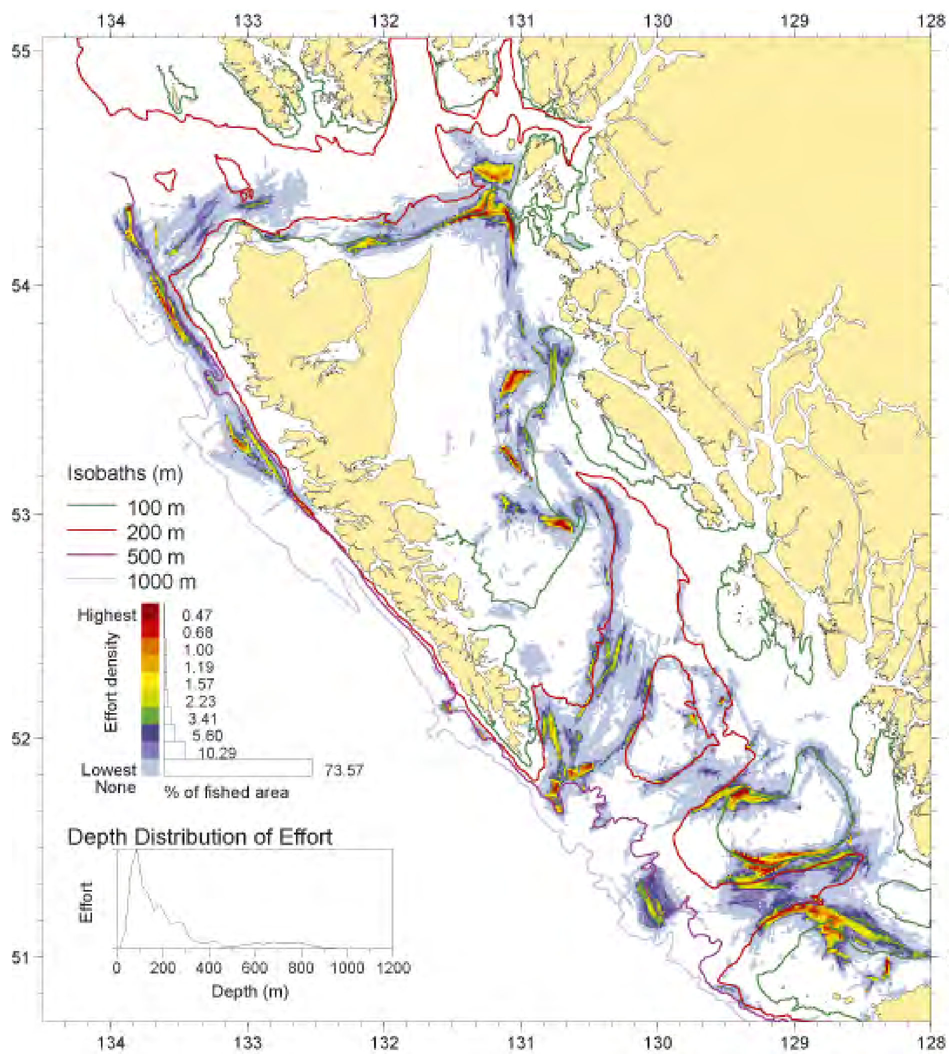

Fig. 2.2.3 Spatial distribution of bottom trawl fishing effort on the BC Central Coast and around the Queen Charlotte Islands (Haida Gwai) from 1996–2004. Data were plotted using a 1 km^2 grid. Grids are colour coded by decile of the cumulative distribution, with the highest density coloured red and the lowest light blue. The histogram summarizes the percentage of the fished area covered by each decile. The line graph shows the depth distribution of effort (from Sinclair, 2007).

killing, harming, harassing, capturing or taking species at risk, and against destroying their critical habitats. Marine PNCIMA species listed at risk under SARA or other criteria can be found in Table 2.2.4. Recovery plans have been developed for many of the COSEWIC-listed species

Protected Areas

Protected areas in PNCIMA have been established under many different federal and provincial *Acts* (Jamieson and Lessard, 2000), and management plans have been written for only some of them. As indicated above, DFO manages all living marine animals, and management plan references for individual species or species groups are given in Table 2.2.3. There are presently no DFO *Oceans Act*-legislated MPAs in PNCIMA, so in the mpas legislated by other provincial or federal *Acts* in PNCIMA, two management plans are needed: one for substrate habitat by the appropriate agency that designated the mpa, and a DFO one for living resources. Many PNCIMA protected areas do not yet have specific management plans for either species or substrate. However, there is a plan to harmonize management objectives for mpas between the different agencies involved, but when this will be effected has yet to be determined.

- **General approach to designation (legal/ regulatory framework), management and recovery of threatened or protected species/ communities** [describe ecological properties of the species or groups that make them vulnerable and in need of protection.]

- *Is there legislation for designating species at risk?*
- *How are threatened species identified, and are there timeframes for developing recovery plans?*
- *Are recovery thresholds identified above which a species no longer needs legal protection?*

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent body of experts, was created in 1977 when the need for a single, official, scientifically sound, national classification of wildlife species at risk was recognized. COSEWIC has developed and periodically modified its operating procedures, the categories of risk and their definitions, and its assessment procedures to fine-tune its operations. COSEWIC's mandate currently considers vertebrates (mammals, birds, reptiles, amphibians and fishes), plants, molluscs, and arthropods. COSEWIC has the power to designate species on an emergency basis when there is a clear immediate danger of serious decline in the species population and/or range, or when such a decline is already in progress and will continue unless immediate corrective actions are taken, and when the delay involved with going through the normal process could contribute to the species' jeopardy.

The COSEWIC process is divided into three sequential steps, each of which has a tangible outcome. These are: 1) selection and prioritization of species requiring assessment – COSEWIC Candidate List and the Priority List; 2) compilation of available data, knowledge and information – COSEWIC status report; and 3) assessment of a species' risk of extinction or extirpation and subsequent designation – the record of COSEWIC assessment results. Species get on the SARA list by being designated 'at risk' by COSEWIC. The federal Cabinet then decides whether those species should get legal protection under the *Act*, following consultations with affected stakeholders and other groups (http://www.sararegistry.gc.ca/default_e.cfm). More details can be obtained at the COSEWIC website (http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm).

In Canada, the identification of recovery thresholds above which a species no longer needs legal protection is proving to be a non-trivial exercise. A national workshop was held on this topic (DFO, 2005), and a precautionary framework that has three zones for a population – healthy, cautious and critical – seems useful. It was determined that there are both strengths and weaknesses in placing a biologically-based recovery target at either the critical–cautious boundary or at the cautious–healthy boundary. There is, at present, no compelling scientific argument pointing to one position or the other, or to any specific position between them.

Table 2.2.4 Status assessments of selected marine species in British Columbia.

Group	Common Name	Scientific Name	Population	Status				
				SARA[1]	GS[2]	BCCDC[3]	IUCN[4]	COSEWIC[5]
Molluscs	Northern abalone	*Haliotis kamtschatkana*	–	1	x	R	–	TH
	Olympia oyster	*Ostrea conchaphila*	–	1	x	B	–	SC
Reptiles	Leatherback seaturtle	*Dermochelys coriacea*	–	1	1	R	–	EN
Mackerel sharks	White shark	*Carcharodon carcharias*	–	DD	5	x	Vu A1cd 2cd	DD
Basking sharks	Basking shark	*Cetorhinus maximus*	–	–	2	x	En A1ad	–
Cow sharks	Bluntnose sixgill shark	*Hexanchus griseus*	–	–	3	x	LR/nt	–
	Broadnose sevengill shark	*Notorynchus cepedianus*	–	–	3	x	DD	–
Hound sharks	Soupfin shark	*Galeorhinus galeus*	–	–	3	x	Vu A1bd	–
Skates	Sandpaper skate	*Bathyraja interrupta*	–	–	3	R	x	–
	Big skate	*Raja binoculata*	–	–	3	x	LR/nt	–
	Longnose skate	*R. rhina*	–	–	3	x	x	–
Ragfishes	Ragfish	*Icosteus aenigmaticus*	–	–	3	x	x	–
Sturgeon	Green sturgeon	*Acipenser medirostris*	–	1	2	R	–	SC
Rockfishes	Bocaccio	*Sebastes paucispinis*	–	3	1	x	CR A1abd+2d	TH
	Canary rockfish	*S. pinniger*	–	–	3	x	x	–
	Darkblotched rockfish	*S. crameri*	–	–	3	x	x	–
	Pacific ocean perch	*Sebastes alutus*	–	–	3	x	x	–
	Quillback rockfish	*S. maliger*	–	–	3	x	x	–
	Redbanded rockfish	*S. babcocki*	–	–	3	x	x	–
	Rougheye rockfish	*S. aleutianus*	–	–	3	x	x	–
	Shortraker rockfish	*S. borealis*	–	–	3	x	x	–
	Silvergray rockfish	*Sebastes brevispinis*	–	–	3	x	x	–
	Widow rockfish	*S. entomelas*	–	–	3	x	x	–
	Yelloweye rockfish	*S. ruberrimus*	–	–	3	x	x	–
	Yellowmouth rockfish	*S. reedi*	–	–	3	x	x	–
	Yellowtail rockfish	*S. flavidus*	–	–	3	x	x	–
	Longspine thornyhead	*Sebastolobus altivelis*	–	–	3	x	x	–
	Shortspine rhornyhead	*S. alascanus*	–	–	3	x	x	–
Osmerids	Eulachon	*Thaleichthys pacificus*	–	–	2	B	–	–

Table 2.2.4 Continued.

Group	Common Name	Scientific Name	Population	Status				
				SARA[1]	**GS**[2]	**BCCDC**[3]	**IUCN**[4]	**COSEWIC**[5]
Salmon	Chinook	*Oncorhynchus tshawytscha*	Okanagan	**	4	Y	–	TH
	Coho	*O. kisutch*	Interior Fraser	2	4	Y	–	EN
	Sockeye	*O. nerka*	Cultus	2	4	Y	–	EN
		O. nerka	Sakinaw	2	4	Y	–	EN
Waterfowl	Western grebe	*Aechmophorus occidentalis*	–	–	2	R	–	–
Seabirds	Black-footed albatross	*Phoebastria nigripes*	–	–	4	Y	EN	–
	Laysan albatross	*P. immutabilis*	–	–	5	B	VU	–
	Short-tailed albatross	*P. albatrus*	–	1	1	R	VU	TH
	Northern Fulmar	*Fulmarus glacialis*	–	–	4	R	LC	–
	Pink-footed shearwater	*Puffinus creatopus*	–	1	1	R	VU	TH
	Flesh-footed shearwater	*P. carneipes*	–	–	3	B	–	–
	Black-vented shearwater	*P. opisthomelas*	–	–	8	A	VU	–
	Buller's shearwater	*P. bulleri*	–	–	3	B	VU	–
	Manx shearwater	*P. puffinus*	–	–	x	A	–	–
	Double-crested cormorant	*Phalocrocorax auritus*	–	NAR	3	B	–	NAR
	Brandt's cormorant	*P. penicillatus*	–	–	2	R	–	–
	Pelagic cormorant	*P. pelagicus pelagicus*	*pelagicus* subspecies	–	4	R	–	–
Shorebirds	Great blue heron	*Ardea herodias herodias*	*herodias* subspecies	–	3	B	–	–
		Ardea herodias fannini	*fannini* subspecies	–	3	B	–	SC
	Wandering tattler	*Heteroscelus incanus*	–	–	3	B	–	–
	Short-billed dowitcher	*Limnodromus griseus*	–	–	3	B	–	–
Waterfowl	Canada goose	*Branta canadensis leucoparieia*	*leucopareia* subspecies	–	4	B	–	–
		B. canadensis occidentalis	*occidentalis* subspecies	–	4	B	–	–
	Long-tailed duck	*Clangula hyemalis*	–	–	3	Y	–	–
	Surf scoter	*Melanitta perspicillata*	–	–	3	B	–	–
	Sandhill crane	*Grus canadensis tabida*	*tabida* subspecies	–	3	B	–	NAR
Raptors	Peregrine falcon	*Falco peregrinus anatum*	*anatum* subspecies	1	3	R	–	TH
		F. peregrinus pealei	*pealei* subspecies	1	3	B	–	SC

Table 2.2.4 Continued.

Group	Common Name	Scientific Name	Population	Status				
				SARA[1]	**GS**[2]	**BCCDC**[3]	**IUCN**[4]	**COSEWIC**[5]
Seabirds	Red-necked phalarope	*Phalaropus lobatus*	–	–	3	B	–	–
	California gull	*Larus californicus*	–	–	3	B	–	–
	Common murre	*Uria aalge*	–	–	2	R	–	CL
	Thick-billed murre	*U. lomvia*	–	–	2	R	–	CL
	Marbled murrelet	*Brachyramphus marmoratus*	–	1	1	R	VU	TH
	Ancient murrelet	*Synthliboramphus antiquus*	–	1	3	B	–	SC
	Xantus' murrelet	*S. hypoleucus*	–	–	5	A	VU	–
	Cassin's auklet	*Ptychoramphus aleuticus*	–	–	3	B	–	–
	Tufted puffin	*Fratercula cirrhata*	–	–	3	B	–	–
	Horned puffin	*F. corniculata*	–	–	2	R	–	–
Marine Mammals	Blue whale	*Balaenoptera musculus*	Pacific	1	1	B	–	EN
	Fin whale	*B. physalus*	Pacific	1	1	B	–	TH
	Sei whale	*B. borealis*	Pacific	1	1	B	–	EN
	Humpback whale	*Megaptera novaeangliae*	North Pacific	1	4	B	–	TH
	Grey whale	*Eschrichtius robustus*	NE Pacific	1	3	B	–	SC
	North Pacific right whale	*Eubalaena japonica*		1	1	R	–	EN
	Killer whale	*Orcinus orca*	NE Pacific southern resident	1	1	R	–	EN
		Orcinus orca	NE Pacific northern resident	1	1	R	–	TH
		Orcinus orca	NE Pacific transient	1	1	R	–	TH
		Orcinus orca	NE Pacific offshore	1	1	B	–	SC
	Harbour porpoise	*Phocoena phocoena*	Pacific Ocean	1	3	B	–	SC
	Steller sea lion	*Eumetopias jubatus*		1	3	R	–	SC
	Northern fur seal	*Callorhinus ursinus*		*	1	B	–	TH
	Sea otter	*Enhydra lutris*		1	1	R	–	TH

[1]**SARA**: *Species at Risk Act*. 1 = species on Schedule 1 legal list of wildlife species at risk; 2 = species not added to legal list; 3 = referred back to COSEWIC for further information or consideration; * COSEWIC status assessment not yet forwarded to the Minister; ** COSEWIC status assessment has been forwarded to the Minister of the Environment; a decision is pending.

Table 2.2.4 Continued.

[2]**GS**: General Status of Wildlife in Canada. 1 = At Risk: a formal, detailed risk assessment has been completed and determined to be at risk of extirpation or extinction. 2 = May Be At Risk: may be at risk of extirpation or extinction and are therefore a candidate for detailed risk assessment by COSEWIC, or provincial or territorial equivalents. 3 = Sensitive: not believed to be at risk of immediate extirpation or extinction but may require special attention or protection to prevent them from becoming at risk. 4 = Secure: not believed to belong in the other categories; includes some species that show a trend of decline in numbers in Canada but remain relatively widespread or abundant. 5 = Undetermined: insufficient data, information, or knowledge is available with which to reliably evaluate their general status. 6 = *Not Assessed:* known or believed to be present regularly in the geographic area in Canada to which the rank applies, but have not yet been assessed by the general status program. 7 = Exotic: moved beyond their natural range as a result of human activity. 8 = Accidental: occurring infrequently and unpredictably, outside their usual range.

[3]**BCCDC**: British Columbia Conservation Data Centre: Provincial list of species of conservation concern in British Columbia. R = Red List: indigenous species and subspecies that are extirpated, endangered or threatened in BC; B = Blue List: indigenous species and subspecies of special concern (formerly vulnerable) in BC; Y = Yellow List: species that are apparently secure and not at risk of extinction, may have Red or Blue listed subspecies. E = Exotic: Species that have been moved beyond their natural range as a result of human activity. Exotic species are also known as alien species, foreign species, introduced species, non indigenous species and non native species. Exotic species are excluded from the Red, Blue and Yellow lists. A = Accidental: Species occurring infrequently and unpredicatably, outside their usual range. Accidental species are excluded from the Red, Blue and Yellow list..

[4]**IUCN**: International Union for Conservation of Nature and Natural Resources: Red List of Threatened Species. EN = Endangered: A taxon is Endangered when the best available evidence indicates that it meets any of the criteria for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild; VU = Vulnerable: A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild' NT = Near Threatened: A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

[5]**COSEWIC**: Committee on the Status of Endangered Wildlife in Canada. EN = Endangered: facing imminent extirpation or extinction, T = Threatened: likely to become endangered if limiting factors are not reversed; SC = Special Concern: particularly sensitive to human activities or natural events but not endangered or threatened (formerly referred to as vulnerable), NAR = Not at Risk: evaluated and found to be not at risk, DD = Data Deficient: insufficient scientific information to support status designation.

3. Habitat Management

- General approach to management of habitats

The mandate of the Habitat Management Program in DFO is to: 1) protect and conserve fish habitat in support of Canada's coastal and inland fisheries resources, and 2) conduct environmental assessments under the *Canadian Environmental Assessment Act* before DFO makes a regulatory decision under the habitat provisions of the *Fisheries Act*.

The federal government has constitutional authority for seacoast and inland fisheries. Legislatively, it has exercised this authority through the *Fisheries Act*, one of the oldest acts in Canada. The *Fisheries Act* contains provisions to conserve and protect fish habitat (defined in subsection 34(1) of the *Fisheries Act* as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes") that sustain Canada's fisheries resources.

There are two types of habitat provisions in the *Fisheries Act*: habitat protection and pollution prevention. A key habitat protection provision is subsection 35(1). This section prohibits the harmful alteration, disruption or destruction (HADD) of fish habitat without an authorization from the Minister of DFO, or by regulation. Other habitat protection provisions include dealing with obstructions impeding the free passage of fish and with the minimum flow of water for fish.

Section 36 of the *Act* is the key pollution prevention provision. It prohibits the deposit of deleterious substances into waters frequented by fish unless authorized by regulation or by federal laws. The administration of section 36 has been assigned to the Minister of the Environment. However, the Minister of DFO is responsible to Parliament for all sections of the *Act*.

The national Habitat Management Plan (HMP) has responsibility for conducting environmental assessments under the *Canadian Environmental Assessment Act* prior to regulatory decisions being made by DFO under laws administered by the Department. This includes the issuance of authorizations of a HADD under section 35 of the *Fisheries Act*.

The Policy for the Management of Fish Habitat, tabled in Parliament in 1986, provides guidance for the administration of the habitat provisions of the *Fisheries Act* and a comprehensive framework for the management of Canada's fish habitat resource base in the context of sustainable development. It includes the overall objective of net gain for habitat for Canada's fisheries resources and outlines the three goals to reach this objective: fish habitat conservation, fish habitat restoration, and fish habitat development. It also includes a guiding principle of 'No net loss' (a working principle by which the Department strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented) which allows development to proceed where compensation of loss of fish habitat is acceptable.

- **General approach to management of habitats (including biological habitat such as corals, seagrass beds, *etc*., as well as physical habitat)** [describe ecological properties of the habitat that makes it significant.]

- *Are specific habitats designated for protection, and what legislation allows for the designation?*

The Policy for the Management of Fish Habitat protects fish habitats by administering the *Fisheries Act* and incorporating fish habitat protection requirements into land and water use activities and projects. Procedures for implementing the no net loss guiding principle are used as an integral part of the strategy to deal with proposed works and undertakings that could affect fisheries. DFO ensures a uniform and equitable level of compliance with statutes, regulations and policies, as necessary to manage and protect fish habitats in jurisdictions where the federal government manages fisheries. The *Fisheries Act* contains powers to deal with damage to fish habitat, destruction of fish, obstruction of fish passage, necessary flow requirements for fish, the screening of water intakes and the control of deleterious substances. Potential adverse effects on fish habitats are frequently avoided by modifying the plans, designs and operating procedures for projects and activities, and by incorporating mitigation and compensatory measures.

- *Are there monitoring and inventory activities in place?*

Proponents of an activity that might affect fish habitat may be asked to provide an assessment of the potential impact of existing or proposed works and undertakings on the fisheries resource. Usually such requests would apply to major projects (potentially having significant negative impacts on the habitats supporting Canada's important fisheries resources). Assessments include project-specific information on the resource in question, and supporting habitat and baseline fisheries information required to assess the potential impact of the proposed project. Costs of mitigating any anticipated damages, and for implementing compensation measures and facilities designed to avoid losses of fish habitat and reductions in the supply of fish, are the responsibility of proponents. DFO conducts detailed reviews, frequently and preferably as a participant in a provincial or federal environmental review process, of major proposed industrial undertakings that could potentially harm habitats supporting the fisheries resources.

- *Are there restoration plans or activities underway?*

DFO initiates projects and provides advice to other interested groups to restore and develop fish habitats, in support of the net gain (an increase in the productive capacity of habitats for selected fisheries brought about by determined government and public efforts to conserve, restore and develop habitats) objective. Under this strategy, habitats may be restored by rehabilitating streams; by eliminating or controlling exotic species, predators, parasites, and competitors; by removing man-made and storm-related physical barriers and other initiatives; and, in cooperation with Environment Canada, requiring the installation and operation of suitable waste treatment technology. Where it manages the fisheries directly, DFO will provide advice and guidance to community and conservation groups that wish to undertake habitat restoration and development projects; financial support also may be provided, depending on the availability of public funds for this purpose.

- Evaluate the effectiveness of decisions taken and techniques used to conserve, restore and develop fish habitats

1. Recognizing limitations in the ability to predict changes to fish habitats arising from proposed actions, the Department aims to monitor the effects, both during and, for a prescribed period, after development. In this way the effectiveness of departmentally prescribed conditions of approval, intended to maintain the productive capacity of fish habitats, would be evaluated and new knowledge acquired.
2. Proponents may be required to undertake follow-up monitoring studies on the effectiveness of habitat mitigation and compensation prescriptions as a condition of project approval by the Department, and subject to prior discussion and agreement with the proponent on the scope and schedule for monitoring.

- *Are there ecologically or biologically significant habitat types/areas that can be identified and are they given special protection, and are there standards (e.g., no activities allowed or just limitation of human activities in the habitat) for the level of protection?*

See "2. Management of Threatened or Protected Species and Communities" for the identification of EBSAs. These areas under IM are to be more closely managed and monitored to ensure the conservation of features identified as ecologically and biologically significant, but IM has yet to be established in Canada.

4. Community/Trophic Structure Management

- General approach to management of food webs in general and of direct feeding interactions specifically

- *Are the characteristics of the community altered by human activities (e.g., eutrophication, pollution, species introductions, sedimentation, altered coastal circulation, dredging and filling, altered hydrography of rivers, fishing, etc.)?*
- *Are management activities affecting food-webs or do existing food web perturbations constrain moving to a desired state?*
  - Does specific legislation address issues relevant to food webs?
  - Are there monitoring and inventory activities in place?
  - Are there restoration plans or activities underway?
  - Are there ecologically or biologically significant species interactions that can be identified and are they given special consideration, and are there

standards (*e.g.*, ballast water, coastal development, water quality) for the level of protection?

Although desirable "Community Properties" have been identified as something to conserve (DFO, 2006), the reality is that in Pacific Canada at least, the required data to evaluate what the current status of these properties is does not exist, and there are no programs underway that are currently collecting the required data for future assessment. However, since species in the higher trophic levels are often the ones that have been, or are being, most perturbed, the *Species at Risk Act* does address indirectly to some extent conservation of community/trophic structure.

5. Management of Contaminants and Pollutants

There are both federal and provincial approaches to the management of toxins and pollutants, in part depending on whether federal or provincial land or water is involved. Canadian Provinces have considerable authority, and are deemed to have control over most terrestrial land, freshwater and coastal seafloors (not the water column) between headlands.

- General approach to management of contaminants and pollutants

Federal Legislation

Canadian Environmental Protection Act (CEPA)

The federal *Canadian Environmental Protection Act* (CEPA) of 1999 authorizes the Minister of the Environment and Minister of Health to investigate a wide variety of substances that may contaminate the environment and cause adverse effects on environmental or human health. The federal government is responsible for the management of risks to health and the environment posed by substances found to be toxic under CEPA. Under the federal Toxic Substances Management Policy, which is administered under CEPA, substances are considered toxic if they conform to the definition of a toxic substance as specified in CEPA. CEPA sets time limits for developing management strategies for substances found to be toxic under the *Act*. These strategies can include the preparation of regulations, pollution prevention plans, environmental emergency plans, environmental codes of practice, and environmental release guidelines. Once a substance has been determined to be CEPA-toxic, management strategies are developed with one of two possible objectives: 1) life-cycle management of the substance to prevent or minimize its release to the environment, or 2) virtual elimination of the substance from the environment. However, for CEPA-toxic substances which are also bioaccumulative, persistent and anthropogenic, the *Act* requires virtual elimination of that substance. CEPA does not regulate pesticides unless the active ingredient also has a non-pesticidal use and has been categorized as toxic under CEPA. The federal government policy for addressing toxic substsances is called the Toxic Substances Management Process.

Under the authority of CEPA, the Minister of the Environment can sign political commitments and agreements to address key issues of environmental protection and health. The Canadian Council of Ministers of the Environment (CCME), which includes federal, provincial and territorial environment ministers, has signed such an agreement, the Canada-Wide Accord on Environmental Harmonization and the Canada-Wide Environmental Standards Sub-Agreement. Under the framework of this agreement, the CCME develops Canada-wide Standards (CWSs) with the objective of establishing and achieving common environmental standards throughout Canada. CWSs can target specific substances or a number of sectors, sources, and substances. Action relating to the CWSs is taken by the jurisdiction deemed most appropriate. For many of the CWSs, action will be implemented by the provinces and territories. Where the federal government is identified as the most appropriate jurisdiction, regulations, codes of practice, or other preventive control instruments may be developed under CEPA.

For more information, refer to the following websites:

- Toxic Substances Management Process: (search in http://www.ec.gc.ca),
- List of CEPA-toxic substances (Schedule 1): http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm,
- Status of management strategies for CEPA-toxic substances: (search in http://www.ec.gc.ca),
- Existing regulations under CEPA: http://www.ec.gc.ca/CEPARegistry/regulations/default.cfm,
- Canada-wide Standards: http://www.ccme.ca/ourwork/environment.html?category_id=108.

Fisheries Act

While responsibility for the administration and enforcement for the *Fisheries Act* lies primarily with the federal Minister of Fisheries and Oceans, since 1978, the Minister of the Environment has had responsibility for the administration and enforcement of subsection 36(3) of the *Act*, which prohibits the deposit of substances that are deleterious to fish into a place where the substance may enter or does enter waters that are frequented by fish. Under this provision, the discharge of any quantity of a deleterious substance is prohibited, unless there is a regulation that permits that discharge. Under the *Fisheries Act*, any substance that may harm fish or alter fish habitat is considered deleterious. In addition, a number of sector-specific regulations under the *Fisheries Act* limit the release of toxic substances to the environment.

In addition, regulations for specific sources or industry sectors have been developed under the *Fisheries Act*. These include Pulp and Paper Effluent Regulations, Metal Mining Effluent Regulations, and Petroleum Refinery Liquid Effluent Regulations.

For additional information on the *Fisheries Act*, the general provisions of subsection 36(3), and the regulations pertaining to sector-specific releases of toxic substances, refer to http://www-heb.pac.dfo-mpo.gc.ca/water_quality/fish_and_pollution/fish_act_e.htm

Pest Control Products Act (PCPA)

The federal *Pest Control Products Act* (PCPA) is administered and enforced by the Pest Management Regulatory Agency (PMRA) for the Minister of Health. The PCPA regulates the use of substances that claim to have a pest control use and also substances such as formulants, adjuvants, and contaminants that are contained in pest control products. All compounds used for pesticidal purposes in Canada must be registered under the PCPA. Applications for pest control product registrations are reviewed by PMRA. In consultation with Environment Canada, PMRA considers science-based health, environmental, value and efficacy assessments for each pesticide prior to approving its use. Revisions to the PCPA have been completed and the revised PCPA came into force June 28, 2006. Under the revisions to the *Act*, PMRA will be able to provide to Environment Canada scientific studies and data that were submitted by chemical companies to support product registration. In BC, Environment Canada, in consultation with Fisheries and Oceans Canada, advises PMRA on regional concerns relating to unregistered pesticides and requests for emergency registrations.

For more information on the PCPA and the regulation of pesticides in Canada, refer to the PMRA website at http://www.pmra-arla.gc.ca/english/index-e.html. For an explanation of the recent revisions to the PCPA, refer to the PMRA website at http://www.pmra-arla.gc.ca/ english/legis/pcpa-e.html.

Canadian Environmental Assessment Act (CEAA)

This *Act* is administered by the Canadian Environmental Assessment Agency, which is accountable to Parliament through the Minister of the Environment. The CEAA specifies the responsibilities and procedures for conducting environmental assessments on projects conducted in Canada, which involve federal government decision making. The objective of the *Act* is to ensure that such projects do not cause significant adverse environment effects, by promoting a cooperative approach under which the federal and provincial governments review the potential impacts of these projects before decisions and actions are taken by the federal government. The process provides an opportunity for First Nations and public participation. The regulations under this *Act* identify the projects and classes of projects whose potential for causing adverse environmental impacts is considered sufficient to require an assessment under the CEAA. For more information on the CEAA, refer to http://www.ceaa-acee.gc.ca/013/index_e.htm.

Migratory Birds Convention Act

Section 35(1) of the *Migratory Birds Convention Act* prohibits the deposit of oil, oil wastes or any other substance harmful to migratory birds in any area frequented by migratory birds. Under this *Act* it is an offence to harm the habitat of migratory birds while the birds are in residence at the site. This includes the release of harmful substances (including pesticides) to areas frequented by them. For more information on the *Migratory Birds Convention Act*, search in http://www.ec.gc.ca.

Fertilizers Act

The *Fertilizers Act* is administered by Canadian Food Inspection Agency (CFIA). Fertilizers and supplements imported into or sold in Canada must be registered, packaged and labelled according to the requirements of this *Act*. In 1997, nonylphenol ethoxylates were banned as an active ingredient in soil supplements under the *Fertilizers Act*. For more information on the *Fertilizers Act*, refer to the CFIA website at http://www.inspection.gc.ca/english/ plaveg/ fereng/ferenge.shtml#actloi.

Federal Programs for Managing Municipal Wastewater Effluents

- In November 2003, the CCME agreed to develop a Canada-wide strategy for the management of municipal wastewater effluents (http://www. ccme.ca/ourwork/water.html?category_id=81). The strategy includes: 1) a harmonized regulatory framework, 2) coordinated science and research, and 3) an environmental risk management model.
- Environment Canada is developing a comprehensive federal strategy for municipal wastewater effluents, including addressing a number of substances found in municipal wastewater effluent that have been assessed as toxic under CEPA 1999. A contemplated long-term requirement of the federal stragegy is a regulation under the *Fisheries Act* which would include wastewater effluent standards equivalent in performance to conventional secondary treatment, with additional treatment where required.
- A CCME CWS on mercury for dental amalgam wastes was prepared in 2001. Through the collection and recycling of amalgam wastes and the use of advanced amalgam separator units at dental clinics, the amount of mercury discharged to sewer systems will be reduced. The intent of the CWS was to reduce environmental releases of dental amalgam in Canada by 95% by 2005, compared to releases in 2001.
- Under the Georgia Basin Action Plan (GBAP), Environment Canada, in cooperation with interested partners, is undertaking a projects to:
  - determine molecular level (genomic) toxicology of municipal wastewater effluents at receiving water concentrations to fish;
  - utilize in-house developed gene micro-arrays for salmonids to evaluate gene expression to either freshwater rainbow trout or seawater acclimated Pacific salmon. Effluents will be collected from the Greater Vancouver Regional District (GVRD) and Capital Regional District and adjusted to relevant receiving water concentrations in concert with District staff;
  - analyze select pharmaceuticals and fragrance compounds in-house and profile for molecular toxicity;
  - conduct sterol and select pharmaceutical chemistry on each effluent sample collected (~60 samples);
  - educate homeowners on the correct ways to care for their septic systems;
  - supporting technical and scientific conferences, such as the Annual BC Waste and Water Association Conference and Tradeshow.

For more information, refer to the following websites:

- CCME initiatives to reduce the release of contaminants in wastewater treatment plant effluent: http://www.ccme.ca/initiatives/water.html?category_id=81,
- CCME MOU with the Canadian Dental Association: http://www.ccme.ca/ourwork/water.html?category_id=118,
- Environment Canada programs to address municipal WWTP effluents: http://www.ec.gc.ca/etad/default.asp?lang=En&n=D5CE3A46-0,
- GBAP initiatives: http://www.ec.gc.ca/nature/default.asp?lang=En&n=B5519CB7-1.

Provincial Legislation

Environmental Management Act (EMA)

The BC Ministry of the Environement (BC MOE) is responsible for managing the release of wastes and other contaminants from the industrial and agricultural sectors, with the exception of waste discharges to the air in the GVRD which is under the jurisdiction of the GVRD. The pertinent provincial legislation is the *Environmental Management Act* (EMA), which controls the handling, disposal and release of wastes from industrial, provincial and municipal sources. The EMA was brought into force on July 8, 2004 and replaced the BC *Waste Management Act* (WMA).

Through a permitting system, the WMA had enabled allowable releases to be determined, based on scheduled standards (generally discharge volume, toxicity and chemical/compound concentration). Monitoring requirements in the permits depended on factors such as daily discharge rate and receiving environmental characteristics and, in some instances, receiving environment monitoring was required and was determined on a facility/site-specific basis.

Under the WMA, all discharges to the environment from industry, trades and businesses had to be authorized by the Ministry. However, the new EMA takes a risk-based approach in the authorization to discharge waste. Activities considered to be of medium to high-risk will require authorization to discharge waste. However, activities considered to be low risk will not require authorization to discharge, but will remain subject to the requirement that they not cause pollution. The BC MOE will prescribe industries/activities which require a waste discharge authorization through the EMA's Waste Discharge Regulation. Industries posing a high risk to the environment (such as mines and pulp mills) will require a valid authorization such as a permit or adherence to an existing regulation. Industries or activities considered to pose a modest risk to the environment will be required to adhere to province-wide codes of practice for that industry sector or activity. Operations will continue to require authorization through a permit, approval or regulation until accepted codes of practice have been established for that prescribed industry sector or activity. For more information on the *Environmental Management Act* refer to http://www.env.gov.bc.ca/epd/main/ema.htm.

Integrated Pest Management Act (IPMA)

The *Integrated Pest Management Act* (IPMA) replaced the *Pesticide Control Act* in 2004. Under this *Act*, the BC MOE addresses the application, storage, sale, transport and disposal of pesticides. The provincial integrated pesticide management program includes education and training programs, the licencing and certification of applicators and vendors, reviewing Pesticide Management Plans for managing pests, and the issuing of permits for the use of certain pesticides. For more information on the *Integrated Pest Management Act* and the provincial integrated pest management program, refer to http://www.env.gov.bc.ca/epd/ipmp/regs/index.htm.

Mines Act

The *Mines Act*, which is administered by the BC Ministry of Energy, Mines and Petroleum Resources, regulates the operation, health and safety of all BC mines. The regulations and orders under this *Act* prescribe most aspects of mine design and operation, like the stability of mine openings, dams and enclosures, and the prevention of pollution such as from acid rock drainage or acid mine drainage (AMD). Since 1969, this *Act* has required all mines to have bonds or letters of credit sufficient to ensure reclamation of mined lands. For more information on AMD, see http://www.focs.ca/reports/Catface_info_pkg/Acid%20Mine%20Drainage--FNEHIN.pdf.

6. Management of Aquaculture

A useful web site to review is the State-of-Knowledge Presentation for the Special Committee on Sustainable Aquaculture of the British Columbia Legislature at http://www.pac.dfo-mpo.gc.ca/science/aquaculture/sok-edc/aquamanage-gestionaqua-eng.htm.

The Strategic Plan objectives of 2005–2010 are to deliver programs that reflect the priorities of Canadians, in which aquaculture governance is a priority to achieve:

- healthy and productive aquatic ecosystems,
- sustainable fisheries and aquaculture.

General characteristics of aquaculture activities (*e.g.*, stocking or releasing of seed/fry/juveniles, production of individuals in contained environments) relative to the PNCIMA are:

- Finfish net pen culture of Atlantic salmon is primarily in the Broughton Archipelago; some sites are likely provincially licenced for sablefish but are not actively culturing this species yet;
- There are some test pilot shellfish aquaculture sites in First Nation territories;
- Very little shellfish culture in the PNCIMA (water is generally too cold);
- Shellfish culture of mussels (*Mytilus galloprovincialis*, *M. edulis*, *M. trossulus*), oysters (*Crassostrea gigas*), scallops (*Pactinopecten yessoensis*), and manila clam (*Venerupis philippensis*);
- The provincial government (Ministry of Agriculture and Lands) has authority to approve species cultured and licence requirements;
- Culture methodology is dependant on the species being cultured;
- Future cultures may include geoducks (*Panope abrupta*) and cockles (*Clinocardium*).

- *Do specific regulations address issues relevant to species selection, scale of the operation, spatial distribution, and environmental impact of activities?*

Species selection:
- is provincially regulated as part of the licence obtained; movement of species is regulated by the DFO introductions and transfer committee, and listed in the licence.

Scale of operation and spatial distribution:
- finfish are regulated by provincial and federal siting rules, provincial Finfish Aquaculture Waste Control Regulation, *Fisheries Act* Authorizations, including DEPOMOD modeling (modelling the deposition and biological effects of waste solids from marine cage farms), provincial land tenure requirements, and Transport Canada approval;
- shellfish are regulated by provincial management plan, conditions, siting and mitigation requirements within the Habitat Management Operational Statement or Letter of Advice, provincial land tenure requirements (some sites require Transport Canada approval).

Environmental impact:
- The provincial government requires monitoring of the benthic condition within the tenure under the provincial Finfish Aquaculture Waste Control Regulation. Under the provincial regulation, restocking cannot occur until near-field oxic conditions are demonstrated. This requirement limits the possibility for long-term habitat loss and cumulative effects. Fallowing is required prior to restocking in the event near-field anoxic conditions reported under the provinicial Finfish Aquaculture Waste Control Regulation. Site-specific differences have been observed with respect to benthic recovery and further research in this area is ongoing. For sites authorized by DFO, additional monitoring may be required on a site-specific basis.

- *Are there monitoring and inventory activities in place?*

Finfish
- Monitoring occurs for environmental effects (near-field monitoring is conducted by industry and far-field is conducted by DFO Science); auditing on-site management includes culture methods, species, *etc.* and is conducted by both the provincial and federal governments; on-site water quality monotoring, including dissolved oxygen levels, is conducted by industry; on-site feed monitoring is conducted by industry; on-site fish health is monitored by industry; escapes are reported to provincial and federal authorities – there is an Atlantic salmon watch program that monitors for Atlantics in natal systems; wild fish health is monitored by DFO/CFIA; sea lice abundance is monitored by industry and DFO Science; wild fish populations are monitored by DFO; CSSP (Canadian Shellfish Sanitation Program) monitoring is conduced by Environment Canada; research into contaminants and potential human health effects is conducted by Health Canada.
- Industry monitors for mortalities in their inventory.

Shellfish
- Government (federal and provincial) provides auditing regarding effectiveness of management approach.
- Culture of new species may require provision of baseline genetic information (*e.g.*, with geoducks).

- *Are there mitigation plans or activities underway?*

Finfish
- Extensive mitigation of harmful effects is required for the industry including meeting provincial environmental performance standards, contingency planning, provincial health plans, siting, best management practices, *etc.* The finfish industry is also required to provide habitat compensation when triggered.

Shellfish
- Conditions of licence, mitigation measures and siting are all used to minimize risk to wild fish and fish habitat.

- *Are there significant ecological and biological interactions that can be identified and are they given special consideration?*

Please see the State-of-Knowledge report, referenced above, for details.

Significance is evaluated on a site-specific basis and afforded appropriate management response based on the level of residual risk determined. The *Canadian Environmental Assessment Act* screening that is conducted for finfish aquaculture sites provides for a structured evaluation of the risks.

DFO management of ecological effects:

- Where an effect cannot be avoided through mitigation or design, those residual effects must be examined more closely to determine if they are negative (some effects can be positive or neutral);
- When a negative (or potentially negative due to uncertainty) residual effect remains, a risk management process is used to apply the appropriate management option.

7. Management of Enhancement Activities (species and habitat)

Management objectives: In 1977, backed by strong public support, DFO launched the Salmonid Enhancement Program (SEP) with the goal of stopping and reversing declines in salmon populations. It partnered with the BC MOE, which had responsibility for steelhead and cutthroat trout. As well, this government program set a new precedent as many British Columbia citizens became vital, hands-on partners in the effort. While DFO built major facilities (hatcheries and spawning channels), individuals and groups went to work cleaning up damaged streams and building small incubation boxes.

In a further effort to keep SEP in tune with local needs, the Community Economic Development Program (CEDP) was initiated in 1977/78, placing contracts with community-based groups to operate local enhancement projects.

Today, the scope of SEP is varied. Major hatcheries and spawning channels, on some of North America's greatest salmonid-producing rivers, incubate and release millions of juveniles each year. Slightly smaller, but effective, are the CEDP projects. Scientific research has contributed another technique: on Vancouver Island fertilization of lakes has greatly increased the production of sockeye salmon.

In some areas, SEP has turned to smaller technologies. Semi-natural spawning and rearing channels that require little or no ongoing staff or maintenance are producing fish in remote regions. Fish ladders and fishways provide access for spawners to areas once barren of salmonids. Volunteer projects have grown and matured. Besides leaving a legacy of improved habitat in many urban areas, these projects often produce salmonids from small, genetically-unique populations that might otherwise have vanished forever. In addition, every spring many neighbourhood creeks receive a few healthy fry that have been raised in a classroom by schoolchildren.

Not every project has been successful; many individual runs are still threatened by too many fishermen and too little habitat. However, in most rivers and streams, salmonids return every fall, as they have done for thousands of years.

The report "Pacific Salmon Hatcheries in British Columbia" summarizes salmon hatchery approaches (http://www.sehab.org/accomplishments/72-reports-recieved/162-pacific-salmon-hatcheries-in-british-columbia).

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2.3 Japan

2.3.1 Ocean Management Activities Relative to Ecosystem-based Management

In Japan, fisheries management is conducted on a species-by-species basis. A national definition of EBM has not been established, but the Japanese *Law of the Preservation and Management of Marine Biological Resources* requires that the government should take inter-specific relationships as well as other biological or socio-economic factors into account when it decides the total allowable catches (TACs) of important fishery resources or total allowable effort (TAE) for certain fisheries. Thus, it is clear that we should take an ecosystem perspective into account. For that purpose, we are monitoring physical environmental factors and marine productivity along with the effects of fishery resource management (Table 2.3.1).

1. Fishery Management

Coastal fisheries

Fisheries resource management in Japan has been basically left to fishermen themselves who are licensed by either the national government or local government. Self-management or mutual regulation has been the traditional style in Japan's fisheries. However, in recent years Western-style fisheries management, that is, with management measures decided by the government on the basis of science and assigned to fishermen using a top-down style, has been also adopted in Japan, mostly for offshore fisheries.

In coastal fisheries especially, the self-management system by fishermen licensed by the government or local governments has been effective. Below, an example of a self-resource management system in a coastal area is shown, *i.e.*, the sand eel fishery in Ise Bay in the central part of Japan.

The sand eel is a cold current fish that has the unique characteristic of estivating in summer by digging into the sand, except in the northern part of Japan. The duration of estivation in Ise Bay is continuous from June to December. The sand eel spawns in winter after estivation. Fishermen are permitted to catch juvenile sand eels from March to May. They start catching from such a young stage because the market value is high in this stage. Sand eel mature one year after hatching and adult sand eel are caught in January and February. The core measures for self-management

Table 2.3.1 Organization of fishery management bodies in Japan.

Level	Organization	Function
National	Fishery Policy Council	The advisory body to the government for national level fishery coordination, design of national fisheries policy, *etc.*
Multi-jurisdictional	Regional Fisheries Coordinating Committees (RFCC)	Coordination of resource use and management of highly migratory species. It also addresses Resource Restoration Plans.
Prefectural	Area Coordinating Committees (ACC)	Mainly composed of democratically elected fishermen. Coordination is through the Fishery Ground Plan, Prefectural Fishery Coordinating Regulations, and Committee Directions.
Local	Local Fisheries Cooperative Associations (local FCA)	Composed of local fishermen. They establish operational regulations (FCA regulations) that stipulate gear restrictions, seasonal/area closures, *etc.* according to the local environment.
More specialized purpose	Fishery Management Organizations (FMO)	Autonomous body of fishermen. FMO rules are more detailed and stricter than the FCA regulations. It is composed of fishermen with the same gear or same target fisheries.

of resources are:

1. Protect spawning fish through preservation of habitat during estivation,
2. Protect larvae and juveniles by establishing a closed season, and

Ensure the proper escapement of sand eels before estivation by closing the fishery.

Other appropriate self-management measures for target resources are carried out in many places around Japan, taking into account the life history of the species and the habitats on which they depend.

Offshore fisheries

Off-shore fisheries, such as purse seining, are also restricted in fishing effort by a Japanese license system that prohibits open access, except for small-scale line fishing. Besides these traditional regulations that still exist, fisheries management under a TAC approach has been conducted since 1997 for some fisheries resources in Japanese offshore waters.

Fishes managed by TACs in Japan are jack mackerel (*Trachurus japonicus*), Japanese common squid (*Todarodes pacificus*), saury (*Cololabis saira*), sardine (*Sardinops melanostictus*), chub mackerel (*Scomber japonicus*), spotted mackerel (*Scomber australasicus*), snow crab (*Chionoecetes opilio*), and walleye pollock (*Theragra chalcogramma*).

These species inhabit the pelagic warm current ecosystem around Japan. They spawn in the southern or middle part off Japan and migrate as far as the extent of the mixed water region, that is, to the area where the warm current (Kuroshio) and the cold current (Oyashio) mix. Biological reference points (BRPs) specific to each species are decided, based mainly on spawner–recruitment relationships in recent years and the allowable biological catch (ABC), which gives a scientific basis of the TAC which is calculated using the BRPs for each species. BRPs are set according to the level of each stock of fish. For fish stocks in a low level of abundance and which require recovery, the target stock level to recovery is determined and a BRP is set to achieve the level within a decided timeframe. For fish stocks in good condition, BRPs are usually set to ensure the current stock level.

Besides the TAC system, a TAE system has been employed since 2003. TAE is a management measure which sets an upper limit to the fishing effort allowed. Target species under this management system are both coastal and offshore species, *i.e.*, flathead flounder (*Hippogrossoides dubius*), sand eel (*Ammodytes personatus*), sharkskin flounder (*Clidoderma asperrimum*), Spanish mackerel (*Scomberomorus maculatus*), tiger puffer (*Takifugu rubripes*), small-mouthed sole (*Limanda herzensteini*), marbled sole (*L. yokohamae*), slippery (willowy) flounder (*Tanakius kitaharai*) and spear squid (*Loligo bleekeri*).

Resource Recovery Plans developed by the government have also been introduced for many coastal and offshore resources since 2002. As of 2006, 28 plans are being implemented in nearly all fishing regions of Japan. Those plans include measures such as:

1. reduction in fishing effort,
2. active cultivation of resources through release of larval and juvenile fish,
3. conservation of the fishing ground environment,
4. ecological properties of the species (*e.g.*, where it is on the r-K spectrum, *i.e.*, top predator, intermediate predator–prey, prey species).

The warm current ecosystem fish species described above, *i.e.*, jack mackerel, Japanese common squid, saury, sardine, chub mackerel and spotted mackerel feed mainly on zooplankton and are categorized in the same ecological niche, *i.e.*, as secondary consumers in the marine pelagic ecosystem. These fishes have experienced wide fluctuations in their stock size on decadal scales and are indicative of the phenomenon that a dominant species is periodically replaced by other species over time. Sequential replacement of dominant species has not been explained by bottom-up control, so the existence of inter-specific relationships among those species is suspected. By this we mean that there is a pathway of sequential replacement of dominant species, *e.g.*, ‘usual’ level of interannual recruitment variability leads to highly variable recruitment interannually which, in turn, leads to episodic recruitment and dominant species shift (Fig. 2.3.1).

The biomass of these fish stocks fluctuates widely in size on decadal scales. In the 1930s, sardine was dominant among these fishes. After sardine declined, Japanese common squid, saury and jack mackerel increased in abundance. After that, chub mackerel increased in abundance in the1960s. In the 1970s and 1980s, sardine increased remarkably again and decreased rapidly in the 1990s. Presently, saury, jack mackerel and Japanese common squid are again showing relatively high stock size levels.

It is thought that sardine stock size fluctuations, which were the most remarkable among those fishes, was mainly due to bottom-up controls in the ecosystem, accompanied by environmental changes such as a regime shift.

- *Planned management responses (control rules, recovery rules and targets)*

The target stock size and B(limit) are set in advance for sardine, chub mackerel, jack mackerel and walleye pollock. When the stock size of a certain stock falls short of its B(limit), F(fishing mortality coefficient) will be reduced linearly.

Target reference points for the following fishes in 2004 are (Table 2.3.2):

Table 2.3.2 Target reference points for Japanese fish stocks in 2004.

Jack mackerel	(Pacific stock): F(sus)* (Tsushima Current stock): F(current)
Japanese common squid	(fall spawning stock): F(msy) (winter spawning stock): F(sus)*
Saury	F(msy)
Sardine	(Pacific stock): F which recovers stock size up to 13,000 t in 2009 (Tsushima Current stock): B(ban)**
Chub mackerel	(Pacific stock): F which recovers spawning stock size up to 100,000 t in 2006 (Tsushima Current stock): 0.8F(current)
Spotted mackerel	(Tsushima Current stock): F(current)

*F(sus) means F which sustains current stock sizes. F(current) means F which sustains current F (Fishing Mortality Coefficient), not current stock size.
**B(ban) is the stock size at which fishing should be stopped.

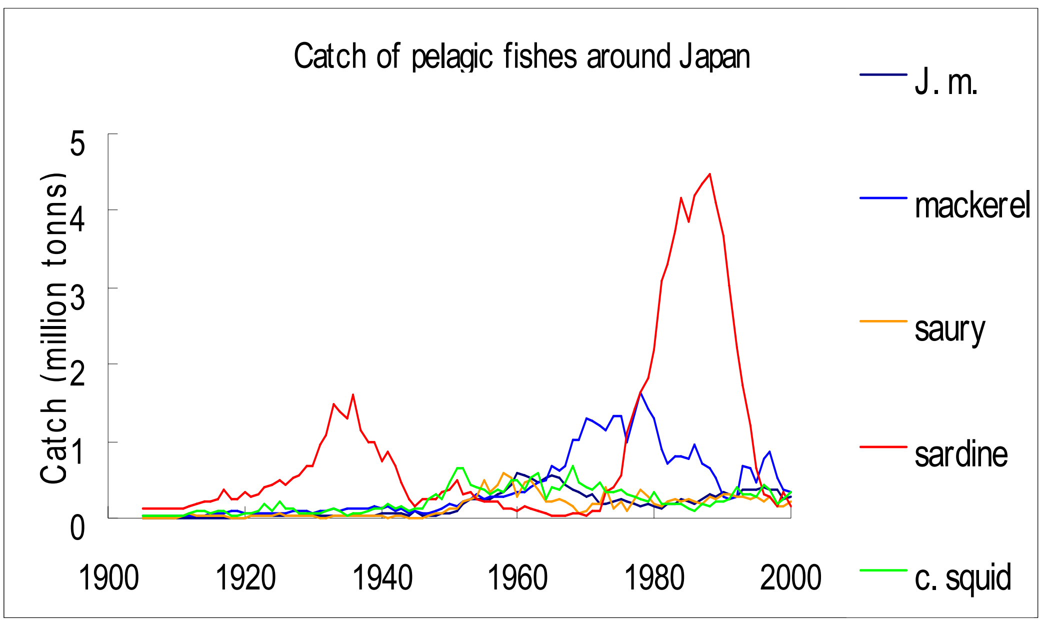

Fig. 2.3.1 Sequential replacement of dominant fish stocks on decadal scales. J.m. = jack mackerel and c. squid = Japanese common squid.

Measures are taken for bycatch species which can be described using a general approach for a representative selection of species/groups. For groups which have a propensity to be caught in bycatch, *i.e.*, sea turtles and sea birds, we are investigating their biology and stock abundance and have developed devices to avoid bycatch and have adopted them in fisheries.

2. Management of Threatened or Protected Species and Communities

Our fishery control rule decides that the allowable biological catch (ABC) should be zero when the stock size falls short of its B(ban). At present, the stock size of the Tsushima Current stock of sardine was nearly equal to B(ban) which was decided on a biological analysis. So an ABC for this stock could not be described or set.

- *Ecological properties of the species or groups*

Sardine showed a remarkable fluctuation in catch on decadal scales. This may be due to a fluctuation in the mortality rate in early life stages, although the details of this process are not clear.

- *Level of natural variability*

The stock size could not be estimated precisely in recent years because the stock is too small. Judging from several indices, the stock size in recent years may be smaller by two orders of magnitude than that of 1980s.

- *Planned management responses (control rules, recovery rules and targets)*

The recovery plan for this stock is to prohibit catch and increase spawning stock biomass.

3. Habitat Management

A few examples are:

- preservation of habitat used during estivation by sand eels in Ise Bay (explained above),
- preparation of seaweed beds for spawning of sailfin sandfish in Akita Prefecture,
- placing blocks on the the seabed to protect young snow crab from trawl fishing in Kyoto Prefecture.

4. Community/Trophic Structure Management

Data here describe the approach to management of food webs, in general, and of direct feeding interactions (predator–prey relationships involving the target species), specifically.

This type of management has not been introduced into practice yet in Japan. However, we understand that we should be clarifying ecosystem structure and quantifying energy flows among ecosystem elements and culls from every trophic level to properly preserve the diversity of marine ecosystems. For direct feeding interactions (*e.g.*, predator–prey relationships) that directly involve the target or other highly valued species, we must particularly define these interactions.

5. Management of the Physical Environment (including Freshwater Discharge from Land)

In offshore ecoregions, influences from land for ecosystem conditions may be negligible, but we think fluctuations in the natural marine environment (the strength of the Aleutian Low, El Niño, *etc.*) are important factors influencing the status of offshore ecosystems. Therefore, we are monitoring general environmental factors over a long timeframe.

In contrast, we must consider many influences by human activities in coastal ecoregions. Local governments, as well as the central government, bear the responsibility for their environments and are responsible for managing the influence of human activities to sustain the environment within a desirable status range.

Generally speaking, environmental factors, such as the quality of water, have improved as compared with the conditions in the 1970s or 1980s, but enviornmental changes, *e.g.*, eutrophication, occurrence of red tides or oxygen deficient waters, all occur around Japan.

6. Management of Contaminants and Pollutants

The permissible amount of contaminants and pollutants is established by law and levels are monitored by environmental authorities.

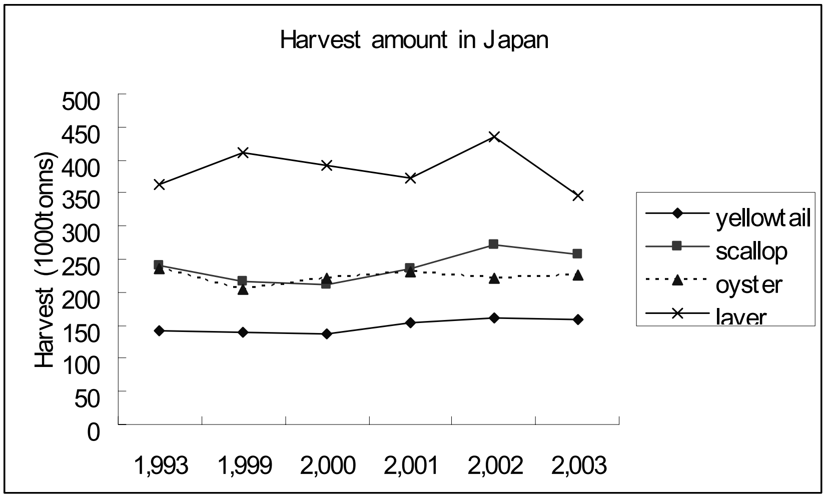

Fig. 2.3.2 Levels of aquaculture harvest in Japan.

7. Management of Aquaculture

The major aquaculture species in Japan are scallops, oysters, yellowtail and laver (marine plants). Scallops are bivalves which occur in coastal areas of the Oyashio current region (cold water). Wild larvae are collected in the sea. Oysters are found all around Japan. Yellowtail is a piscivorous fish which hatches mainly in the East China Sea but is distributed all around Japan. Wild juveniles found under drifting seaweeds are the source of fish for their culture. Laver is a red algae which occurs in semi-closed coastal shallow seas.

- Level of harvest variability

Harvest levels of these species are relatively stable (Fig. 2.3.2).

8. Management of Enhancement Activities

- General properties of enhancement activities (*e.g.*, stocking or releasing of fry/juveniles, constructing artificial reefs, making seaweed beds, *etc.*)

The released fry/juveniles of chum salmon and scallops are numerically the most heavily stocked species in Japan. Other major species whose juveniles are released for stock enhancement are Japanese flounder (*Paralichthys olivaceus*), red sea bream (*Pagrosomus major*) and prawn (*Marsupenaeus japonicus*).

2.4 People's Republic of China

In China, coastal waters have mostly been fully or over-exploited by activities, including fishing and mariculture. High fishing intensity, increasing pollution and climate change have caused stock depletion of some commercially high-valued, large-sized species, and this, combined with environmental degradation, has brought attention to the loss of marine habitats and frequent outbreaks of toxic red tides. Mariculture also has adverse effects, including contamination of the coastal environment by fish wastes, pesticides, and antibiotics; spread of diseases; and escapement of non-native species. The Chinese government has recognized these problems and has promulgated several laws and regulations to prevent pollution, both directly in the sea and from land-based sources, and has zoned marine areas to include rational arrangements for the siting of mariculture areas and designation of marine protected areas.

For ecosystem-based management (EBM), a better understanding of ecosystems is essential. Food web dynamics and species interactions have been studied in China through the GLOBEC (Global Ocean Ecosystem Dynamics) programs in the Bohai Sea, Yellow Sea and East China Sea. Although scientific knowledge is still insufficient and the coastal zones, especially, were not well included, work has progressed. The effects on the ecosystem from releasing species need to be evaluated. In order for EBM to be understood by all people and to be more operational, socio-economic factors must be considered in the establishment of an integrated management system. All management agencies, not just those relevant to fisheries, should participate.

2.4.1 Agencies Involved in Ocean Management

In China, several government agencies are involved in regional governance of the Yellow Sea region and other marginal seas. The national government is the most important stakeholder in regional environmental governance in the ocean, and local governments' involvement is low. The State Oceanic Administration has been heavily involved in all ocean affairs, except for management of fishery resources and fisheries activities which are managed by the Ministry of Agriculture. The State Environmental Protection Administration is mostly involved in the control of land-based sources of coastal pollution and the Ministry of Communications is in charge of shipping and harbors. Therefore, several ministries have authorities for ocean issues.

The promulgation and enforcement of the Law of Fisheries of the People's Republic of China in 1986 is a milestone in the development of China's fisheries history. Since that time, Chinese fisheries have been in a period of rapid development. The Law of Fisheries prescribes the legal basis for a fishery development policy suited to China's conditions. This legislation has been important to the adjustment of fisheries activities, and to conservation and rational utilization of fishery resources, as fishery enforcement capability has been strengthened. The Law of Fisheries was amended in 2000, and a quota management approach was determined to be the way forward. In addition, the Law of Marine Environment Protection and Law of Sea Use Management were put into effect in 2000 and 2002, respectively.

However, due to the effects of global changes and increasing human activities, inshore fishery resources in Chinese coastal waters have mostly been fully or over-exploited. These fisheries highly depend on a market for small-sized, low-valued species. With the development of industrial fisheries and aquaculture near coastal populated areas, pollution and habitat degradation in the coastal waters is recognized as serious. In addition, the frequent occurrence of harmful algae blooms and introduction of non-native species through aquaculture and ballast water discharges are adversely affecting Chinese coastal waters and threaten the health of the ecosystem and its biodiversity.

For sustainable utilization of marine living resources and maintenance of biodiversity, EBM is necessary and it is a management target for Chinese ocean and fisheries policies in order to benefit the social economy. EBM of marine fisheries in China is, at the least, related to tasks under the jurisdiction of the Ministry of Agriculture (fisheries), State Oceanic Administration (oceanic affairs excluding fisheries), and State Environmental Protection Administration (pollution control). There is no single governmental agency designated to coordinate integrated EBM policies.

2.4.2 Fisheries Management Measures for Ecosystem-based Management

EBM is related to the management and the direct and indirect human activities which affect the ocean, particularly with respect to fisheries resources. The following are management measures for EBM.

1. *Output Control* – Based on the existence of high fishing pressures and many fishermen, a single species total allowable catch (TAC) is not practical to enforce at present.

2. *Fishing Measures* – China has established banned fishing areas for motorized trawlers in coastal waters, closed seasons and areas for major spawning grounds, licensing, minimum mesh sizes, and minimum landing size and limits on the percentage of bycatch for young fish. These regulations have been in effect since the 1950s.

3. *Catch Limits* – China has established a cap (limit) on total marine catches since 1999 (zero growth policy).

4. *Input Control* – In order to reduce fishing effort (and by inference, fishing mortality), the Chinese government has arranged payment of 270 million CNY each year since 2002 to subsidize the scrapping of old fishing boats and to encourage fishermen to change to alternative employment. The number of marine fishing boats is planned to be reduced from 222,000 boats in 2002 to less than 192,000 boats in 2010, with an average reduction of 3,750 boats each year. Meanwhile, the building of new fishing boats is strictly controlled.
5. *Summer Fishing Ban* – Since 1995, China has completely closed fishing in the Yellow, Bohai and East China seas for 2–3 months in the summer. In 1999, this ban was extended for 2.5 months in the region north of 35ºN, 3 months for south of 35ºN, and 2 months on the continental shelf of the South China Sea. These measures are effectively protecing spawners and juveniles, and catches and size of fish caught have observably improved.

6. *Mariculture* – Mariculture is being managed to achieve better distribution of siting relative to production and pollution control

7. *MPAs* – Ten marine protected areas were established in 2007. They are, so far, limited in distribution to coastal waters.

8. *Stock Rebuilding* – To enhance ecosystem health, stock enhancement has been in effect for more than 20 years. The main species are high-valued species, particularly penaeid shrimp (*Penaeus chinensis*) in the Bohai Sea, Yellow Sea and East China Sea since the mid-1980s. Other artificially hatched juvenile species, such as scallop, abalone and jellyfish are also released into coastal waters. Since the late 1980s, some artificially hatched juvenile fishes have been released, such as red sea bream (*Pagrosomus major*), marbled sole (*Pseudopleuronectes yokohamae*) and redlip mullet (*Liza haematocheila*). In recent years, juvenile large yellow croaker (*Pseudosciaena crocea*) have been released in the East China Sea to rebuild the depleted stock. Artificial reefs are being built in some coastal areas.

9. *Monitoring* – Parameters that are being monitored in China with respect to fisheries ecosystems are: 1) relative biomass, species composition, variation in mean length, trophic level of the catch, size-at-maturity, biophysical characteristics, long-term effects on the ecosystem of different fisheries management measures, 2) ecological effect of enhancement, 3) effectiveness of the complete summer ban on the conservation of juveniles, and 4) ecosystem benefits, and total economic benefit to society.

2.5 Republic of Korea

2.5.1 Ocean Management Activities Relative to Ecosystem-based Management

Elements of ecosystem-based management (EBM) may be 1) sustaining yields, 2) maintaining biodiversity, 3) protection from the effects of pollution and habitat degradation, and 4) maintaining or increasing socio-economic benefits. Based on these elements, initiatives in the spirit of EBM have been established in 14 *Acts* and 15 Presidential and Ministerial Orders. One of the major EBM initiatives in Korea is the *Basic Act of Ocean and Fisheries Development*, which describes the maintenance of biodiversity in marine ecosystems, and the protection and restoration of habitats for marine living resources.

Most of the Korean *Acts* in the context of EBM are focused more on the elements of the maintenance of biodiversity and protection from the effects of pollution and habitat degradation, rather than on sustainability of yields and provision of socio-economic benefits. The *Basic Act of the Land* also describes the conservation of the natural ecosystem, including mountains, rivers, lakes, estuaries, and oceans, and the mitigation and restoration of the ecosystem, based upon comprehensive EBM.

1. Fishery Management

Korean fisheries have been managed by a variety of tools, such as input and output controls and technical measurements. Current initiatives of EBM in Korea include the establishment of precautionary total allowable catch (TAC)-based fishery management, closed fishing seasons/areas, fish size- and sex-controls, and fishing gear restrictions.

The general approach to retained species management in fisheries is the annual TAC-setting process under a precautionary TAC-based fishery management system. Recognition of uncertainty and its potential consequences have led to the adoption of a precautionary approach (PA) in many international agreements on fish stocks. The PA is focused on reducing the likelihood of fisheries having adverse impacts on marine resources and the host ecosystem.

Since 2000, Korean fisheries law has made provisions for the implementation of a TAC-based fishery management system in order to conserve and rationally manage fisheries resources in the Korean Exclusive Economic Zone (EEZ). A comprehensive monitoring and enforcement program has been developed for this management system. Ten species are currently managed under the Korean TAC-based fisheries management system: three species of pelagic fish (chub mackerel, jack mackerel, Pacific sardine); four species of shellfish (pen shell, hen cockle, spiny top shell, common squid); and three species of crabs (snow crab, red snow crab, blue crab). The annual stock assessment report is prepared by the stock assessment scientists of the National Fisheries Research and Development Institute (NFRDI) which sets the allowable biological catch (ABC) based on stock assessment models listed in the order of the quality and quantity of information required. Five tiers of information are used to estimate ABC (Zhang and Marasco, 2003). In tiers 1 to 3, reference points of management are suggested, that is, fishing mortalities (F) of $F_{35\%}$, $F_{40\%}$, and $F_{0.1.}$ In tiers 4 and 5, ABC is estimated from the fishery-dependent information, that is, time-series catch and effort data. The ABC recommendation from NFRDI is passed directly to the TAC Committee of the Ministry of Maritime Affairs and Fisheries (MOMAF) for the selection of TACs for target species and target fisheries by gears within the Korean EEZ, which are determined to be less than or equal to the ABCs estimated by stock assessment scientists.

Based on the *Fishery Act*, fishing seasons and fish size/weight limits are enacted for 41 species including Pacific cod, walleye pollock, and salmon. In Korea, fishing seasons for 24 species during their main spawning seasons are closed. Fish size or weight regulation is applied for 27 species, based on the 50% spawning length or weight of each species. Both fishing seasons and fish size or weight regulations are applied for 10 species, including Pacific cod. In July 2005, MOMAF added 31 species (19 fish, three crustacean, two shellfish, five seaweeds, and two cephalopods) to the list of fishing seasons and/or fish size or weight regulations. Catch of females of two crab species (snow crab and red snow crab) are not permitted.

Restrictions on some fishing gears are enacted, for instance, gillnets of more than two layers of netting are prohibited in Korean waters. The sizes of nets and meshes are restricted in 19 fisheries. Gear restrictions are set for 18 fisheries to conserve spawning and juvenile stocks and their habitats. The size of offshore and coastal fishing vessels is limited in terms of gross tonnage. The number of licenses for five kinds of aquaculture farming and set net fisheries is limited by fishing gear and area, and the duration of a license is limited to 10 years. Permission to fish is required for 13 kinds of offshore fishing gears, 16 kinds of coastal fishing gears, 10 kinds of deep-sea fishing gears, and two kinds of set net; and for seed production fisheries. Fishing using trawl, purse seine, gillnet, stow net, and dredge net for 12 species is not allowed in coastal areas year-round but permitted offshore, based on the distance of conventional fishing areas from land.

Zhang *et al.* (2009) recently developed a pragmatic ecosystem-based fisheries risk assessment method for Korean fisheries. This approach was developed to measure the risks associated with Korean fisheries relative to three different management objectives (sustainability, diversity, and habitat quality). For each objective, Zhang *et al.* (2009) assessed the risk of achieving an ecosystem goal by developing reference points for each indicator. Based on this information, the study developed pragmatic risk indices that were used to assess the status of a management unit. This assessment framework is expected to be used for implementing an EBM for Korean fisheries in the near future.

2. Management of Threatened Protected Species and Communities

When an animal species is categorized as an endangered species, the Minister of Food, Agriculture, Forest and Fisheries (MIFAFF) should take action to conserve the animal. The designation of endangered fisheries animals requires consideration of all of the following: 1) fisheries animals which are regulated by CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), 2) endangered wild fauna and flora, specified by the *Natural Environment Conservation Act*, Article No. 2 Clauses 6 and 7, and 3) fish species which are valuable for protection scientifically, and which are requested for protection for research by research institutes that are endorsed by the Minister of MIFAFF. The Minister has to announce the designated fish species as a protected target species according to the above provisions (1) and (2), and should conduct proper steps to protect it.

3. Habitat Management

The habitats that are used by some or all of the life history stages of many species of fish are sometimes known, but the habitat utilization does not mean that the habitat is obligatory (*i.e.*, that the species must have the habitat to successfully carry out its whole life cycle). The mechanistic relationship between a fish species at a particular life history stage and the type of habitat it occupies should be known for most species and life history stages. It is most critical to understand the essential fish habitat inshore, where anthropogenic effects on habitat are likely to be most significant.

To ensure the opportunity for the propagation and conservation of fisheries resources, spawning and nursing areas are protected from fishing in Korea. Currently, a total of 10 areas in bays and estuaries (1,289 km^2 of land, 2,542 km^2 of shore) and 21 areas around lakes are regulated by *Acts*. To conserve biodiversity in wetlands, five areas (141 km^2) along the west coast and seven areas (44.48 km^2) around mountains, lakes and estuaries are designated and managed by *Acts*, and nine more areas along the coastline from the west coast to the south coast are scheduled to be designated in the near future.

The Korean government is currently developing a comprehensive ecosystem-based marine ranching program. This program is designed to carry out the enhancement and efficient management of fisheries resources, and thus requires an understanding of ecological interactions among major species with respect to predation, competition for prey species, effects of climate on fish ecology, interactions between fishes and their habitats, and the effects of fishing on fish stocks and their ecosystems. Based on the knowledge and such an understanding, fisheries management could avoid significant risks and potentially irreversible changes in marine ecosystems caused by fishing or marine ranching. The Tongyoung Marine Ranching Program has been conducted since 1998 as a pilot program for a comprehensive EBM in Korea. Currently the marine ranching programs are carried out in four other areas: in Gangwon, Taean, Jeonnnam, and Jeju.

4. Community/Trophic Structure Management

Recently, research projects for developing a management plan considering trophodynamic relationships in marine ecosystems were initiated in Korea. These are some marine ranching ecosystem management projects, such as Tongyoung, the Jeonnam Archipelago area, and three other marine ranching areas, which aim to understand the structure and function of an ecosystem using the Ecopath/Ecosim model. This kind of research is still at the beginning stages, and these projects will be gradually extended in Korea.

5. Management of Physical Environment (including Freshwater Discharge from Land)

Ecosystem monitoring in the East China Sea takes place where the construction of the Changjiang River dam has been conducted to understand how changes in freshwater discharge off the land can influence coastal and offshore fish populations and their ecosystem around the Korean Peninsula. The study area of this monitoring includes geophysical, chemical, and biological oceanographic characteristics and ecological modeling.

6. Management of Contaminants and Pollutants

Contaminants and pollutants have been managed by the *Basic Act of Environment Policy* (BAEP) since 1980. The management regions are categorized into river, pond and lake, and ocean. The management targets are based on eight standards measurements of the environment including pH, BOD, COD, DO, total nitrogen, and nine standards related to the protection of human health, including Cd, As, CN, Hg, and PCBs. The classification of river, pond and lake quality using five levels of freshwater quality, and as a system for the ocean using three levels of ocean water quality is monitored by an integrated coastal environment management system. For the preservation of a clean and safe ocean environment with systematic water-quality control, sea areas for special environmental management will be expanded from nine areas in 2000 to 30 areas in 2010. MIFAFF has tried to conserve coastal ecosystems by mapping estuaries and by providing necessary laws to create wetland conservation areas. NFRDI has continuously developed techniques to prevent or mitigate the effects of red tides. Moreover, NFRDI tries to make the ocean environment cleaner and safer by formulating a national contingency plan against oil spills, and by establishing a comprehensive marine traffic management network.

7. Management of Aquaculture

The total size of aquaculture areas is about 122 kilohectares (kha) and that of seaweed culture areas is 68 kha, accounting for 55.8% of the total area of aquaculture. Current cultured species number about 50, including seaweeds, flounder, rockfish, oysters, clams, shrimps, scallops, and abalone. Management activities of aquaculture are focused on the development of aquaculture species in order to meet the demand of the global fish market and sustainable production, and to follow the global market system, such as World Trade Organization/Doha Development Agenda (WTO/DDA) and Free Trade Agreement (FTA). Development of new aquaculture species is strictly banned and renewing the expired licenses of aquaculture is very limited.

8. Management of Enhancement Activities

In Korea, construction of artificial reefs is aimed at improving productivity of devastated fishing grounds by providing fish resources with habitats, and spawning and nursery grounds. Since 1971, 2,818 fishing grounds have been augmented, with artificial reefs covering a total area of 168 kha, requiring an investment of 550 billion Won, as of 2003. A total of 55% of the area with artificial reefs is utilized as fishing grounds and the other 45% is preserved for fisheries. In terms of construction area by sea region, the area off the East Coast of Korea accounts for 25.8%, off the West Coast, 19.4% and off the South Coast, 54.8%, *i.e.*, more than half of the artificial reefs were laid off the South Coast.

In Korea, construction projects for seaweed culture enhancement started in 2002. The project spent 3.49 billion Won from 2002 to 2004. In 2005, the Fisheries Resources Enhancement Center of NFRDI conducted a preliminary experiment in three provinces (Gangwon, Kyungbuk, Jeju) for three years, investing three billion Won each year to the seaweed bed project (Jeon, 2004).

Since 1998, NFRDI has developed seed production technology to release strong juveniles of rockfish and sea bream. Seed production has successfully enhanced fishery resources and increased the incomes of fishermen. In the early stages of seed production, national facilities took the lead to develop techniques, but private companies produce the seed currently. A total of 19 species, such as abalone, flatfish, sea bream and sea slug, are targets to be produced and a total of 203 million juveniles of all species have been stocked in the sea. A total of 19 million juveniles of horseshoe crab, carp, crucian carp and another seven species were stocked in inland waters (Jeon, 2004).

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2.6 Russia

2.6.1 Ecosystem-based Principles in Contemporary Fisheries Management in the Russian Far East

This paper consists of three parts. First, is a general characterization of contemporary Russian fisheries made with special attention given to the Russian Far East. The total allowable catch (TAC) setting system is briefly described and catch values for recent years are presented. Attention is also paid to legislation and problems derived from its implementation in fisheries management.

The second part deals with the ecosystem studies of marine biological resources. Using the recent literature review by Professor V. Shuntov *et al.* (2007), contemporary results and understandings of fishery stock dynamics are presented. These create a good basis for the current ecosystem-based principles in Russia.

The third part is devoted to fishery rules in the Far Eastern Basin, based on a new 2007 document. On one hand, this document is a fundamental basis for future developments in this field. On the other hand, it is also changeable like the famous "soft watches" painted by Salvador Dali. [Author's note: "Soft watches" – an allegory presented by Salvador Dali in his famous 1931 painting "The Persistence of Memory" to indicate that things may not be as rigid as usually assumed (Garcia and Charles, 2007).] Four significant changes were made in this code of rules in 2008 and more may be forthcoming.

2.6.2 Ecosystem Approaches to Management

First, it is necessary to characterize Russian fisheries and fishery management zones. Four Fisheries Management Region (FMR) patterns (gradually becoming more complex) were established in the former USSR in 1975, 1980, 1988 and 1989. Each of these patterns corresponded to the specific period in development of understandings about fishery management tasks. The first pattern (1975) corresponded to the time before the establishment of vast exclusive economic zones (EEZs) by coastal countries. The second and third patterns were established under the influence of the potential fisheries area limitation imposed by the newly formed EEZs. The most recent FMR pattern (1989) introduced further detailed elaboration (Fig. 2.6.1).

Actual removals of fisheries resources, *i.e.*, fishery harvest or catch, are influenced by a range of factors which are not always taken into account (*e.g.*, size of fishing fleet, control and enforcement of the regulations, industry investments, and markets for the commodities produced). Management is largely through effort control, and enforcement is in place. Additional data on the ecosystem, and to some extent, information on the impact of fisheries, is sometimes provided and occasionally fleet information is given as well (Hoydal, 2007).

Traditional fishing areas of the Soviet expeditionary fishery period at the end of 1980s were found in all the world's oceans. Russia was the biggest player in the global fisheries economy with an annual harvest of more than 11 million metric tons (mt). These indices are still in wide use now as a kind of target reference level when the national fisheries outlook is discussed. Even now, the biggest expectations for Russian fisheries still relate to the expeditionary fishery in open oceanic waters.

In reality, the Russian fishing fleet has retreated to Russia's own EEZ, yet the number of vessels has increased by 13.7% since 1990. At the same time, the grand total fisheries harvest by national fisheries has decreased by a factor of 3.5 times below the peak level in 1960. The main causes for these changes, besides the reduction of fishing in foreign waters, are higher fuel prices, the breaking up of fisheries ventures, and difficult business conditions, including the institution of administrative barriers and high transportation tariffs. These factors have resulted in the fishery harvest being largely exported, *i.e.*, redistributed from the domestic market in interior regions to the nearest foreign markets where higher prices are being paid. The services and repair base of the fishery fleet, material supplies, and banking facilities have followed the 'escaped' fleet that is delivering its catch in foreign markets; fishery ventures have also obtained their supplies and services in ports outside Russia. The annual average of Russia's consumption of fishery products has decreased from 22 kg per person to 10–12 kg.

Relatively few species contribute to the bulk of the total fishery harvest in the Russian Far East: in 1989–1990, walleye pollock contributed up to 2,930,000–3,120,000 mt; Japanese sardine, or iwashi, contributed up to 734,900–762,200 mt in 1989–1990.

Other important fish in the Russian Far East are Pacific herring (*Clupea pallasii*) and Pacific salmon (*Oncorhynchus* sp.), with pink salmon (*O. gorbuscha*) accounting for the biggest landing. In 2007, the Russian fishery harvest of pink salmon reached a level of 250,000 mt for the second time in recent history. Several other species have a regional significance: Commander squid (*Berryteuthis magister*) and Pacific saury for the oceanic waters, and Pacific cod (*Gadus macrocephalus*) and flatfish in the Bering Sea.

When walleye pollock catches decrease below the range 1,016,000–1,211,000 mt, the total fishery harvest on the Russian Far East shows a significant decrease (1,970,000–2,150,000 mt in 2006–2007). The significance of this is reflected in the analysis of fisheries gear in use. About 76.3% of the total fishery harvest was caught by trawls in 2005, with trawls the primary method used to catch walleye pollock. Beach seines and stationary traps are the main gears in the Pacific salmon fishery. Saury is caught using both liftnets and Dutch seines. Pot fisheries also account for landings by gear.

The contemporary legislative basis for Russian fisheries management was developed in 2003. Prior to this time, some temporary *Acts*, instructions, and guidelines were in force. Planning for fisheries development in the Russian Federation until 2020 and Procedure of Biological Resources Usage (approved by the Russian Government Resolution No. 704 of 20.11.2004 regarding quotas for aquatic biological resources) have established a basis of long-term (five-year) quota allocations between fishery ventures. The federal law on Fisheries and Water Biological Resources Conservation was signed on December 20, 2004. Its realization required 30 more legislative documents, including 15 governmental resolutions. Among other statements, this federal law strengthened the main principle of contemporary Russian fisheries management: annual TAC setting

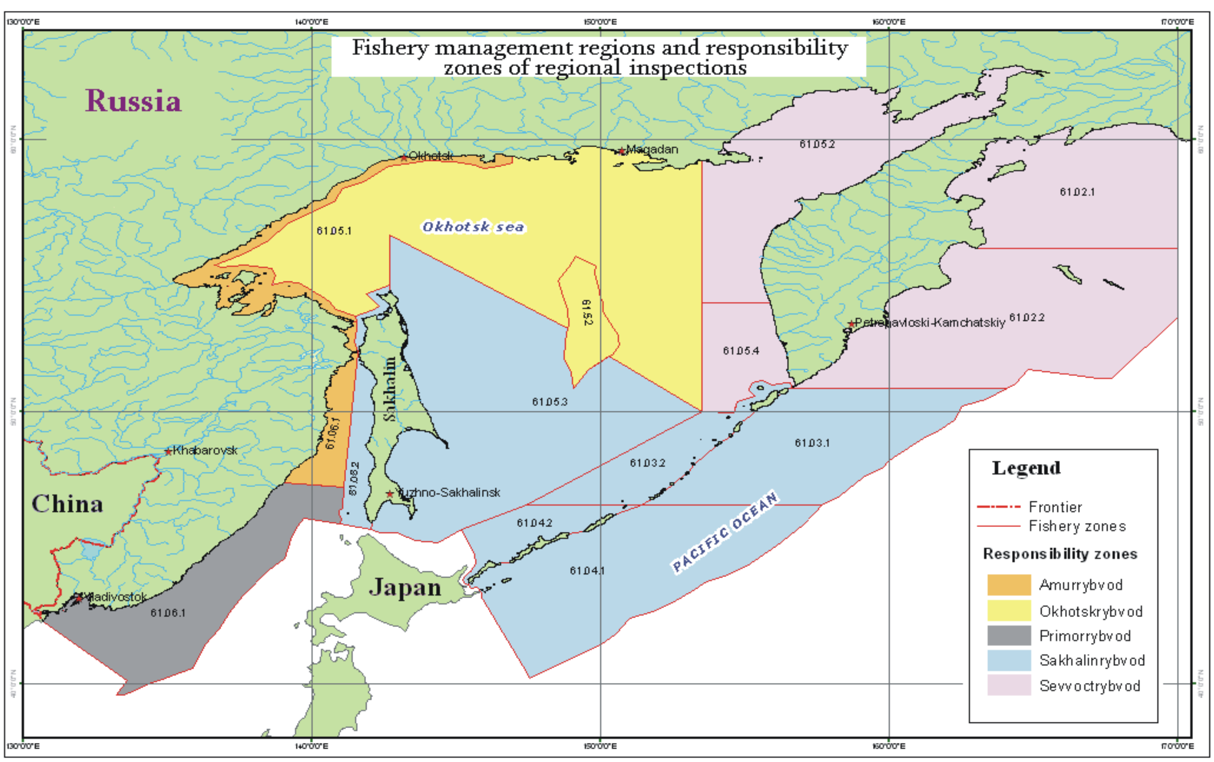

Fig. 2.6.1 Fishery management regions and responsibility zones of regional inspections.

for target fisheries. However, there was neither emphasis in this law nor in the governmental resolution after its issue (No. 583 of September 26, 2005) that the TAC principle is obligatory for all marine biological resources, as it was in the documents previously enacted by the Duma. Then, the Russian federal agency on fisheries issued an order (No. 219 of October, 2, 2008) approving a list of water biological resources, which will be further managed by the TAC principle.

In summary:

- The legislative basis for the Russian Far East fisheries is still being reformed. The basic principles predicated on current statements about reforms are long-term quota allocations for fishery ventures, negotiation of administrative barriers, and strict poaching control.
- The annual TAC setting procedure has some benefits for fisheries, as it compelled fisheries managers to undertake a comprehensive review of all commercial species and stocks, *i.e.*, it:
  - ensured a unified approach and centralized management of all biological resources;
  - made preconditions for objective rules of quota allocations; and
  - cut down the number of users of marine biological resources which had become excessive and had led to deterioration of the most valuable fishery stocks.

  This allows the formation of new approaches for tax collection from biological resource usage instead of the previous procedure, *i.e.*, when fishery rights were being auctioned off. However, the aggressive development of the TAC setting and the TAC limitation approach also led to negative consequences, such as bycatch discard problems, deterioration of fishery statistics, and new obstacles to the optimization of fishery management. These were the main reasons to abolish TAC settings for all fisheries since 2009.

2.6.3 Ecosystem Studies

Russian fishery science has identified 374 fishery stocks in 11 fishery zones (note: three zones (61.06.1, 61.06.3 and 61.06.4; see Figure 2.6.1) are divided internally but are in fact managed as a single zone, thus giving the appearance of there being 14 zones) and sub-zones in the Far East, excluding the Chukchi Sea and freshwater. An annual TAC setting is executed for each of these stocks. The largest number of stocks (52) is in the Primorie fishery sub-zone, and the smallest (22) is in the Northern Kurils zone. The total average TAC for these regions was 3,207,500 mt for the 2003–2007 five-year period. The Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO) is responsible for a significant part of this area. Pelagic fish contribute to a large proportion of the total TAC as well as to the total harvest. In contrast, pelagic squid and kelp resources in the southernmost zones are probably being underestimated. Some resources of mysids, jellyfishes and tunicates occur but they are relatively small.

2.6.4 Science for Ecosystem Approach to Management

The summary below demonstrates the long-term forecast capability of fishery stock conditions as a result of ecosystem studies of biological resources. These forecasts are based on our understanding of element relationships with respect to ecosystem trophic structure: common species of pelagic and groundfish, benthos, and plankton. The main theses under consideration are briefly listed.

Russian fishery science has completed an inventory of the aquatic biological resources in the pelagic layer of the Far Eastern seas with publication of a series of "Atlases of nekton distribution" (Shuntov and Bocharov, 2003a, 2004a, 2005a, and 2006a) in the Far Eastern seas and adjacent Pacific waters, and volumes of quantitative data as references for these atlases named "Nekton distribution" in the same years (Shuntov and Bocharov, 2003b, 2004b, 2005b, and 2006b). The database for these eight volumes includes results of 22,200 trawl hauls during research cruises. This will be an important database for future comparative monitoring and consideration in the development of fishery management advice.

According to forecasts from the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), the fisheries harvest in the Far Eastern seas could reach 3.8 million mt by 2015. This is less than the historical high of 5 million mt of 1988 but about 1 million mt higher than the level of 2.48 million mt in 2009. Realization of this forecast depends on several factors:

- general socio-economical conditions in the Far Eastern region,

- fishery management improvement and optimization,
- scientific and technical assessment activities,
- demand for utilization of currently unfished and under-fished resources (*e.g.*, mesopelagic fish, pelagic squids, marine mammals, small bivalves, kelp, jellyfish),
- abundance dynamics of common pelagic fish (*e.g.*, walleye pollock, sardine, herring, Pacific salmon).

From the ecosystem study results, Shuntov *et al.* (1997) forecasted a decrease of total nekton biomass as well as biological and fishery productivity in the early 1990s, with further stabilization at a lower level in the first years of the present century. These predictions have been realized. Long-term dynamics of pelagic nekton distribution in the biostatistical areas in the Far Eastern seas resulted in a landing decrease in the first half of 1990s and then some recovery in most recent years, with the northeastern and eastern parts of Russian EEZ recently contributing the greatest amount of catch.

Biomass declines in the Far East are mostly attributable to decreases in pelagic fish. Pelagic squid abundance subesquently increased because of a reduction in both predation pressure and competition for food. Current high indices of pelagic squid abundance suggest that pelagic fish abundance is still far below the level of the 1980s.

Recent results, however, suggest future growth in abundance of other common commercial fishery species. The present understanding divides herring in the northern Sea of Okhotsk into two stocks. These stocks are generally fished under catch limits in two adjacent fishery zones, with notably different allowed catches. In recent years, some portion of the under-fished Gizhigin-Kamchatsky herring stock was allowed to be caught in the Northern Okhotsk zone, together with the Okhotsk herring stock. However, each stock did not respond similarly to fishery effort and now it is believed that the herring population in the northern Sea of Okhotsk has a more complicated structure, represented by three stocks instead two. This will require changes in fishery management.

Recent Pacific herring catch dynamics closely repeat the previous period of intensive fishing during the 1960s–1970s, despite different fishery gears and methods in those times. It is well known that Pacific herring resources undergo significant predation pressure, and that herring are sensitive to spawning conditions. Herring stocks respond to climate change, as evidenced during the mid-1970s after the well-recognized 1977 regime shift.

Walleye pollock in the Sea of Okhotsk demonstrate an expected spawning stock stabilization and gradual growth. Some peripheral regional spawning groupings of pollock show higher rates of abundance growth than the core stock in the western Kamchatka and northern Okhotsk fisheries areas. The TAC in the Eastern Sakhalin fishery sub-zone increased seven times during a relatively short period (2006–2008, from 5000 to 35,000 mt). It has continued to increase, with TAC of 50,000 mt in 2010 and 82,000 mt projected for 2011. Fisheries there are more intensive after the spawning period, which is promising in relation to a proposed division of pollock fishing into two seasons.

Pacific salmon marine life has been well studied by dozens of expeditions from 1990 to the present. Data now allow the TINRO-Center to construct an annual pattern of Pacific salmon residence in the Russian EEZ. The Sea of Okhotsk is the main forage ground for pink and chum salmon juveniles, while the Bering Sea is for larger salmon. In recent years, pink salmon catches reached new records for the period after the middle of the last century, even in the odd years. This may be, in part, because the success of pink salmon hatchery production has smoothed total annual salmon production by providing practically the same numbers of annual juvenile as from natural spawning. In any case, these data testify to recent good conditions for pink salmon survival during their marine stage.

Results of benthic TINRO-Center surveys suggest an interaction level between the benthic and pelagic ecosystems. A comparison of recent results with the estimates of benthos abundance in the 1970s–1980s does not reveal large differences. Shuntov (2001) considered that average benthos biomass varied among the Far Eastern shelf areas between 300–500 g m^2, and that the benthos biomass contained forage benthos for groundfish. Annual benthos consumption by groundfish was estimated to range from 30– 129 g m^2 in the various regions, including a part of the nekton-benthic species, so fish consumption of benthos appear to have a relatively minor influence on benthic biomass dynamics.

Food competition among groundfish does not, therefore, appear to reach a level where it could be a limiting factor for their abundance. Formation of groundfish year class strength occurs in the early ichthyoplanktonic stages when groundfish roe and larvae exist in the same habitat with the early stages of pelagic fish and bottom invertebrates, and with zooplankton, including predatory species. Another issue is that some groundfish species consume the juvenile stages of other commercially valuable species, *e.g.*, Pacific cod eat juvenile walleye pollock, shrimp and snow crabs. On the western Kamchatka shelf, such consumption was estimated at 100,000 mt of shrimp and 11,000 mt of snow crabs annually. That is higher than the TACs for these groups. Thus it seems to be sensible to keep the Pacific cod stock at the lower edge of its optimal size to prevent excessive predation upon other commercial fishery targets. A similar situation exists with the large sculpin species, snailfish, and skates, which are practically unfished now. Sculpins and skates were targeted but their fishery now has a low intensity due to low market prices. Snailfish are untargeted. Greater fishing for these lower unit value predators, with a subsequent lowering of their abundances, may thus help increase higher unit value fishery resources.

With respect to ecosystem studies, the following is observed:

- Most stocks of biological resources in the Far Eastern seas and adjacent Pacific waters remain in satisfactory and/or good condition. The resource base of the Russian fishery consists of numerous species and types of resources, some of which are under-utilized.
- The main factors affecting biological and fishery productivity of the Far Eastern seas are natural ones, *i.e.*, biotic and physical. Data from ecosystem status monitoring show a cyclic nature of many natural processes, with different (often hidden) periodicity. Regular monitoring is necessary.
- Consideration of global and large-scale physical factors may be insufficient for analysis of processes in marine populations and communities in individual seas and smaller areas. Local (provincial) conditions can affect them to a greater degree than global ones.

2.6.5 Fisheries Regulation

With respect to the fishery regulation procedure established by new legislative *Acts*, the Fisheries Rules for the Far Eastern Basin (hereinafter referred to as Fishery Rules) was signed on March 1, 2007. This document deals with all seven kinds of fishery target removals from the marine environment, *i.e.*, the commercial fisheries in the territorial waters, on the continental shelf, and in the EEZ.

The Fishery Rules have established 54 permanent and three seasonal area closures for commercial fisheries for all species: three closures are for trawls, one is for bottom gillnets, and others are for all gears for vessels whose total length is geater than 24 m. There are exceptions for shorter fishery vessels conducting coastal fisheries, and four which exempt Pacific salmon and kelp harvesting. There are additional area closures for some species: *e.g.*, nine for walleye pollock, two for holothurians, and one or two for each of the eight crab species. Many of these limitations protect marine mammals' rockeries and the forage grounds around them, as well as some valuable bottom biotopes which are protected from the negative influence of the bottom trawl fishery.

The Fishery Rules have established 44 seasonal fishery closures that deal with 20 species and groups of fishery targets. Most of the closed areas protect spawning and early development of commercial species. Other closures are efforts to restrict large-scale fisheries to the most profitable period (time with the highest catch per unit efforts) to reduce the total effects of a fleet presence on ecosystems. When a fishery quota is realized in the shortest time period, the fleet's environmental impact, because of its discards, noise and wastes on the marine ecosystem, also occurs over a shorter time.

The Fishery Rules have established 26 prohibitions and limitations that deal with fishing gears and method of catch, such as restriction in the crab fishery of any gear except specially equipped pots. These measures protect fishery stocks from overfishing and they may reduce the juvenile and non-target bycatch. These rules also prohibit the hunting of marine mammals, excluding seals, by nets, traps, seines, and rifles, and there is a requirement for vessels being used to have a winch, ropes, *etc.* to ensure the immediate extraction of killed animals from the water. Loss of marine mammal bodies in the sea is prohibited and is regarded as polluting. A minimal distance of beach traps from spawning rivers for Pacific salmon is also established.

The Fishery Rules have also established legal fishery size limitations for 85 fishery targets, including local populations of the same species. It is interesting that this section of Rules has an individual species focus, which is not implemented in TAC setting requirements and in fishery landing reporting. In the TAC setting procedure and fishery statistics, all small flatfish species are supposed to be grouped and reported together, irrespective of the actual species composition in the catch. However, the new Fishery Rules separate starry flounder, Alaska plaice, longhead dab, Sakhalin sole, and other species.

Permitted fishery bycatch regulated by TAC settings is limited to 2% in weight (excluding marine mammals, crabs, and shrimp), and to a maximum 8% in number for undersized individuals in all specialized fisheries. While this standard has also been called for in previous legislation, a new aspect is that the permitted bycatch of non-target species, for which TACs have not been established, is limited to 49% of total harvest weight. These non-target species include *e.g.*, mesopelagic fish, lumpsuckers, and poachers and usually are discarded. New limitations in the Fishery Rules serve as a conservation measure for these species and for fish communities as a whole. It prohibits a fishery by non-selective gears in areas where non-target species are spawning, overwintering or are otherwise aggregated.

Nevertheless, the TAC system based on single-stock approaches fails to account for interactions between different stocks caught together in the same fishery. Continuation of fisheries for one species may undermine conservation targets for another and lead to increased discarding. Mixed fishery considerations need to be included in setting annual TACs (Penas, 2007).

In summary:

- Different fishery regulation methods are widely applied in the fishery management in the Russian Far East. A TAC setting for all fishery targets and every fishery is not an optimal approach. This situation can hopefully be changed through prioritization of fishery regulation measures for different fishery types (*e.g.*, the trawl fishery on common pelagic fishes, coastal groundfish, *etc.*), and a transition from single-species management to multiple species-type regulations;
- Russian fishery science possesses comprehensive knowledge on fishery resources composition, stock abundance and dynamics. Permanent multipurpose monitoring is necessary to improve a long-term forecasting;
- Russian Far East fisheries currently possess all the preconditions for successful application of basic ecosystem-based principles.

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2.7 United States of America

2.7.1 Definition of the Ecosystem Approach to Fisheries Management

The National Oceanic and Atmospheric Administration (NOAA), the primary ocean research agency of the U.S., has defined an ecosystem approach to fisheries management as one that is geographically specified, adaptive, takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives. Implementation will need to be incremental and collaborative. Sissenwine and Murawski (2004) formally introduced this definition, and elaborated further on its components. The geographic specification should be scaled hierarchically according to the processes being studied or managed. The approach should account for several high-priority issues that have not traditionally been monitored in fishery management programs, namely bycatch and fishery interactions, indirect effects of harvest, and interactions between biotic and abiotic ecosystem components. Finally, this approach is ideally an inclusive, integrative process that accounts for the needs and interests of a diverse set of stakeholders throughout society, and helps those stakeholder groups to understand and anticipate both the costs and benefits of sustainable marine resource management.

2.7.2 Overview of Fisheries Management Implementation at the Federal Level

Management of fisheries in federal waters of the U.S. is governed by several federal *Acts* that extend protection to fish, seabirds, marine mammals, endangered species, and the coastal zone. Most significant is the *Magnuson-Stevens Fishery Conservation and Management Act* (MSFCMA) passed in 1976, amended in 1996 by the *Sustainable Fisheries Act* and again in 2007 (http://www.nmfs.noaa.gov/msa2007). Implementation of the requirements of the MSFCMA by the North Pacific Fishery Management Council (NPFMC) is aided by national standard guidelines (http://www.afsc.noaa.gov/refm/stocks/nsgfinal.pdf).

The MSFCMA explicitly provides for institution of key components of ecosystem-based fisheries management. It contains standards and provisions that relate maintaining or rebuilding the productivity and economic benefits of fisheries to broader suites of ecological interactions and ecosystem processes extending beyond single-species considerations. Some examples are described in the following paragraphs.

National Standard 9, added to the MSFCMA in 1996, states that "conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch." This standard gave rise to a federal plan for managing bycatch (http://www.nmfs.noaa.gov/bycatch.htm). The MSFCMA defines bycatch as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards…[but not] fish released alive under a recreational catch and release fishery management program."

The MSFCMA calls for direct action to stop or reverse the continued loss of fish habitats. Congress mandated the identification of habitats essential to managed species and measures to conserve and enhance these habitats. The MSFCMA requires cooperation among NOAA, the councils, fishing participants, and federal and state agencies to protect, conserve, and enhance essential fish habitat (EFH) to the extent that is practicable. The amended MSFCMA requires NOAA to minimize damage to EFH from fishing practices, to the extent practicable. Federal agencies that authorize, fund, or conduct activities that "may adversely affect" EFH must work with NOAA to develop measures that minimize damage to EFH. Federal agencies proposing to dredge or fill habitats in or near EFH, for instance, must consult with NOAA to develop EFH conservation measures if the action may adversely affect EFH. While NOAA does not have veto authority over federal projects adversely affecting EFH, this mandate enables NOAA to provide guidance to federal action agencies on ways to tailor their projects to minimize harm to EFH. By requiring the consideration of impacts on EFH from both fishing and non-fishing activities, the MSFCMA ensures that NOAA takes a more holistic approach to fish habitat protection. Laws and regulations on EFH can be found at http://www.habitat.noaa.gov/protection/index.html.

The MSFCMA approach to management of food webs, in general, and of predator–prey relationships involving target species, has several facets. First, the MSFCMA defines optimum yield (OY) as the amount of fish that will provide the greatest overall benefit to the nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems. An OY is prescribed on the basis of the maximum sustainable yield (MSY) from the fishery, as reduced by any relevant economic, social, or ecological factor. Examples of ecological factors are given in the National Standard guidelines and include predator–prey or competitive interactions, and dependence of marine mammals and seabirds or endangered species on a stock of fish. Thus, fishery managers are given direction in modifying maximum biological yield targets to account for ecological factors such as predator–prey relationships.

An even broader piece of legislation than the MSFCMA is the *National Environmental Policy Act* (NEPA; http://ceq.hss.doe.gov). NEPA governs the actions of federal fisheries managers by requiring public officials to make decisions that are based on an understanding of environmental consequences, and take actions that protect, restore, and enhance the environment.

Another relevant piece of legislation is the *Marine Mammal Protection Act* (MMPA; see http://www.nmfs.noaa.gov/pr/laws/mmpa/text.htm). The MMPA establishes a federal responsibility to conserve marine mammals, with a goal of obtaining an optimum sustainable population of marine mammals within the carrying capacity of the habitat. If a fishery affects a marine mammal population, then the potential impacts of the fishery must be analyzed in an environmental assessment or environmental impact statement required by NEPA. No directed harvest may occur on any marine mammal, regardless of their population status. However, the MMPA allows for a limited incidental 'take' that must be less than the potential biological removal (PBR) rate, the maximum level of incidental mortality that still allows the species to attain its optimum sustainable population (http://www.nmfs.noaa.gov/prot_res/PR2/Fisheries_Interactions/TRT.htm). The MMPA further establishes management for cetaceans and pinnipeds (by NOAA) and sea otters (by the U.S. Fish and Wildlife Service) and requires regular stock assessments of all populations. Mammals whose population status is depleted receive protections that may include restrictions on fishing in their habitats or on fish species that they prey upon.

Legislation comparable to the MMPA has been passed for other species groups as well. The *Migratory Bird Treaty Act* (MBTA; http://laws.fws.gov/lawsdigest/migtrea.html), forbids the directed take of seabirds. The *Endangered Species Act* (ESA; http://www.nmfs.noaa.gov/pr/laws/esa/) provides protection for fish and wildlife species that are listed as threatened or endangered.

Other significant legislation deals with issues of water quality and coastal management. A major overarching piece of legislation is the *Coastal Zone Management Act* (CZMA; http://laws.fws.gov/lawsdigest/coaszon.html) which mandates that federally managed activities in coastal waters be consistent, to the maximum extent possible, with coastal zone management policies adopted by the states possessing the coastline. A wide range of local, state, and federal laws are in place that set standards for levels of point and non-point pollution (*e.g.*, http://www.ecy.wa.gov/programs/wq/nonpoint/index.html). Reflecting research which demonstrated that increased nutrient levels can lead to harmful algal blooms (HABs), Congress passed the *Harmful Algal Bloom and Hypoxia Research and Control Act* in 1998 (http://www.cop.noaa.gov/pubs/habhrca/1998_pl105-383.pdf), and amended and reauthorized it in 2004 (http://www.cop.noaa.gov/pubs/habhrca/2004_publ456.108.pdf). This *Act* created a coalition of federal agencies to assess the ecological and economic impacts of HABs, bloom-derived toxins, and bloom-related hypoxic conditions. Action plans have been developed for HAB species associated with fish kills, human shellfish consumption warnings, and marine mammal and seabird mortalities. Vessel-based dumping of materials into waters of the U.S. Exclusive Economic Zone (EEZ) is regulated under the *Marine Plastic Pollution Research and Control Act* (MARPOL) (http://www.csc.noaa.gov/opis/html/summary/mpprca.htm) and the *Marine Protection, Research, and Sanctuaries Act* (http://epw.senate.gov/mprsa72.pdf). The latter legislation, passed in 1972 and amended in 2000, includes regulatory language for dumping of dredge spoils which often contain contaminated sediments.

Below, we offer two case studies that illustrate the practice of U.S. ocean management under the laws listed above. We also outline some basic interactions between the federal government, regional fishery management councils, states, and other agencies, organizations and stakeholder groups. We offer two case studies from the U.S., in part, because the U.S. EEZ in the PICES region spans from the Eastern Pacific to the extreme north, and thus presents geographically and ecologically contrasting systems that are managed under a relatively common framework.

2.7.3 Case Study 1: Eastern Bering Sea

Ocean Management Activities

Alaska ocean management activities occur in a large area encompassing southeast Alaska, Gulf of Alaska, Aleutian Islands, Eastern Bering Sea, and the Chukchi/Beaufort seas in the Arctic. The Eastern Bering Sea is a large focus for many of the ocean management activities. The Bering Sea is a semi-enclosed high-latitude sea with a deep basin (3,500 m), and shallow (<200 m) continental shelves. The broad shelf in the east contrasts with a narrow shelf in the west. In summer on the eastern shelf, coastal, middle, and outer domains can be distinguished by their hydrography and circulation patterns. The domains are separated by fronts that constrain cross-shelf exchange and are important locations for ecosystem interactions. There are large seasonal differences in solar radiation, wind forcing, and sea ice. The Bering Sea is connected to the North Pacific through the Aleutian archipelago and there is a shallow connection with the Arctic Ocean through the Bering Strait. The region can be considered as a continuation of the North Pacific subarctic gyre.

The region has high biological productivity that is strongly seasonal. Over 266 species in eight taxonomic classes of marine phytoplankton have been identified in the Bering Sea community. Rates of primary productivity up to 225 gC m^{-2} y^{-1} have been reported from the most productive areas. Zooplankton biomass production is strongly seasonal but varies regionally, with estimates up to 64 gC m^{-2} y^{-1} from the shelf edge to 4 gC m^{-2} y^{-1} for the coastal domain. The region includes more than 450 species of fish and invertebrates, of which about 25 are commercially important.

1. Fishery Management

The groundfish fishery is managed by the North Pacific Fishery Management Council (NPFMC; http://www.fakr.noaa.gov/npfmc/) under the Bering Sea/Aleutian Islands Groundfish Fishery Management Plan (http://www.fakr.noaa.gov/npfmc/fmp/bsai/bsai.htm). Management of commercially important crabs is delegated to the State of Alaska. Alaska is also responsible for managing harvests of salmon, herring, and scallops.

Alaska groundfish fisheries

Federally-managed Alaska groundfish fisheries occur in the U.S. EEZ, primarily on the shelf and slope areas of the Gulf of Alaska (GOA) and Bering Sea and Aleutian Islands (BSAI). These fisheries are managed under two fishery management plans: the Bering Sea/Aleutian Islands Groundfish Fishery Management Plan (http://www.fakr.noaa.gov/npfmc/fmp/bsai/bsai.htm).

Acceptable biological catch (ABC) and total allowable catch (TAC) levels are prescribed for a number of species in the BSAI, although some may not necessarily be a target species of the groundfish fisheries. The environmental impact statement for the final specifications for the 2006–2007 fisheries on these species, which includes information on the biomass, ABC, overfishing levels, TAC levels, and the past year actual catch amounts can be found at http://www.fakr.noaa.gov/analyses/specs/06-07tacspecseafrfa_v4.pdf.

The following species/groups are actively managed in the BSAI region: walleye pollock, Pacific cod, yellowfin sole, Greenland turbot, arrowtooth flounder, rock sole, flathead sole, Alaska plaice, ‘other flatfish’ (mostly starry flounder, rex sole and butter sole.), sablefish, Pacific ocean perch, northern rockfish, shortraker and rougheye rockfish, other rockfish (two predominant species: light dusky rockfish and shortspine thornyheads), Atka mackerel, squid, and an ‘other species’ group (including sculpins, skates, sharks, and octopus).

Another essential aspect of the management program is the large Observer Program. Data provided by the

Observer Program is a critical element in the conservation and management of groundfish, other living marine resources, and their habitat. For example, these data are used for: 1) assessing the status of groundfish stocks; 2) setting groundfish quotas and monitoring them in season; 3) monitoring the bycatch of non-groundfish species in season; 4) assessing the effects of the groundfish fishery on other living marine resources and their habitat; and 5) assessing methods for improving the conservation and management of groundfish, other living marine resources and their habitat. The Observer Program also provides the industry with bycatch data it needs to make timely fishing decisions that decrease bycatch and increase productivity.

Retained species

The general approach to retained species management is the annual TAC-setting process and an at-sea Observer Program to monitor TAC. Stocks or stock complexes within the retained (or target) species category are part of this process. TACs are set by the NPFMC and are less than or equal to the ABCs set by stock assessment scientists which are, in turn, less than defined overfishing levels (OFLs). The following document summarizes the tier system for setting groundfish ABCs and includes life history parameters for the managed stocks in the BSAI region: http://www.fakr.noaa.gov/npfmc/summary_reports/bsstock.htm. Federal fishery scientists are, in general, responsible for deriving ABC and OFL estimates that are then reviewed by a panel of federal, state, and independent scientists who are on the Groundfish Plan Teams of the NPFMC. These ABCs and OFLs are then presented to the Council's Science and Statistical Committee for review. The SSC then makes the ABC and OFL recommendations to the NPFMC. Groundfish stock assessment documents each contain an ecosystem considerations section that outlines the ecosystem effects on the stock and the potential effects of that stock's fishery on the ecosystem. The ecosystem is also taken into account through the TAC setting process in which an Environmental Impact Statement (EIS) is prepared.

Bycatch species

There are several facets of bycatch management in Alaska groundfish fisheries, depending on the type of bycatch. One is the accounting of bycatch of target groundfish species that are discarded, and these amounts are included in total catch estimates of the target species. In 1998, an improved retention and utilization (IR/IU) amendment was approved that mandated the retention of pollock and cod in groundfish fisheries. No special consideration is being given to species biodiversity among the bycatch species although biodiversity measures that include target and nontarget species are under development.

For bycatch of non-target species, there is a special category called 'prohibited species' that is managed. In the Eastern Bering Sea (EBS), prohibited species include salmon, herring, crab, and halibut, and caps are placed on the amounts that can be caught by groundfish fisheries. In addition, there are many gear/area restrictions that have been made to provide further protection to these prohibited species, which are the target for non-groundfish fisheries and are managed by either the State of Alaska (salmon, herring, and crab) or an international commission (halibut). These agencies' management practices promote sustainable stocks and, in some cases, catch mortality in groundfish fisheries is accounted for in stock assessments of these prohibited species. A detailed history of the regulation of Alaska groundfish fisheries with regard to prohibited species can be found at http://www.fakr.noaa.gov/npfmc/sci_papers/MFR.pdf. There are many time/area closures, gear restrictions, and seasonal TAC apportionments designed to reduce bycatch of prohibited species. One benefit of individual fishing quota (IFQ) fisheries (sablefish) is the reduced catch of prohibited species. There is a detailed reporting and accounting system that includes at-sea observers who provide estimates of total catch and discard mortality for prohibited species in the groundfish fisheries to ensure that catches are not exceeded.

In some groundfish fisheries, particularly flatfish fisheries, the halibut cap is constraining and prevents the flatfish fisheries from achieving ABC. Groundfish fishery bycatch removals of these prohibited species do not significantly impact these stocks because groundfish fishery removals are much less than directed harvest amounts. Halibut and herring are in good condition, some crab stocks are considered overfished (although directed fishing may not have been the proximal reason for some crab stocks falling below their minimum stock size thresholds (MSSTs). Some western Alaska salmon stocks are depressed and the impact of bycatch removals are unknown for some stocks. In general, the detailed accounting and bycatch cap approach to management of these species is very successful at providing protection to this group, although these constrain the groundfish fishery and thus may not be optimal from an economic point of view.

Catch of a 'forage species' group is managed to prevent target fisheries from being initiated on those species, which include smelts, stichaeids, euphausiids, sandlance, sandfish, lanternfish, and gunnels. These species are generally species with fast turnover rates but are not well studied in the region. A maximum retention allowance (MRA) for each groundfish fishery is set at 2% of the total fishery catch for these species in aggregate. Commerce in these species is currently prohibited, except for the small amounts retained under the MRA rates and for artisanal or subsistence uses. Abundance estimates are not available for these species so their status is unknown. This group of fast turnover rate species is likely afforded sufficient protection by these maximum retainable bycatch limits that prevent target fisheries from starting on them.

Although species contained in the 'other species' category are included in the target species management description, above, because they are managed using ABCs derived from the target species tier system, the species in this category are not currently economically important in North Pacific groundfish fisheries, but were perceived to be ecologically important and of potential economic importance, as well. 'Other species' in the BSAI and GOA include sculpins, skates, sharks, squid and octopus (squid is catagorized as a separate group in the BSAI). Stock assessments are conducted and TACs are established for other species and separately for squid in the BSAI. Discussions are underway for improving the management of these groups through, for instance, improved detail in catch reporting.

A group of invertebrate species called HAPC (habitat areas of particular concern) biota has been defined. This group consists of living structural habitat species such as corals, sea pens/whips, sponges, and anemones. Some of these species, particularly deep water corals, are very long-lived and sensitive to fishing removals. Large areas of the Aleutian Islands have now been designated as off limits for bottom trawling.

Finally, there is a group of nonspecified species that are captured in the groundfish fisheries. These include a huge diversity of fish and invertebrate species. There is currently no management and only partial catch monitoring of species in this category, although retention of any nonspecified species is permitted. The complete lack of reporting requirements may be problematic. Research is ongoing to identify population trends in non-commercial species relative to fishing and climate. Species identification is very detailed for fish species in research surveys of the area but not very detailed for non-commercial invertebrates.

2. Management of Threatened or Protected Species and Communities

A number of threatened or endangered species or habitats for these species occur in Alaskan waters and these species are afforded protection under the ESA. The species include some marine mammals, seabirds, and fish. The full list is available at http://www.nmfs.noaa.gov/pr/pdfs/esa_factsheet.pdf. Other marine mammal species are also afforded protection under the MMPA. The general approach to fisheries management with respect to these species is the management of direct takes of species, utilization of take reduction devices, area closures to protect foraging habitat, and harvest rules that provide additional protection to key forage of some of these species.

With the exception of salmon, the majority of these species are long lived K-selected species with a variety of foraging strategies. There are difficulties in quantifying the level of natural variability in some of these stocks due to the past effects of direct harvest of mammals, and degradation of freshwater habitats of salmon, *etc.* that confound interpretation of species declines. However, there have been observations of large variability in species abundance trends over the last 30 years that has been partly linked to climate variation, particularly for salmon.

Fishery management restrictions that have been placed on Alaska groundfish fisheries because of ESA concerns are primarily for the protection of Steller sea lions and short-tailed albatross. Measures are in place to protect Steller sea lions in nearshore and critical habitat areas through fishing closures in certain areas and temporal–spatial distribution of the catch. Overall abundance of key Steller sea lion prey (walleye pollock, Atka mackerel, and Pacific cod) is regulated through a lower threshold harvest when spawning biomass reaches 20% of the projected unfished biomass ($B_{20\%}$), which is more conservative than is used in single-species harvest strategies for those stocks. The primary management concern for short-tailed albatross is direct take in fisheries and very low take limits have been set (four takes within two years) that will trigger consultation. In addition, seabird avoidance measures for fishing vessels have been mandated.

Understanding and data are limited to providing general indications of status and change – often with many different plausible interpretations. There is large uncertainty, particularly with regard to Steller sea lions, of the factors influencing the dynamics of this stock. Large amounts of research funding and efforts of independent panels of scientists are being spent to evaluate the reasons for the decline.

- Status of Steller sea lions and short-tailed albatross with respect to endangered listing reference point: these animals are still considered endangered.
- Status of the fishery interactions with these species with regard to direct take limits: interactions are below the direct take limits.
- Status of the fishery interactions with regard to the indirect effects of fishery removal of prey: enactment of biological opinion protection measures should remove any adverse modification of habitat or jeopardy of species existence due to fishing but this is uncertain due to the difficulty in quantitatively evaluating these indirect effects.

Direct take catch limits, gear modifications, and take reduction teams all provide good mechanisms for reducing direct takes of endangered and protected species. Take limits, such as PBR rates, vary relative to the status of the stock of concern and relate to the stock's productivity, and provide a sufficient trigger for management intervention The qualitative nature of determining the degree of protected species protection provided, due to area closures and prey species harvest control rules when indirect interactions are the concern, are problematic and uncertain. Considerable work needs to be done to determine more quantitative standards for reference points that ensure fisheries will not jeopardize the continued existence or adversely modify the critical habitat of listed species for these indirect interactions. However, detailed analysis of Steller sea lions and measures for their protection have been instituted through a Steller sea lion protection measures environmental impact statement (EIS) and a Biological Opinion. An open public process has been employed, including the use of a unique stakeholder constituent committee, to develop fishery management alternatives.

No consideration has been given to community biodiversity, except through protection of the individual pieces (individual community members). Development of biodiversity indices is ongoing though, typically, marine mammal and seabird communities are excluded from these because there is a lack of population abundance and trend information for many of the species.

3. Habitat Management

Habitat management for Alaska groundfish fisheries includes the consultation process mentioned above and the development of an Essential Fish Habitat Environmental Impact Statement (EFH EIS). In addition, habitat protection is provided by a variety of area closures and bottom trawling restrictions that have been put in place over the years (see summary Bering Sea habitat conservation measures at http://www.fakr.noaa.gov/npfmc/current_issues/BSHC/BSHC.htm). Habitat assessment reports were developed for EFH of all managed species in Alaska (http://www.fakr.noaa.gov/habitat/).

The BSAI and GOA groundfish management regions encompass a variety of habitat types. The EBS shelf consists primarily of sand, mixed sand and mud, and mud substrates and an outer continental shelf. The GOA has shallow, deep and slope areas that consists of soft (sand to gravel) or hard (pebble to rock) substrates. The Aleutian Islands region also consists of soft and hard substrates. Efforts are ongoing to better map the distribution of living organisms that provide structural habitat to fish, but the AI and GOA are known to have deep-water corals that are long-lived. Sponges also occur in all of these areas and are thought to be relatively long-lived, though present research is showing a range of recovery times. Other epifauna that could be impacted by fishing gear include sea pens/whips and anemones, and not much is known about the recovery rates of these organisms. Of the infauna in these regions, larger, longer-lived organisms include clams. Smaller, higher turnover-rate organisms such as polychaetes also occur throughout the regions but little effort has been expended in mapping these distributions after U.S. surveys conducted in the late 1970s and early 1980s, although bottom typing efforts are ongoing. Little is known of the natural levels of variability of these organisms although research is being conducted to compare densities and average sizes of organisms in trawled *versus* untrawled regions. A habitat impacts model has recently been developed to provide a quantitative basis for relating fishing intensity and habitat recovery in the process of evaluating fishing effects.

The main management response at this point is the requirement for federal agencies to consult with NOAA to see if that agency's actions may adversely effect EFH, and for NOAA to provide conservation recommendations if deemed necessary. For details on the consultation process, see http://www.nmfs.noaa.gov/sfa/reg_svcs/Council%20stuff/council%20orientation/2007/2007TrainingCD/TabT-EFH/EFH_factsheet.pdf.

Reference points being developed for evaluating habitat effects relate to a standard for determining "adverse effects on EFH" that are "more than minimal and not temporary". Temporary impacts are defined as those that are limited in duration and that allow the particular environment to recover without measurable impact. Minimal impacts are described as those that may result in relatively small changes in the affected environment and insignificant changes in ecological functions. In the EFH context, the terms 'environment' and 'function' refer to the features of the environment necessary for the life history requirements (spawning, breeding, feeding and growth to maturity) of the managed species and their function in providing that support. Presently, for managed Alaska groundfish, the standard for assessment is the stock's ability to remain above the minimum stock size threshold.

Assessment of the status of groundfish species relative to this threshold is presently being done in the EFH EIS and the Programmatic Alaska Groundfish EIS. It appears that groundfish stocks are above this threshold (for those in which MSST can be calculated, or else MSST is unknown). Although MSST is a quantitative standard, it cannot be defined for some stocks due to lack of data. Also, it provides only an indirect method of assessing the possible effects of habitat changes on a species' productivity. It seems there could be confounding factors, such as physical environmental regime shifts, that could make a species' production appear to be unchanged, while habitat degradation could be ongoing and not noticed until a regime shift occurred. Further research is required to quantitatively link habitat amount and condition with species production. The Sitka Pinnacles Marine Reserve was designated, in part, because of the high diversity of organisms in that region, so some consideration to diversity is being given in management. Also, the EFH EIS and Programmatic Groundfish EIS consider fishing effects on several types of diversity, including species diversity and structural habitat diversity. Fishing effects on structural living habitat and benthic communities are considered qualitatively in these EIS documents that are being prepared.

4. Community/Trophic Structure Management

- General approach to management of food webs

The MSFCMA allows the modification of a target species' biological yield estimates to be modified to an OY that takes into account the protection of marine ecosystems and that is prescribed on the basis of the MSY from the fishery, as reduced by any relevant economic, social, or ecological factor. Examples of ecological factors are given in the National Standard guidelines and include predator–prey or competitive interactions, and dependence of marine mammals and birds or endangered species on a stock of fish. Thus, fishery managers are given direction in modifying maximum biological yield targets to account for ecological factors such as predator–prey relationships. In practice, an OY range is specified in the management of Alaskan groundfish. In the EBS, the maximum OY is capped at 2 million metric tons (mt) and has proved constraining on individual target fisheries. Guidelines indicate that OY should be a target reference point and not an absolute ceiling, but rather a desired result. The EBS OY cap was not derived from a specific food web concern but rather as a general way of buffering total removals in the system.

The Stock Assessment and Fishery Evaluation (SAFE) documents of the Alaskan groundfish fisheries includes an Ecosystem Considerations appendix that summarizes the best information available on the status and trends of various ecosystem components that are predators and prey of managed groundfish species, and includes the results of multispecies and ecosystem models of the region. Individual stock assessment reports now include a qualitative evaluation of the trends of predators and prey of the managed species. Some species, such as walleye pollock, are cannibalistic and stock assessment of those species implicitly includes consideration of the cannibalism via the stock-recruitment curve.

As mentioned in the "Bycatch species" subsection, the NPFMC has also designated a 'forage fish' category that consists of relative fast turnover rate forage species such as gunnels, bathylagids, gonostomatids, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. A maximum retainable bycatch (MRB) rate for each groundfish fishery is set at 2% of the total fishery catch for these species in aggregate. Commerce in these species is currently prohibited except for the small amounts retained under the MRB rates and for artisanal or subsistence uses. Abundance estimates are not available for these species so their status is unknown.

Key forage species that are important prey of the endangered Steller sea lion and that are the target of commercial fishing in the region include walleye pollock, Pacific cod, and Atka mackerel. Steller sea lion protection measures are in place to protect Steller sea lion foraging in nearshore and critical habitat areas through fishing closures in certain areas. Overall abundance of key Steller sea lion prey (walleye pollock, Atka mackerel, and Pacific cod) is regulated through a lower threshold harvest when spawning biomass reaches 20% of the projected unfished biomass ($B_{20\%}$), which is more conservative than is used in single species harvest strategies for those stocks.

The direct feeding interactions that involve target species primarily revolve around middle trophic level species such as walleye pollock and Atka mackerel, which are targets of fisheries and are prey of other target groundfish species in the BSAI and GOA. Cannibalism by walleye pollock in the EBS is well documented and explains part of the density dependence in the spawner–recruit relationship of pollock. Single-species models of walleye pollock in the EBS and GOA have been developed which include predation by other species, including target groundfish. A multispecies virtual population analysis (MSVPA) model has also been developed for the EBS. It showed that most predation mortality on target species tends to occur in juveniles. The trophic level of the groundfish catch has also been estimated for the EBS, AI, and GOA and appears to be relatively high and stable (see p. 224 of the Ecosystem Considerations appendix of the SAFE report: http://www.afsc.noaa.gov/refm/docs/2002/ecochap.pdf).

Levels of natural variability in feeding interactions that involve target species are relatively high because of the variability in predator stock size and variability in the abundance of target species that serve as prey. MSVPA results from the EBS show that predation mortality of walleye pollock at age 1 can have relatively large interannual variability.

Aside from the Steller sea lion prey protection rules mentioned above ($B_{20\%}$ lower threshold for walleye pollock, Pacific cod, and Atka mackerel spawning biomass and closed areas in sea lion foraging areas), the forage species maximum retainable bycatch rules and stock assessment scientist considerations of qualitative trends in predator or prey abundance for their stock (which could be used to justify changes in ABC recommendations but which, so far, has not been used in that way), there are no other planned management responses.

The level of information available to parameterize models of groundfish predator–prey dynamics is relatively good – MSVPA, which has been developed for EBS and statistical catch at age models that include predators, has been developed for EBS and GOA pollock. There are still lots of uncertainties about seasonal feeding dynamics, spatial–temporal variability in predation, and the form of the functional feeding responses of groundfish.

Multispecies reference points have not been defined for this system, and for cannibalistic species such as walleye pollock and Pacific cod, such reference points may result in F_{msy} estimates that are higher than in the single-species case. Walleye pollock, Pacific cod, and Atka mackerel are above the $B_{20\%}$ value established for Steller sea lions and MRBs of forage species have not been exceeded. The 2 million mt OY cap on total groundfish catch in the EBS is frequently reached and constrains the groundfish catch. For example, the sum of the recommended ABCs for BSAI groundfish in 2003 was 3.2 million mt, which is 1.3 million mt above the OY cap.

These reference points provide protection for endangered species that rely on target groundfish, prevent target fisheries from starting on some small pelagic fish stocks, and provide an overall cap on catch that is less than the sum of the individual ABCs. However, these do not provide explicitly for the needs of other predators in a particular year (*i.e.*, through predator set-asides). The OY cap constrains catch but does not explicitly constrain catch for a particular species, thus leading to ABC reductions based on economic considerations but not due to food web considerations.

The EBS food web in general has been described in Aydin *et al.* (2002) (http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-130.pdf) based on parameterization of an Ecopath model of the system. Similar models are being developed for the

GOA and AI. Ecosystem indicators are also under development, and the present state of indicators are reflected in the Ecosystem Considerations appendix of the SAFE report (http://www.afsc.noaa.gov/refm/docs/2002/ecochap.pdf). Most of these indicators reflect status and trends of environment, fishing pressure, and species abundance trends. Aggregate indicators reflecting various ecosystem-level measurements, including types of diversity are also being developed.

There is a fair amount of natural variability in the EBS, AI, and GOA food webs based on observations of species responses to climate variability. Although primary and secondary production are not regularly evaluated in these systems, there have been unusual phytoplankton blooms occurring in recent years, along with dramatic changes in non-target species abundance including fish, bird, and marine mammals.

There are no planned management responses to deal with the food web, except the inclusion of ecosystem information in the Ecosystem Considerations appendix of the SAFE report and the ongoing efforts to develop reference points that deal with the food web, in general. General thresholds for evaluating fishing effects on ecosystem attributes have been developed as part of the requirements under NEPA to evaluate ecological effects of human activities (Table 2.7.1). Environmental impact statements which evaluate fishing effects on these ecosystems are being prepared. Significance thresholds have been defined for food web effects of fishing on pelagic forage availability, spatial and temporal concentration of fishery on forage, removal of top predators and introduction of non-native species. Ecosystem-level thresholds dealing with fishing effects on energy redirection and removals have been defined along with thresholds for species diversity, functional diversity, and genetic diversity. Application of the thresholds require knowing either the natural levels of variability of a species or system attribute and the potential for fishing to bring that attribute either below a single species limit, such as MSST, or to bring a system attribute outside the range of natural variability. Since these thresholds are difficult to define quantitatively in practice, indicators are used to evaluate whether or not particular organisms, groups, or ecosystem attributes are changing in an undesirable direction (Table 2.7.1).

The level of information presently being used in this evaluation is mainly limited to providing general indications of status and change – often with many different plausible interpretations. No target reference points at the general ecosystem level are being used, with the exception of keeping the sum of the individual species ABC limits within an OY range. This range was originally set equal to 85% of the range of the summed species-specific MSYs in the BSAI, in part to insure that future harvests would be sustainable. Status of the food web relative to an ecosystem reference point is not known and heavy reliance is still placed on individual species status.

The strengths/limits of general food web reference points are that the OY range provides some general food web protection although this should be evaluated using ecosystem models that have been developed for these regions. It might be more appropriate to use OY constraints for trophic level groups (the forage fish MRBs could be thought of as an OY constraint for a trophic-level group though some central forage species, such as walleye pollock and Atka mackerel, might need to be included in an OY constraint that considers all mid-trophic level species). Single-species thresholds appear to provide ecosystem protection – by protecting the individual pieces, you protect the whole. However, there are many uncertainties about the effects of fishing on the food web as a whole, and the work developing ecosystem indicators and ecosystem models will be useful to evaluate the potential effects.

5. Management of Contaminants and Pollution

Fishery management in Alaska is primarily concerned with the effects of the physical environment on individual species production patterns because there is a great deal of evidence that climate influences are a strong driver of species recruitment in the region. Other agencies, such as the Environmental Protection Agency (EPA) and Alaska, have primary responsibility for water quality issues, and fishery impacts on water quality through dumping of fish processing offal or vessel-related pollution is monitored and evaluated by these entities. Individual permits are given to fish processing plants which are required to follow 'total maximum daily load' (TMDL) plans for impaired waters to attain water quality standards for Alaskan waters. TMDLs are specified individually to fish processing plants and depend partly on the characteristics of the receiving water basin with respect to water depth and exchange. See http://yosemite.epa.gov/R10/Homepage.NSF/webpage/Alaska's+Environment?opendocument for more details on environmental protection in Alaska.

Table 2.7.1 Significance thresholds and indicators for determining fishery-induced effects on ecosystem characteristics in the Eastern Bering Sea (EBS).

Issue	Effect	Significance threshold	Indicators
Predator–prey relationships	Pelagic forage availability	Fishery induced changes outside the natural level of abundance or variability for a prey species relative to predator demands	Population trends in pelagic forage biomass (quantitative: walleye pollock, Atka mackerel, catch/bycatch trends of forage species, squid and herring)
	Spatial and temporal concentration of fishery impact on forage	Fishery concentration levels high enough to impair the long-term viability of ecologically important, nonresource species such as marine mammals and birds	Degree of spatial–temporal concentration of fishery on walleye pollock, Atka mackerel, herring, squid and forage species (qualitative)
	Removal of top predators	Catch levels high enough to cause the biomass of one or more top level predator species to fall below minimum biologically acceptable limits	• Trophic level of the catch • Sensitive top predator bycatch levels (quantitative: sharks, birds; qualitative: pinnipeds) • Population status of top predator species (whales, pinnipeds, seabirds) relative to minimum biologically acceptable limits
	Introduction of nonnative species	Fishery vessel ballast water and hull fouling organism exchange levels high enough to cause viable introduction of one or more nonnative species/invasive species	Total catch levels
Energy flow and balance	Energy re-direction	Long-term changes in system biomass, respiration, production or energy cycling that are outside the range of natural variability due to fishery discarding and offal production practices	• Trends in discard and offal production levels (quantitative for discards) • Scavenger population trends relative to discard and offal production levels (qualitative) • Bottom gear effort (qualitative measure of unobserved gear mortality, particularly on bottom organisms)
	Energy removal	Long-term changes in system-level biomass, respiration, production or energy cycling that are outside the range of natural variability due to fishery removals of energy	Trends in total retained catch levels (quantitative)
Diversity	Species diversity	Catch removals high enough to cause the biomass of one or more species (target, non-target) to fall below or to be kept from recovering from levels below minimum biologically acceptable limits	• Population levels of target, non-target species relative to MSST or ESA listing thresholds, linked to fishing removals (qualitative) • Bycatch amounts of sensitive (low potential population turnover rates) species that lack population estimates (quantitative: sharks, birds, HAPC biota) • Number of ESA listed marine species • Area closures
	Functional (trophic, structural habitat) diversity	Catch removals high enough to cause a change in functional diversity outside the range of natural variability observed for the system	• Guild diversity or size diversity changes linked to fishing removals (qualitative) • Bottom gear effort (measure of benthic guild disturbance) • HAPC biota bycatch
	Genetic diversity	Catch removals high enough to cause a loss or change in one or more genetic components of a stock that would cause the stock biomass to fall below minimum biologically acceptable limits	• Degree of fishing on spawning aggregations or larger fish (qualitative) • Older age group abundances of target groundfish stocks

MSST = minimum stock size threshold, ESA = *Endangered Species Act*, HAPC = habitat areas of particular concern

Environmental impact analyses of the effects of fishing on the environment also consider the effects of fishing on the physical environment through water pollution.

6. **Management of Aquaculture and Enhancement Activities**

The EPA regulates all aquaculture activities in Alaska. Alaska aquaculture activities mainly consist of hatchery operations for rearing and release of salmon smolts. Most salmon enhancement in Alaska is occurring outside of the GOA and is primarily focused on pink and chum salmon. There are 30 nonprofit hatcheries, two federal and two state hatcheries according to the latest Alaska Department Fish and Game (ADFG) salmon enhancement program report (http://www.sf.adfg.state.ak.us/FedAidPDFs/fmr07-04.pdf). Alaska's hatcheries are primarily for sport fishing enhancement while the nonprofit hatcheries are for commercial enhancement goals. ADFG geneticists, pathologists, and biologists review all projects before issuing a permit to operate a salmon ranching facility, transfer eggs or fish, or release any fish into Alaskan waters. Production levels are relatively stable at this time. EPA regulates hatchery operations by issuing permits to manage wastewater effluent (http://yosemite.epa.gov/R10/WATER.NSF/webpage/Current+NPDES+Permits+in+Alaska).

In Alaska, saltwater aquaculture or sea culture of organisms by a variety of means to maturation only includes the farming of aquatic plants and shellfish. Farming of finfish is prohibited. In 2006, there were 60 farms producing primarily oysters, with small numbers of clams and mussels being produced. Most of this is occurring outside of the EBS. Broodstock must be from state certified sources or else an application must be made to acquire broodstock from other sources. Regulation of the farming of these products is primarily to ensure food safety and quality and to ensure disease-free stock. A growing area classification must be completed before shellfish may be harvested for sale. Classification is a two-part process, the water quality survey and shoreline survey. The water quality survey consists of the collection of water samples that are taken from designated stations. The shoreline sanitary survey is a physical on-site evaluation of all actual and potential sources of pollution that may affect the growing area.

2.7.4 Case Study 2: U.S. Pacific Coast Groundfish

Ocean Management Activities

The federally-managed groundfish community off California, Oregon and Washington occurs on the shelf and slope areas in the U.S. EEZ. This area is located entirely within the California Current Large Marine Ecosystem. The fishery is managed by the Pacific Fishery Management Council (PFMC; http://www.pcouncil.org) under the Groundfish Fishery Management Plan (FMP; http://www.pcouncil.org/groundfish/), with catch levels proposed in the Groundfish EIS (http://www.pcouncil.org/groundfish/current-season-management/). In-season adjustments are often recommended by the PFMC and must then be approved by NOAA. Every two years, the PFMC and NOAA convene to update and adjust policies that are currently in place.

1. **Fishery Management**

The Pacific Coast groundfish fishery has limited entry, open access, recreational, and tribal components. Most take is allocated to the limited entry permit fishery, comprised of separately regulated trawl and fixed-gear fleets; most landings come from trawlers. The open access fishery cannot use trawl gear directed at groundfish harvest. Landings have recently been managed by cumulative trip limits and seasonal or annual quotas, although a transition to a catch-share system, known as 'rationalization,' is now underway (details available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/). The text below generally reflects management practices prior to rationalization.

The general approach to retained species management is the annual TAC-setting process and an Observer Program to monitor TAC. Stocks or stock complexes within the retained (target) species category are part of this process. TACs are set by the PFMC and are less than or equal to the ABCs set by stock assessment scientists, which are, in turn, less than defined OFLs. Alternative ABCs, OYs and TACs for the fishery are prescribed in Chapter 2 of the Groundfish EIS (http://www.pcouncil.org/groundfish/current-season-management/). The alternatives are offered because there are multiple goals of fishery management that may be at odds with one another; chief among these potentially conflicting goals is the desire to maximize the economic value of the fishery and the need to rebuild depleted stocks that co-occur with healthy target species. Federal fishery scientists are, in general, responsible for deriving ABC and OFL estimates that are reviewed by the Groundfish Management Team, a panel of federal, state, and tribal scientists. These ABCs and OFLs are presented to the Council's Science and Statistical Committee for review. The SSC then makes the ABC and OFL recommendations to the PFMC. The observer program (http://www.nwfsc.noaa.gov/research/divisions/fram/Observer/) provides targeted catch, bycatch, and discard data in addition to the logbook data maintained by fishing vessels, and also monitors changes in fishing behavior as vessels approach their limits for target species. Observer coverage in the Pacific Coast groundfish fleet is designed so that all limited entry trawling vessels are observed for a minimum of two consecutive months every two years. The exception is the at-sea hake fishery (vessels that catch hake and deliver them to at-sea processing vessels), which receives 100% observer coverage. Some additional observer effort focuses on fixed gear fisheries.

Routine (*i.e.*, on-going but regularly updated) restrictions on limited-entry fisheries are in place for several species, based on PFMC recommendations and on the classification of certain groundfish stocks as overfished. Principal among those restrictions is setting seasonal quotas and/or cumulative trip limits that may be geographically based. Routine restrictions are in place for all groundfish caught by open access or recreational fisheries. The PFMC can recommend, and NOAA can implement, management actions beyond the scope of the routine actions in order to address arising conservation or socio-economic concerns. Some notable examples are described below.

Time/space closures to some, or all, fishing gears can be enacted when certain species reach defined quotas in a season or year, or they may be established on a permanent basis. Recently there have been several large-scale closures throughout the EEZ. In June 2005, the PFMC voted to permanently close all EEZ waters deeper than 1280 m to bottom trawling, and closed seamounts to all bottom-contacting gears. Several times in recent years, the PFMC has temporarily closed bottom and midwater trawling on the continental shelf in regions referred to as Rockfish Conservation Areas (RCAs). These areas are large, complexly shaped polygons defined by many waypoints in order to cover the appropriate depth strata, which define preferred habitat for overfished rockfish species such as bocaccio, canary rockfish, darkblotched rockfish, and Pacific ocean perch. Other year-round closed areas that have been in place since the late 20th Century are the Cowcod Conservation Areas (CCAs) located off the coast of southern California, and the Yelloweye Rockfish Conservation Area (YRCA) located off the coast of Washington. The PFMC is currently exploring the use of electronic vessel monitoring systems (VMSs) to track the movement of fishing vessels through closed areas. Finally, there are dozens of much smaller marine reserves throughout the region, typically in coastal regions, with varying degrees of restrictions on fishing and other human activities.

A second management tool is restricted size of footropes on shelf trawls. Rollers on footropes may be no greater than 8 inches (20.3 cm) in diameter, which essentially prevents fishing in rocky habitats because of the high likelihood of gear damage (Hannah, 2003). Management believes that rocky habitats are critical for several life stages of groundfish, particularly rockfish, and that protecting these habitats by making them effectively untrawlable will improve rockfish rebuilding efforts.

Another notable management tool was the recent buyback of trawl permits and vessels in the limited entry fishery. This federal legislation, implemented in 2003, was intended to reduce fishing effort on groundfish by roughly one third, and to increase financial stability among the fishing community. It ultimately funded the buyout of 92 vessels and 92 groundfish permits. This effort may be further augmented by a combined trawl permit buyback and marine protected area establishment proposed by The Nature Conservancy and the Environmental Defense Fund, non-governmental organizations that plan to purchase the permits for roughly half of the remaining trawlers in Central California and then establish marine reserves in the same areas to conserve sensitive benthic habitats, fish species, and related marine resources (see details in Appendix F of the Groundfish Essential Fish Habitat Environmental Impact Statement, available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/).

- **General approach to management for target and bycatch species**

Eighty-nine fish species are actively and specifically managed under the Pacific Coast Groundfish FMP: 62 species of rockfish (59 species of the genus *Sebastes*; shortspine and longspine thornyheads; California scorpionfish); 12 species of flatfish (arrowtooth and starry flounder; Pacific sanddab; butter, curlfin, Dover, English, flathead, petrale, rex, rock and sand sole); six roundfish (lingcod, cabezon, kelp greenling, Pacific cod, Pacific whiting (hake) and sablefish); one morid (finescale codling); one grenadier (Pacific rattail); and seven chondrichthyans (leopard and soupfin sharks; spiny dogfish; big, California and longnose skates; ratfish). However, the FMP states that any 'rockfish' (*i.e.*, a member of the family Scorpaenidae) is subject to management under the FMP. Pacific and California halibut are not managed under this FMP.

The dominant retained species are hake, rockfish, sablefish, and flatfish. Hake are potentially highly productive, with relatively short generation times (8 years) and high fecundity, but their production is constrained by stochastic recruitment success such that hake biomass is typically dominated by a few strong year classes. In general, rockfish (particularly large-bodied species) are slow to mature and have slow growth rates. Rockfish generation times are often measured in decades. They are live-bearing fish with very high fecundities, but survival of larvae is very poor and, in some species, episodic. Adult natural mortality rates are assumed to be low. These life history characteristics render rockfish susceptible to overfishing even at moderate rates of fishing mortality (Parker *et al.*, 2000). Sablefish have longer generation times than hake and episodic year class strength that appears strongly related to climate conditions. Flatfish vary broadly in terms of life span and size-specific fecundity.

Juvenile and adult hake eat mostly euphausiids, with larger adults also eating amphipods, squid, herring, smelt, crabs, and other fish, including juvenile hake. Juvenile hake are also eaten by lingcod and some rockfish while adults are eaten by sablefish, sharks, and marine mammals. Rockfish occupy a broad range of trophic roles owing to their species diversity, size diversity, and habitat diversity. Their diets range from gelatinous zooplankton to fish, with euphausiids being almost universally important. Larval, juvenile, and smaller adult rockfish provide food for other groundfish, albacore, marine mammals, sharks, and birds. Sablefish diets include fishes, cephalopods and benthic invertebrates. Young sablefish provide food for seabirds, fishes (including lingcod), and marine mammals. Juvenile and adult flatfish eat benthic invertebrates and fish, and are preyed upon by sharks, marine mammals, sablefish, and other flatfish. Some flatfish, such as English sole, inhabit estuaries at early ages, and are vulnerable to wading birds.

Population status of Pacific Coast groundfish is monitored through regular field surveys, using both fishery-independent trawl surveys and hydroacoustics. These surveys provide data on spatial distributions, habitat-specific abundances, and age structure of groundfish populations in trawlable habitats. NOAA scientists are attempting to improve monitoring of groundfish stocks in untrawlable habitats, but that is a relatively new research effort. Additionally, acoustic surveys concurrent with midwater trawl sets are done to monitor hake which inhabit midwater regions. Data from these surveys and from the fishery are incorporated into formal stock assessments; a compilation of SAFE documents for Pacific Coast groundfish from 2001 to the present is available at http://www.pcouncil.org/groundfish/. However, given the time required to conduct a stock assessment, the number of species in the FMP and the constant need to update assessments of key species, the number of species actually assessed is far less than the total number of species managed. For example, during the 2007–2008 biennium 23 species were assessed.

For the purposes of management, a species in this FMP is designated at 'precautionary status' if its spawning stock biomass (SSB) falls below 40% of the estimated unfished biomass. More drastically, a species is considered 'overfished' if its SSB is below 25% of the estimated unfished biomass. When fish are declared overfished, formal rebuilding plans are initiated; if SSB reaches 10% of initial, a zero catch policy is enacted. Rebuilding plans are currently in place for several overfished rockfish species; owing to the long generation times and low productivity of rockfish, target biomasses for some rockfish are not expected to be achieved for many decades.

Because several rockfish species have been declared overfished, and because their life history renders them especially sensitive to fishing mortality, fishing mortality target levels are being re-evaluated for rockfish. In the early 1990s, stock assessments of rockfish suggested that a fishing mortality (F) of $F_{35\%}$

would be sustainable; this was soon changed to $F_{40\%}$ (Clark, 2002). This indicates a fishing mortality that would reduce the spawning biomass per recruit (a proxy for lifetime egg production) to 40% of that in an unfished population. On subsequent analysis, this strategy was found to be unsustainable because of the low resiliency of rockfish to exploitation (Clark, 2002). More conservative *F* levels are being considered and implemented in current OY determinations for rockfish. For example, recent draft stock assessments of vermilion rockfish (MacCall, 2005a), widow rockfish (He *et al.*, 2005), and bocaccio (MacCall, 2005b) are all using $F_{50\%}$ in their yield determinations.

Other species listed in FMP are considered either at target level, above target level, or have insufficient information to assess their populations. In cases where the abundance of species is based on either limited modeling ('data moderate' species) or solely on landed catch ('data poor' species), the PFMC may consider lowering the prescribed OY by 25% or 50%, respectively. A data-moderate OY reduction is under consideration for two flatfish (sanddabs and rex sole) that have not been assessed recently.

The bycatch mitigation plan (see http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/) goes into considerable detail about the species listed in both this section and the following "Threatened or Protected Species" section. It describes several alternative strategies for reducing the total bycatch and subsequent bycatch mortality in the groundfish fishery through changes in effort or catch limits. These alternatives have broad overlap with management strategies intended to optimize yield in the overall fishery while concurrently rebuilding stocks of depleted species, as drawn out in the Groundfish Environmental Impact Statement (http://www.pcouncil.org/groundfish/current-season-management/).

Many categories of bycatch species are recognized within the FMP, including overfished groundfish, highly migratory species (HMS), coastal pelagic species (CPS), prohibited species, and protected species. Incidentally caught overfished groundfish are often referred to as bycatch because they are rarely targeted, particularly those that have SSBs below the critical threshold of 10% of unfished biomass. Nonetheless, they are unavoidably caught in fisheries targeting more abundant groundfish. Although this bycatch is recognized as unavoidable, the PFMC and NOAA attempt to restrict it by setting low quotas for overfished species and monitoring those catches in season through the Observer Program. Meeting or exceeding those quotas may result in activation of a time/space closure such as an RCA.

HMS (tunas, billfishes, pelagic sharks) are mostly pelagic and are rarely caught in groundfish gears, and thus are not likely to be affected by groundfish management, unless perhaps by effort re-allocation related to groundfish permit buybacks or decreases in groundfishing opportunities.

CPS (*e.g.*, squid, sardine, anchovy, mackerel) are often caught in the hake fishery, which is a midwater trawl fishery, and in much lower numbers in groundfish gears associated with the bottom. Bycatch in the hake fishery can be large. For example, >80 mt of squid were caught in the 2001 at-sea hake fishery. The Pacifc Coast Groundfish FMP and EIS require that these species' status be considered in terms of impact. For that reason, take of these species is monitored, although any bycatch-related management decisions have to be made in conjunction with the CPS FMP, under which these species are managed. Current assessments indicate that biomasses of sardine and mackerel are increasing relative to other coastal pelagics, with both species being harvested at near-record levels. In contrast, squid population dynamics are highly variable and recruitment-driven. Sardine and anchovy population dynamics are strongly driven by interactions with climate regimes (Chavez *et al.,* 2003) as well as by fishing.

There is a special category of non-target bycatch species called 'prohibited species', meaning that they must be returned to the sea as quickly and safely as possible if brought on board. In the Pacific Coast Groundfish FMP, prohibited species include all Pacific salmon, Pacific halibut, and Dungeness crab (although Dungeness crab take is permitted in California waters, if done in accordance with California law). In addition, joint-venture operations (in which foreign processors receive fish caught in the U.S. EEZ) are prohibited from receiving salmon, Pacific halibut, Dungeness crab, and species outside of specific authorization or in excess of limits or quotas. Pacific salmon bycatch mostly occurs in the hake fishery, and specific fleet-wide bycatch rates have been established for Chinook salmon, which is the species most likely to overlap spatially and temporally with hake (the allowable rate has rarely been exceeded). These fish must be immediately returned; if retained, they are turned over to the state at which they are landed. Pacific halibut may only be kept if they are tagged, provided that the tag is returned to the International Pacific Halibut Commission (IPHC), the body that manages Pacific halibut. Bycatch of Pacific halibut that results in halibut mortality probably does not affect the overall status of the halibut population because halibut caught in Washington, Oregon, or California waters are likely at the southerly extent of the population and do not represent large numbers of the spawning stock biomass. However, fishing mortality of Pacific halibut incidentally caught by groundfish gear does count toward the total quotas established by the IPHC. Although this bycatch has been substantial on occasions, it is likely to have been curtailed in recent years by the establishment of RCAs which overlap with much of the Pacific halibut habitat off Washington, Oregon, and California. Dungeness crab are often taken in groundfishing gears, and all must be returned to the sea in Washington and Oregon. Despite this regulation, some mortality occurs, especially when the crabs are in the vulnerable soft-shell state following molting. Some RCA boundaries have been extended into shallower waters in molting seasons to minimize this impact. In California, some take of Dungeness crab is allowable in accordance with state regulations, which include size limits and a strict prohibition on the retention of female crabs.

Recently, the deep-sea coral communities of the continental slopes have attracted special attention with respect to groundfish fisheries. In slope regions, large footrope gear is permissible, and there is growing concern that these and other trawl gears will impact deep-sea coral communities, which are poorly studied. The impact of groundfish fishing on deep-sea coral communities remains unknown.

More generally, bottom trawling likely has a strong impact on substrates and associated organisms, especially benthos such as sponges, anemones, sea cucumbers, sea stars, sea pens, sea whips, and sea urchins, and benthopelagic organisms such as octopus. Little is known about the intensity or impact of trawl contact with benthic communities, although some generalizations can be hypothesized. For example, one might expect trawl impacts to be greater in relatively stable habitats that are not affected by strong current or wave action compared to more disturbance-prone habitats associated with higher wave energy. Also, there are some fishing grounds off California, Oregon, and Washington that are known to be regions of relatively high trawling intensity (NRC, 2002). However, the overall quantitative impacts of bottom trawls on these habitats remain unknown. As part of the evolution of the Essential Fish Habitat Environmental Impact Statement (EFH EIS) process, however, these issues will be addressed. Additionally, in the standard fishery-independent trawl surveys of groundfish abundance conducted annually by NOAA, biologists are now recording data on benthic invertebrates although these data are essentially limited to presence/absence of species.

Many other species are captured in groundfish fisheries, including some fish and invertebrate species with commercial value that are managed at state levels (*e.g.*, California halibut, shrimp, crab, sea cucumber), and others with recreational value (*e.g.*, California sheepshead, greenlings, ocean whitefish) or low human value (*e.g.*, eelpouts, midshipman, cat sharks). There is currently no management but some catch monitoring of species in this category, and retention of any nonspecified species is permitted. The impacts of different management alternatives on species such as shrimp, finfish, and other species not directly covered by the Groundfish FMP are discussed in the bycatch mitigation plan (available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/). Devising effective management measures to reduce bycatch will require additional economical and socio-cultural information.

2. Management of Threatened or Protected Species and Communities

In addition to the prohibited species noted in the previous section, there are several threatened and protected species in the EEZ off the Pacific Coast. These species fall under three overlapping categories (ESA-listed species, marine mammals, and seabirds), reflecting four mandates (the ESA, the MMPA, the MBTA, and Executive Order 13186, which gives further protection to migratory birds). Further protection for some of these species is outlined in the MSFCMA.

A number of threatened or endangered species or habitats for these groups occur in Pacific Coast EEZ waters, and these species are afforded protection under the ESA. Those species (and their ESA listing status) include: Pacific salmon (numerous threatened and endangered stocks in California, Oregon, Washington, and Idaho), sea turtles (endangered: leatherback; threatened: green, loggerhead, olive Ridley), seabirds (endangered: California least tern, California brown pelican, short-tail albatross; threatened: marbled murrelet), and marine mammals (endangered: blue whale, fin whale, humpback whale, North Pacific right whale, sperm whale; threatened: Steller sea lion, Guadalupe fur seal, sea otters in California). The listing status of some species, such as the southern resident killer whale (listed as 'depleted' under the MMPA), is the subject of some controversy. One mollusk, the white abalone, is endangered in this region, although it dwells in rocky, untrawlable habitat and is thus not likely to be directly affected by groundfish harvesting.

Take of Pacific salmon was discussed above in the section on bycatch; as prohibited species, Pacific salmon must be returned to the sea as quickly as practicable, regardless of their status under the ESA.

Interactions between sea turtles and groundfish gear or vessels are rare; most fishery-related sea turtle mortality appears to occur in gillnets (which are not used in groundfish harvest) or longlines (which are rarely used by the groundfish fleet in depths inhabited by sea turtles).

The Pacific Coast groundfish fishery is considered a low-risk fishery in the context of the MMPA. Direct incidental take of marine mammals by Pacific Coast groundfishing vessels has occurred in the hake fishery, but the take has been minimal. For example, between 1997 and 2001, by far the most frequently taken marine mammal was the Dall's porpoise, but the average annual take by the entire hake fleet was 2.56 porpoises/year. Observer coverage from the remainder of the fishery indicates little direct take. For example, observer coverage of 30% of the limited entry fixed gear and 10% of the limited entry trawl fishery in fall 2001 to fall 2002 found a total take of 11 marine mammals, mostly California sea lions. The overall fishery is regarded as Category III under the MMPA, indicating a remote likelihood of mortality or injury related to fishing activity. The more likely impact of groundfish fishing is in changes to marine mammals' food supply, whether by removal of their prey, alteration of the food webs in which they exist, or through provision of food via discard. These impacts, however, are not well known.

As with marine mammals, direct impacts of groundfishing on birds appear to be minimal, whereas indirect effects (*e.g.*, food web effects) are poorly studied. Observer data suggest that direct mortality of seabirds is very low. For example, observer coverage of 30% of the limited entry fixed gear and 10% of the limited entry trawl fishery in fall 2001 to fall 2002 found a total take of 5 birds. Most direct interaction appears to be birds scavenging offal on decks or discarded overboard, but there are little spatial or temporal data to quantify such interactions with birds and vessels.

Besides the ESA-listed seabirds mentioned previously, the U.S. Fish and Wildlife Service designated several birds as 'species of special conservation concern.' These include black-footed albatross, ashy storm petrel, gullbilled tern, elegant tern, arctic tern, black skimmer, and Xantus's murrelet. Furthermore, migratory seabirds receive protection from the MBTA, an international treaty among Canada, Japan, Mexico, Russia, and the U.S. which forbids the killing, taking, or possessing of a migratory bird. EO 13186 mandates agencies to work with the Fish and Wildlife Service (FWS) to establish Terms of Understanding about the impact of human activities upon migratory birds; NOAA and the FWS are currently developing such Terms for migratory birds. Finally, the MSFCMA requires compliance among NOAA-enforced fisheries management actions and all legislation designed to protect seabirds.

3. Habitat Management

Essential fish habitat (EFH) for Pacific Coast groundfish is defined generally as the aquatic habitat necessary for groundfish production that supports both long-term sustainable fisheries and healthy ecosystems. To satisfy this description, EFH must be described for all life history stages of managed species. Pacific Coast groundfish species managed by the Pacific Coast Groundfish FMP occur throughout the EEZ and occupy diverse habitat types at all stages in their life histories. EFH for any one species may be large (*e.g.*, a species with pelagic eggs and larvae that are widely dispersed) or comparatively small (*e.g.*, nearshore rockfish which show strong affinities for a particular location or type of substrate).

EFH descriptions and management were originally incorporated into the Pacific Coast Groundfish FMP in Amendment 11 (available at http://www.pcouncil.org/groundfish/, but EFH designation and management were updated in 2006 with the adoption of Pacific Coast Groundfish FMP Amendment 19 (available at http://www.pcouncil.org/ groundfish/). This Amendment was a result of the process of developing a Groundfish Essential Fish Habitat Environmental Impact Statement (EFH EIS), which was finalized in late 2005 (http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/). Although EFH designation does not, by itself, confer protection upon a habitat, it does bring that habitat into the context of the EFH habitat management plan, which is intended to maintain or enhance habitats and their associated ecological and/or socio-economic benefits. The EFH EIS presents a framework for: 1) identifying groundfish EFH (waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity) and habitat areas of particular concern (HAPC; EFH that is especially important, sensitive, rare, or threatened by potential human activity); quantifying the 'habitat suitability probability' of potential groundfish habitat; 3) identifying strategies to minimize fishery-related impacts on EFH and HAPC; 4) conducting research and monitoring to evaluate the effectiveness of groundfish habitat management; and 5) identifying the ecological and socio-economic benefits and costs of implementation alternatives. The EFH EIS also describes the legislative basis for cooperative EFH management between the federal government, state governments, and tribal groups.

Habitat management for Pacific Coast groundfish fisheries has been done primarily through the standard federal consultation process. Specific cases in which action has been taken to minimize fishing impacts on EFH are limited to a few cases, although those cases are considerably important. A chief example is limiting bottom trawling to soft sediments; the mandatory small rollers on trawl footropes mean that vessels are unlikely to trawl around rocky bottoms due to potential gear damage. This means that rocky reef habitat, considered critical habitat for groundfish, is 'untrawlable', and is mostly fished by sport anglers or commercial longliners. Also, closing large areas to fishing is intended not just to lower fishing mortality, but also to protect habitat where fish species of concern (*e.g.*, yelloweye rockfish, cowcod) are found.

The standard consultation processes involved in identifying EFH, the modeling involved in the EFH EIS, and a general assessment of groundfish fishing impacts on marine habitats are data-intensive endeavors. Many programs exist for identifying and quantifying different habitat types in the Pacific Coast EEZ. At the federal level, these efforts include bottom mapping and related groundtruthing, using multibeam sonar equipment, echo sounders, and remote operated vehicles (ROVs) with cameras. Overlapping surveys are done to assess the physical and chemical characteristics of the water overlying different habitat types. More recently, NOAA biologists have begun efforts to assess the populations of groundfish in untrawlable habitats through use of ROVs and towed camera sleds, hook-and-line surveys, and mark-recapture studies. Such information will increase the accuracy of coastwide stock assessments.

Regarding empirical monitoring and research of human impacts on benthic habitats inhabited by groundfish, there are many human activities that have direct and indirect effects; these include fishing, dumping, dredging, oil and gas production, oil spills, water intake, cabling, pollution via runoff or wastewater discharge, coastal development, kelp harvesting, and introduction of non-indigenous species.

Fishing with bottom-contact gears, as described in the previous section, has numerous impacts on habitat (NRC, 2002), although they have not been well documented in this fishery (see Appendix C of the Groundfish EFH EIS, available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/). Bottom-contact gears can remove or damage benthic habitat-forming species, ranging from macrophytes to corals to invertebrates, as well as infaunal species that influence sediment stability by burrowing and water quality by filter feeding. It can also disrupt soft sediments through creating trawl scars that last anywhere from hours to years, depending on circulation patterns, sediment type, trawling speed, and trawl door size and weight; such areas can experience local areas of high sediment suspension and resettlement, nutrient release, and hypoxia (Kaiser *et al.*, 2002). Through repeated trawling of the same area, soft sediments can also become compacted. Other potential direct impacts on habitats include loss of gear, such as pots, traps, longlines or gillnets on hard substrates, which could result in 'ghost fishing' by those gears and local, habitat-specific increases in fish mortality until the gears biodegrade or are salvaged. Fishing vessel discards of unwanted bycatch or offal that sink to the bottom and decompose may result in localized hypoxia.

Direct and indirect impacts of the non-fishing human activities are described in Appendix C of the

Groundfish EFH EIS, available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/. Most of these descriptions are general, not specific to the U.S. Pacific Coast. These activities are regulated by established legislation (*e.g.*, the federal *Clean Water Act*, http://www.epa.gov/agriculture/lcwa.html) and by local, state and federal permitting processes, which often involve a full environmental impact statement. Specific impacts of these activities on groundfish habitats (and, by extension, groundfish ecology) have not been well documented, although it is likely that many of the activities occur in relatively nearshore habitats and thus have a low impact on continental shelf or slope species.

4. Community/Trophic Structure Management

- General approach to management of food webs

At present, there is little empirical or modeling information on the extent to which food web interactions affect the population biology of Pacific Coast groundfish species, and hence the stock assessment models for these species remain essentially single-species models. In 2001, a panel of NOAA scientists compiled a Stock Assessment Improvement Plan (SAIP; http://www.st.nmfs.gov/st2/saip.html) to address ways to augment stock assessments through, among other things, incorporating food web interactions into population dynamics. A specific need cited in that document for Pacific Coast groundfish was to account for the role of increased pinniped abundance which could signal an increase in predation mortality on groundfish. Still other cases involving predation by groundfish on other groundfish have gained attention in the recent literature (*e.g.*, Mangel and Levin, 2005), and the PFMC has acknowledged the importance of food web interactions by banning the harvest of euphausiids (http://www.pcouncil.org/coastal-pelagic-species). This ban was enacted not because krill are overfished (in fact, they are not harvested at all), but precisely because they are a ‘fundamental food source’ for many marine species. The same document notes the possibility of extending this ban to other forage species. Thus, it is clear that food web interactions are considered important in managing this system.

Diets of many key Pacific Coast groundfish species have been studied quantitatively, including Pacific hake (Gotshall, 1969; Outram and Haegele, 1972; Livingston, 1983; Tanasichuk *et al.*, 1991; Buckley and Livingston, 1997; Grover *et al.*, 2002), sablefish (Laidig *et al.*, 1997), some shelf rockfish (Reilly *et al.*, 1992; Lee, 2002) and nearshore rockfish (Hallacher and Roberts, 1985; Hobson and Chess, 1988; Murie, 1995), arrowtooth flounder (Gotshall, 1969), and spiny dogfish (Tanasichuk *et al.*, 1991). Many of those studies evaluated diets over limited spatial and temporal scales. Diets of multispecies groundfish assemblages are summarized in some sources (*e.g.*, Quast, 1968; Lea *et al.*, 1999; Love *et al.*, 2002). Buckley *et al.* (1999) present quantitative, coastwide diet data from several size classes, seasons, and years for hake, sablefish, three flatfish, two thornyheads, and two grenadiers. Also, some prey (squid, euphausiids, and certain myctophids) are relatively ubiquitous and can thus be described as key to groundfish production. There is, however, a general scarcity of quantitative diet data that span large geographic ranges, multiple ontogenetic stages, seasons, or changes across climate regimes of different temporal scales.

Diets of several rockfish species off the Oregon coast have been inferred through analysis of stable isotope ratios (Bosley *et al.*, 2004). Tracer methods like stable isotope analysis are an attractive research avenue because they capture diet habits over a longer time scale than stomach analysis; they are not subject to some sources of bias in stomach analysis (*e.g.*, empty stomachs, stomach eversion, feeding while in the capture gear); and they provide information about the ultimate sources of production that support a species.

Our growing knowledge of diets will bring a better notion of bottom-up and top-down forces that structure groundfish populations and communities. The effects of bottom-up forces, such as the quality and quantity of prey on rockfish growth and reproductive fitness, have been shown both empirically (Lenarz *et al.*, 1995; VenTresca *et al.*, 1995) and with bioenergetics modeling (Harvey, 2005). Cases where poor spring and summer feeding conditions constrain female rockfish from storing enough lipids to produce a normal amount of larvae (Guillemot *et al.*, 1985; Lenarz *et al.*, 1995; VenTresca *et al.*, 1995) clearly link food web processes to rockfish population biology. Top-down forces, apart from fishing mortality, have been difficult to identify in groundfish communities, but some models argue for their importance and demonstrate their potential importance if overlooked. Mangel and

Levin (2005) developed alternative models of marine reserves intended to enhance a population of bocaccio rockfish. The efficacy of some marine reserves hinged on whether or not lingcod, which prey on young bocaccio, were included in the model. This was because lingcod, which have faster growth rates and shorter generation times, responded more rapidly to the cessation of fishing and quickly reached sizes and numbers capable of suppressing juvenile bocaccio through predation.

Bottom-up and top-down forces occur in concert, with varying degrees of impact, against a backdrop of environmental variability and fishery exploitation. Because of this complexity, scientists are using community-level or ecosystem-level modeling tools to simulate ecological dynamics. Field (2004) developed a model of the Northern California Current ecosystem using the Ecopath with Ecosim software (Christensen and Walters, 2004). The Ecopath mass-balance model was used to estimate, for example, linkage strengths in the food web, the effects of hake predation on different forage bases, the relative impacts of fishing and predation on groundfish stocks, and how the importance of thornyheads in sablefish diets has been overestimated (Field, 2004). The dynamic Ecosim model was used to estimate food web responses to fisheries and climate anomalies (upwelling, PDO). Among the inferences Field (2004) made concerning groundfish were: that hake compete for prey with Pacific salmon; that hake are a key source of mortality for pink shrimp; and that populations of longspine thornyheads, which are expected to decline due to fishing, may actually remain stable because their major predators, sablefish and shortspine thornyheads, have also been fished down.

Food web modeling may also help to demonstrate relationships between groundfish and other members of the community. Larval and juvenile groundfish are known to be important prey for seabirds (Sydeman *et al.*, 2001; Miller and Sydeman, 2004). Also, although the groundfish fishery has little impact on seabirds and marine mammals in terms of bycatch mortality (PFMC, 2004a), it likely influences their population in other ways: fisheries may deplete stocks of groundfish that apex predators depend on, whereas scavenging birds and mammals certainly feed on bycatch or offal that vessels discard.

Finally, it is noteworthy that there are relatively few specifics concerning food web dynamics in the FMP (PFMC, 2004a) or the fishery EIS (PFMC, 2004b). This does not indicate a lack of concern on the part of the PFMC – rather, it illustrates the difficulty in acquiring food web information and integrating it into an already complex system of population assessment and management. This underscores the strong potential of food web models: once user-friendly ecosystem-level food web models are available to decision-makers, the models can be used to synthesize available information and generate hypotheses or serve as guidelines toward determining the strength of food web interactions that ultimately may shape groundfish population dynamics. This, in turn, will lead to empirical studies designed to provide quantitative information for use in stock assessments.

5. Management of Physical Environment

The groundfish community occurs against a backdrop of physical conditions characterized by bottom topography and sediment type, bathymetric gradients, dynamic current structures at many spatial scales, chemical gradients, water temperatures, and climate. All of these factors can influence fish distribution.

The bottom habitat of the Pacific Coast EEZ is characterized by a fairly narrow continental shelf (rarely wider than 50 km) and a broader slope; most trawling for groundfish occurs on the shelf at depths up to about 500 m. Bottom types are typically sand, mud, gravel, boulders, rocky pinnacles, or exposed bedrock. Major geological features include capes and points (notably Point Conception and Cape Mendocino) and submarine features (notably Monterey Canyon, the Mendocino Escarpment, and Astoria Canyon) that often mark approximate boundaries for shifts in groundfish species composition. Species composition of groundfish communities is also linked to more basic physical gradients such as latitude and depth. For example, Williams and Ralston (2002) classified several distinct assemblages of rockfish based on latitude and depth, and Love *et al.* (2002) have found that rockfish species diversity increases from north to south along the North American coast. Estuaries provide habitat for juvenile life stages of some groundfish, including English sole and lingcod.

In terms of oceanography, the dominant feature of this region is the California Current, a large clockwise surface current that branches off the North Pacific Current in the region of Vancouver Island. It brings relatively cool water southward along the coast until roughly Point Conception, where it moves away from the coast. The California Current is strongest and closest to shore during the summer. The deeper, slower California Undercurrent runs northward along the Pacific Coast. Dynamics within the California Current, along with major wind events, can lead to the coastal upwelling of cold, nutrient-rich water which leads to increased primary production that can be propagated throughout the food web. Upwelling is often associated with areas that have submarine canyons. While upwelling is typically associated with episodes of high primary productivity, a recent large upwelling event introduced hypoxic water to waters off the northern U.S. Pacific Coast, causing large amounts of groundfish mortality and stress on other demersal and benthic communities (Grantham *et al.*, 2004). Many eddies and jets occur along the coast, often created or influenced by coastal geologic features such as capes and points. These localized current dynamics may be especially important to groundfish species whose larvae undergo a prolonged pelagic larval stage because current-driven dispersal and/or retention of larvae can have strong influence on recruitment. South of Point Conception is the Southern California Bight, dominated by a counterclockwise eddy of relatively warm water.

Much research in recent years has focused on the importance of climate variability on growth, survival, recruitment, and spatial distribution of groundfish. Variability ranges from changes in wind, temperature, and upwelling intensity on the scale of 1 to 2 years (El Niño Southern Oscillations (ENSOs) and La Niñas) to decadal-scale climate regime shifts (the Pacific Decadal Oscillation (PDO)). ENSOs have probably received the most attention, and their effects vary among different groundfish. For example, the warm waters and poor upwelling associated with an ENSO often create poor conditions for rockfish recruitment and have led to poor growth, reduced fecundity, and increased mortality among adult rockfish. Changes in temperature caused by ENSO events may also result in dramatic shifts in species composition of the groundfish prey community (Brodeur and Pearcy, 1992). In contrast, hake recruitment has been strong in years after ENSOs (Hollowed *et al.*, 2001). A shift from one PDO regime to another leads to differences in air pressure, oceanic circulation, and other key oceanic properties that affect primary production and consumer species composition (Francis *et al.*, 1998). Among rockfish off Southern California, the 'cool' PDO regime appears to be more favorable, as measured by larval abundance (Moser *et al.*, 2000). Pacific Coast groundfish may also be influenced by other sources of long-term variation: strong year classes for some groundfish have been associated with decadal-scale variation related to Aleutian Low pressure events in conjunction with ENSO events, rather than the timing of PDO regimes (Hollowed and Wooster, 1992, 1995). Sablefish year class strength off some regions of the Pacific Coast appears related more to factors such as seasonal Ekman transport and sea level than to adult abundance in a traditional stock-recruit relationship (Schirripa and Colbert, 2006).

Overall, despite the research dedicated to relationships between climate and groundfish, there has been little done to incorporate this research into management. Integrating climate variability into stock assessments, and understanding the relationships between climate and recruitment, are high priorities for Pacific Coast groundfish management.

6. Management of Contaminants and Pollution

There are many potential sources of contaminants and pollutants that can impact the ecosystems supporting Pacific Coast groundfish, and pollutants can take the form of toxic substances, discarded or lost materials such as plastics, or thermal discharges. Notable sources are point sources (rivers, sewage outfalls, power plants), non-point source runoff, atmospheric deposition of globally dispersed chemicals, oil spills, dumping, military activities, and shipping (via engine exhaust, materials lost overboard or dumped, or shipwrecks). Some human activities may also encourage production of natural toxins, such as those occurring in certain algal blooms. While other factors such as species introductions and sonar equipment have been described in similar terms ('biological pollution' and 'noise pollution', respectively), those factors will not be addressed in this section as they are probably more relevant to other ecosystems (*e.g.*, estuaries and intertidal habitats for species introductions) or communities (*e.g.*, marine mammals for sonar activity).

In the Pacific Coast region, there has been widespread addition of terrestrial nutrients from point sources and non-point runoff, and a wide range of local, state, and federal laws are in place that set standards for levels of point and non-point pollution (*e.g.*, http://www.ecy.wa.gov/water.html). Considerable research has been done on the effects of eutrophication on nearshore habitats, especially estuaries, bays, and seagrass beds. Little information is available on how eutrophication directly affects groundfish production, however. Similarly, it is well known that increased nutrient levels can lead to harmful algal blooms (HABs) on the U.S. Pacific Coast, including red tides, brown tides, and blooms of the diatom *Pseudo-nitzschia* that produce domoic acid, a toxin readily incorporated into marine food webs. However, there is little research directly connecting HABs with the ecology of groundfish.

In contrast, many anthropogenic contaminants and toxins have been found in tissues of groundfish on the U.S. Pacific Coast. These chemicals likely arrived in groundfish systems via point sources (rivers, outfalls, oil spills, urban centers, anti-fouling treatments) and non-point sources (terrestrial runoff, atmospheric deposition). They can then be taken up by direct absorption across gill membranes or indirectly via bioaccumulation through the food web, producing lethal and sublethal affects. Contaminants buried in marine sediments can also be resuspended by dredging activities. A large body of recent literature is devoted to levels of chlorinated hydrocarbons and heavy metals in groundfish tissues, not only around urban centers such as south Puget Sound (*e.g.*, Stein *et al.*, 1992; Johnson *et al.*, 1998; O'Neill and West, 2004) but also around relatively undeveloped areas such as the Farallone Islands (Sydeman and Jarman, 1998). Most of the impacts evaluated in these studies are sublethal, such as effects of exposure levels on enzyme levels or reproductive output. While guidelines for human consumption of groundfish have been set in many areas (*e.g.*, http://www.doh.wa.gov/ehp/oehas/fish/default.htm), and overall domestic release of organochlorines and heavy metals has been greatly reduced by legislation such as the *Clean Water Act* (http://www.epa.gov/agriculture/lcwa.html) and *Clean Air Act* (http://www.epa.gov/air/caa/), there have not been sweeping ecosystem management actions in specific response to contaminant levels in Pacific Coast groundfish. Recommendations on how to minimize contaminant impacts on groundfish were made in Amendment 11 of the FMP.

Oil and petroleum spills are a major problem on the U.S. Pacific Coast, owing to extensive oil production on the continental shelf in California waters, and the large amount of oil that is shipped through areas subject to strong storms and characterized by rocky coasts or shoals. While coastwide programs are in place to coordinate response to spills (*e.g.*, www.oilspilltaskforce.org/index.htm), they remain essentially inevitable: whereas the global trend has been one of fewer major spills in recent decades, the number of yearly oil or petroleum spills >37,850 L in the California Current region has been relatively unchanged from 1978–1999 (Mearns *et al.*, 2001). Over 150 spills of this magnitude occurred on the U.S. Pacific Coast in this period (the vast majority in California), and many more small spills also occurred; the dispersal characteristics of these spills vary considerably (Mearns *et al.*, 2001). Oil and petroleum spills can have lethal or sublethal effects on groundfish (Marty *et al.*, 2002) and the species that they depend on for prey or habitat. Species that feed on groundfish (sea birds, marine mammals) are also adversely affected, as are fisheries that typically close while clean-up activities are occurring. Oil spill dispersant chemicals are, themselves, potentially toxic to some fish and to other species that provide biogenic habitat or prey, although often less so than the oil that they are used to disperse (Singer *et al.*, 1995). Regarding management responses and recovery rules concerning oil and petroleum spills, it seems likely that species groups other than groundfish will dictate the course and pace of decision making, particularly because many of the species most obviously affected by oil spills are also federally protected species, such as marine mammals and seabirds, or are targets of surface-oriented fisheries, such as salmon and herring.

Debris, garbage, and dredge spoil have been dumped regularly at sea in the U.S. Pacific Coast region, as evidenced by a survey that found debris on 14% of the seafloor between 10 and 200 m off Southern California (Moore and Allen, 2000). The debris in that study was patchy and occurred at low density. It was comprised mostly of fishing gear, plastics, metal, glass, and miscellaneous items. Debris on the sea floor may be the result of intentional actions (*e.g.*, dumping, littering, military exercises) or accident (*e.g.*, loss of fishing gear, shipwrecks, loss of cargo in inclement weather, discharge of debris in stormwater). Dredge spoil dumping may also introduce some debris in addition to large loads of sediment.

Overall, the impacts of non-fishing activities, including pollution and contaminant production, on groundfish in this region are very poorly studied, and thus there are no reliable measures of target levels for management responses, nor have risk assessments and mitigation plans been developed.

7. Management of Aquaculture

Currently, there is little or no aquaculture for groundfish species in the U.S. Pacific Coast EEZ. However, pen rearing of groundfish to market size is certainly feasible, and captive breeding of some groundfish species, notably lingcod, sablefish, and brown rockfish, is being studied in the U.S. at the Northwest Fisheries Science Center (NWFSC, NOAA, Seattle; http://www.nwfsc.noaa.gov/research/divisions/reutd/marineenhance.cfm and www.nwfsc.noaa.gov/publications/issuepapers/pdfs/reut6203.pdf). Extensive aquaculture of at least one rockfish species, *Sebastes schlegeli*, occurs in Asia, underscoring the feasibility of groundfish culture.

Wild groundfish may be affected by regional aquaculture activities that produce non-groundfish species. For example, oyster and other bivalve culture in coastal regions may affect groundfish by providing habitat, affecting prey abundance, or by altering water quality. Whether such effects would be positive or negative has not been established experimentally owing to the difficulty of conducting controlled field studies in such areas. Salmon net pen aquaculture has been linked to many localized environmental problems, including eutrophication, hypoxia, and disease introduction; Kent *et al.* (1998) found that groundfish near a salmon net pen were infected with viral and bacterial infections previously only seen in pen-reared salmon. Further studies assessing links between groundfish ecology and non-groundfish aquaculture practices would be valuable.

Aquaculture has changed the global fish market because fresh, domesticated finfish and shellfish are now available in large quantities at all times of the year. These resources are cheaper to produce than wild finfish and shellfish, which has driven seafood prices down. To remain competitive, groundfish managers, harvesters and processors have attempted to allocate harvest more evenly over the course of a calendar year (*e.g.*, Chapter 7 of the 2009–2010 Groundfish EIS, avaliable at http://www.pcouncil.org/groundfish/current-season-management/). How this temporal allocation of fishing mortality will affect groundfish ecology is unclear, as is the impact of changing price structures caused by global aquaculture.

8. Management of Enhancement Activities

As referred to in the “Management of Aquaculture” section, researchers at the NWFSC have undertaken captive breeding studies for lingcod, sablefish, and many rockfish species. This research covers topics such as physiology, nutrition, pathology, developmental biology, and optimal conditions for rearing larvae, with a long-term goal of large-scale culturing (see http://www.nwfsc.noaa.gov/research/divisions/reutd/marineenhance.cfm and http://www.nwfsc.noaa.gov/publications/issuepapers/pdfs/reut6203.pdf).

As of this writing, there have been no artificially reared larval or juvenile groundfish releases (akin to the release of hatchery-reared Pacific salmon smolts) into Pacific Coast waters of the U.S. As captive breeding methods at the NWFSC are developed and refined, subsequent research (as listed in the issue paper cited above) will shift to:

- establishing captive broodstocks of marine species to provide offspring for research;
- determining appropriate conditions for using hormonal and environmental manipulation to stimulate and synchronize spawning;
- developing egg incubation, larval culture, and juvenile rearing technologies;
- developing environmentally-sound aquaculture techniques, feed and health-management practices for rearing juveniles to maturity and spawning;
- developing rearing technologies that are both cost-effective and environmentally friendly; and
- investigating the genetic and ecological effects of released fish on wild populations.

Longer-term groundfish enhancement efforts noted in the issue paper include:

- establishing and maintaining captive broodstocks for future research;
- raising sablefish and rockfish broodstocks under photoperiods that have been shifted to provide offspring out of season (doubling the amount of research that can be done on critical larval stages);
- training state biologists, tribal members and entrepreneurs in large-scale rearing technologies;
- conducting stock-enhancement aquaculture trials in cooperation with state and tribal fisheries agencies.

Despite the groundfish stock enhancement research focus described above, there are no plans for artificial groundfish propagation listed in the current FMP or the groundfishing EIS.

Another means of groundfish enhancement is creating or restoring habitat that promotes groundfish production. Groundfish, such as rockfish, clearly aggregate around artificial substrates such as oil and gas platforms off the California coast, and there is considerable support from multiple public sectors to preserve decommissioned platforms as artificial reefs although more research is needed as to the suitability of oil platforms as productive groundfish habitat (Helvey, 2002). Restoration of large kelp species, which form dense stands that provide habitat for nearshore groundfish and valuable recruitment substrate and nursery habitat for juveniles of many inshore and offshore species, has been undertaken in many areas. For example, in Southern California waters, the California Coastkeeper Alliance and NOAA have a project in which laboratory-reared kelp sporophytes are transplanted to reefs in the wild (see details at http://www.cacoastkeeper.org/). The transplants are monitored regularly, and potential grazers, such as sea urchins, are relocated to preserve kelp growth. Other researchers have used plastic kelp blades which act as a mechanical defense for living kelp against sea urchins in Southern California waters (Vasquez and McPeak, 1998).

As with any project designed to increase groundfish abundance, responses to habitat enhancement will be difficult to monitor because of the long generation times and unpredictable recruitment success of many groundfish species. The inherent difficulty in observing and enumerating these species in non-trawlable habitats adds further complication.

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2.8 Progress Toward Ecosystem Approaches to Management – Fisheries

To various degrees, the country profiles discussed above have responded to the explicit request to identify the extent to which fisheries management in each country is developing an EAM. This responds to part of the charge to WG 19. In addition, there has been attention to broader questions of how an EAM can be implemented across sectors. As a means of documenting the ability of countries to implement EAM, WG 19 devised a template (Appendix 2) to allow reporting of progress towards EAM. In the experience so far from Canada and the U.S., we are in the early stages of implementing an EAM for fisheries.

WG 19 explored various ways to identify how a country may take on a full-scale EAM (Table 2.8.1). In the Working Group approach, this would require that additional sectoral approaches to EAM be considered and that eventually an integrated approach to ocean management across all sectors be made.

WG 19 members from each country reviewed the list of EBM components in the Fisheries Management Sector matrix (Table 2.8.1); only Canada and the U.S. reported on progress in their respective country in using each of those components under each management category. The scoring system used is given below, followed by an example of a completed matrix for Canada and the U.S. (Table 2.8.2):

1. Use this component sometimes or a little
2. Use this component a moderate amount
3. Use this tool frequently or a lot

Table 2.8.1 Fisheries management sector – Conceptual matrix.

EBM component [management tool]	**I. Traditional resource management**	**II. Single-sector EBM fisheries**	**III. Integrated multisector EBM**
Define ecosystem boundaries	Defined by fishing areas	Defined by management around ecosystem boundaries	Area-based management using ecosystem principles
Stock assessments	Single species stock assessments	Single species stock assessments with consideration of ecological interactions	Fishing assessed relative to other activities and ecosystem services
Harvest level	MSY is the management target for key species	Harvests consider other ecosystem variables (*e.g.*, biodiversity, habitat, *etc.*)	Considers non-fishery and fishery interactions (cumulative effects)
Cap on total ecosystem removal	Sum of all captures (including bycatch)	Examine effect of total captures on total fishery production	Examines cumulative capture effects on ecosystem
Specific protection of prey species	Prey species are not considered except as a target species	Managed use of prey species relative to impacts on other fish species	Prey considered for their roles in food webs
Use of ecosystem information from monitoring in management; a) physical data and b) biological data	a) generally not considered b) fishery-dependent data or single-species fishery-independent data	Used to manage fisheries in an ecological context	Used to manage all impacts on the ecosystem
Species capture accounting (logbooks, observers, VMS)	Focus on target species only	Focus on all exploited species (including discards and bycatch)	Focus on all species, *e.g.*, biogenic habitat, turtles, mammals, birds

Table 2.8.1 Continued.

EBM component [management tool]	**I. Traditional resource management**	**II. Single-sector EBM fisheries**	**III. Integrated multisector EBM**
Bycatch/discard management	Seldom done	Bycatch and discard controls on exploited species, *e.g.*, selective gears, closed area	Bycatch and discard management of all species, *e.g.*, selective gears, closed area
Seasonal closures	Focus on single species, *e.g.*, for reducing gear conflicts, protection of spawning populations	Focus on exploited species	Management of all species
Area closures	Focus on single species, *e.g.*, for limiting gear conflicts, protection of spawning areas and habitat	Focus on exploited species	Management of all species
Protect vulnerable and rare species	Not generally considered	Focus on exploited species, *e.g.*, depleted species management	Management of all species and processes, *e.g.*, biogenic habitat, availability of prey
Endangered or threatened species [Species at Risk]	Not important unless required by law	Specific measures taken to mitigate impacts of fisheries	Specific measures to mitigate impacts on all species at risk from human activities
Management plans	Single-species based management	EBFM, based on species complexes, multiple species interactions and habitat	IEM, *e.g.*, using suite of available management tools across sectors
Environmental impact assessment (EIA) of management activities	As required by law	As required by law with emphasis on fishing impacts in ecological context	EIA applied to multiple sectors as required by law
Vessel [Location] Monitoring Systems	Limited use for fishing	More extensive use across fleets for fishery monitoring	Monitoring of all vessel activity/safety, *etc.*
Limited fishing effort	Minimal application for fishing – primarily for economic considerations	Improves fisheries management for ecological reasons	Effort limitation to mitigate impacts on all species at risk from human activities
Habitat protection	Relatively little consideration, except as an obstacle (gear hazard) and protection of single-species spawning and nursery grounds	Protect habitat for ecological reasons to improve fisheries or reduce damage from fisheries	Protect habitat relative to cumulative impacts of all sectors
Biodiversity [species, population, genetic] management	Not generally considered, except to ensure availability of the targeted species or stocks	Consider ecological effects of fishing on community structure and function	Consider cumulative impacts on ecosystem structure and function from all sectors
Cultural heritage preservation (*e.g.*, historical or subsistence fishing, recreational fishing)	Generally not considered by traditional fishery management	Considered in ecological fisheries management as a legacy value	Considered as a component of cumulative effects by all sectors
Species enhancement	Single-species population rebuilding and enhancement	Enhancement of species in ecological and genetic contexts (habitat, trophic structure, *etc.*)	Ecosystem enhancement and/or restoration; integration of enhancement across sectors

EBM = Ecosystem-based management, MSY = Maximum sustainable yield, VMS = vessel monitoring system, EBFM = Ecosystem-based fisheries management, EIM = Integrated ecosystem management, EIA = Environmental impact assessment

Table 2.8.2 Ecosystem approach to management (EAM) fisheries mangement sector matrix examples for Canada and the U.S.

	I. Traditional resource management		**II. Single-sector EBM fisheries**		**III. Integrated multisector EBM**	
EBM component	**Canada**	**U.S.A.**	**Canada**	**U.S.A.**	**Canada**	**U.S.A.**
Define ecosystem boundaries	3	3	2	2	–	–
Stock assessments	3	3	1	2	–	–
Harvest level	3	3 (MSY as limit)	1	1	–	1
Cap on total ecosystem removal	3	2	–	–	–	–
Specific protection of prey species	3	3	1	2		1
Use of ecosystem information from monitoring in management;						
a) physical data	3	2	1	3	–	–
b) biological data	3	3	1	3	–	–
Species capture accounting (logbooks, observers, VMS)	3	–	2	3	–	2
Bycatch/discard management	3	–	2	3	–	2
Seasonal closures	3	3	–	2	–	1
Area closures	3	3	–	2	–	1
Protect vulnerable and rare species	–	–	2	3	–	2
Endangered or threatened species [Species at Risk]	–	–	–	2	3	2
Management plans	3	–	1	3	–	1
EIA of management activities	–	–	2	3	–	2
[Location] VMS	3	3	–	2	–	–
Limited fishing effort	3	3	–	1	–	–
Habitat protection	3	–	1	3	–	1
Biodiversity [species, population, genetic] management	3	3	–	–	–	–
Cultural heritage preservation (*e.g.*, historical or subsistence fishing, recreational fishing)	3	2	–	2	–	–
Species enhancement	3	3	–	–	–	–

VMS = Vessel Monitoring System, EIA = Environmental impact assessment, MSY = maximum sustainable yield

At present there is considerable discussion about which approach to management should be used and what would be the differences between approaches. Table 2.8.3 builds off the fisheries oriented conceptual matrix (Table 2.8.1) and the examples of how it could be used to guage progress toward an ecosystem approach to fisheries management (Table 2.8.2). In Table 2.8.3 we explore how an ecosystem approach could be implemented across multiple sectors in integrated multisector ecosystem-based management. An integrated multisector approach clearly requires taking into account different uses and evaluating trade-offs among uses, including higher priorities for protecting habitat, biodiversity and aesthetic values.

Similar approaches could be developed for other key sectors of economic and management significance, *e.g.*, aquaculture, wildlife, shipping, and energy in the North Pacific in the coming years, as appropriate.

Table 2.8.3 Progress measurement actions in ecosystem approaches in ocean management (from single sector toward integrated multisector management for fisheries as conceptualized in Table 2.1.3).

EBM Component	I. Traditional resource management	II. Single-sector EBM fisheries	III. Integrated multisector EBM
Define ecosystem	Define fishing areas	Define management around ecosystem boundaries	Space based zoning using ecosystem principles
Harvest rates	At or above MSY	Conservative – below MSY	Subject to ecosystem context
Cap on total removals	Best practice is sum of MSY of target species	Examine effect of total removals on ecosystem [including bycatch and harvest effects]	Examine cumulative impacts on ecosystem
Stock assessments	Single species stock assessments	Single species stock assessments with ecosystem interactions factored in	Fishing assessed relative to other activities and ecosystem services
Protection of prey species	Prey species target of fishing or otherwise not considered	Limited use of prey species relative to other fish species management, *e.g.*, ban on industrial harvests	Prey considered for its contribution to food webs for all species
Use of ecosystem information, Physical Biological	Not considered	Use to understand the ecosystem relative to fisheries	Use to understand the ecosystem relative to all activities
Catch accounting	Accuracy – low?	Accuracy high, *e.g.*, observers	Only one of metrics relevant to ecosystem
Bycatch/discard accounting	Seldom done – estimated	Accuracy high, *e.g.*, with observers [fish, marine mammals, seabirds, other	Only one of metrics relevant to ecosystem
Closed areas [broad definition of MPAs]	Sometimes for reducing gear conflicts, protect nursery areas	Significant use to protect fish and habitats utilized by fish	Significant use to protect key features, vulnerable species
Protect vulnerable and rare species	Not important	Important in context of fisheries	Important to protect key features, vulnerable species
Endangered or threatened species [Species at risk]	Not important unless required by law	Specific measures taken to mitigate impacts of fisheries	Specific measures to mitigate impacts of human activities
Management plans	Single species	Species complexes, multiple species interactions	Ocean zoning and plans
Environmental assessment	As required by law	As required by law with emphasis on fishing in ecosystem context	EA applied to multiple sectors
Use of VMS	Not likely	As a way of monitoring fishing behavior	Monitoring a vessel activity / safety, *etc.*
Limiting fishing effort	Minimal – primarily economic consideration	Effort limitation improves management for ecosystem concerns and to limit ecosystem impact	Balance of marine uses for sustaining ecosystem health
Habitat	Relatively little consideration except as objective hazard	Protect habitat relative to feedback in fisheries [minimum] protect habitat from damage from fisheries	Protect habitat relative to cumulative impacts of all sectors
Biodiversity	Ignore biodiversity effects in fished populations – deny impacts	Consider ecosystem effects on biodiversity [species, population, genetic – ecosystem structure from fishing	Consider ecosystem effects on biodiversity [species, population, genetic – ecosystem structure from all sectors
Natural heritage/ preservation	Seen as threat to fishing – unnecessary	Should be considered in fisheries management – legacy value	Should be considered as part of mix of cumulative effects of all sectors

2.9 Relevant National Marine Ecosystem Monitoring Approaches

An initial term of reference for WG 19 was to describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Key information gaps and research and implementation challenges were to be identified. Working Group members informally reported on national monitoring efforts at the first two working group meetings. However, after reviewing the nature of the work already completed as part of the PICES/Census of Marine Life/IPRC Workshop on "*Impact of Climate Variability on Observation and Prediction of Ecosystem and Biodiversity Changes in the North Pacific*" (Alexander *et al.*, 2001) on summarizing national monitoring and modeling efforts, this term of reference was deemed to be a duplication of that effort. WG 19 focused instead on linking monitoring efforts to our third term of reference on indicators. In the section on Ecosystem Indicators that follows, member countries focused on reporting on the availability of monitoring information that could be used to report on ecosystem status through key indicators identified by the Working Group. The following is a summary provided by WG 19 of the key considerations of monitoring with respect to implementing ecosystem approaches to management which requires developing a monitoring and reporting system that provides information on ecosystem status, threats, and success of management efforts relative to stated management objectives.

- A common set of indicators is proposed for PICES member countries to monitor ecosystem status with respect to fisheries impacts.
- Monitoring systems in place at the present time are sufficient for calculating many of these indicators of ecosystem status and change.
- Enhancements to the monitoring system are needed in all member countries to measure habitat, size-based indicators, benthic invertebrates, and total fishery removals.
- Predicting future ecosystem conditions will require advancement of a variety of models that incorporate human and climate factors.
- Further work is needed to define a broader set of human impact indicators outside of the fisheries context, including socio-economic.
- Understanding and communicating the main drivers of change in each region will be important.

2.9.1 Reference

Alexander, V., Bychkov, A.S., Livingston, P. and McKinnell, S.M. (Eds.) 2001. Proceedings of the PICES/CoML/IPRC Workshop on "Impact of Climate Variability on Observation and Prediction of Ecosystem and Biodiversity Changes in the North Pacific". PICES Sci. Rep. No. 18, 210 pp.

3 Ecosystem Indicators

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3.1 Introduction

Development and discussion of marine ecosystem indicators is currently a very active research topic worldwide. This is connected with the increased interest in moving forward with ecosystem-based management (EBM) of marine resources, and recognition of the need to index and summarise the state of marine ecosystems.

There are many types of indicators, including those of the physical environment (*e.g.*, climate), ecological, and socio-economic conditions. There is an entire professional journal devoted to the topic, called *Ecological Indicators*. Within marine systems, the most recent focus has been on developing indicators for ecosystem-based *fisheries* management (EBFM). Significant recent literature on this topic includes the symposium on "Quantitative ecosystem indicators for fisheries management" hosted in Paris in 2004 by the SCOR Working Group 119, of which a selection of papers were published in the *ICES Journal of Marine Science* (Vol. 62(3), May 2005; see the Introduction by Cury and Christensen (2005) and the afterward by Daan (2005)). Additional important reviews are by Degnbol and Jarre (2004), Fulton *et al.* (2004), Jennings (2005), and Link (2005). Important contributions focussed on the North Pacific are those by PICES (Jamieson and Zhang, 2005; Kruse *et al.,* 2006).

This section does not attempt an exhaustive and critical review of the 'state' of marine ecosystem indicators. Rather it provides a summary of the emerging consensus views on indicators of marine ecosystems, and makes recommendations applicable to North Pacific waters of PICES interest. In addition, this section attempts to take a broader view of indicators for EBM of marine systems rather than the narrower application to fisheries management (even though most of the research to date has focussed on this narrower application).

3.1.1 Classes of Indicators

The desire to develop indicators for EBM is rooted in the need to reduce the complexity of natural systems to an ideally small set of synthetic indices of ecosystem state, and to measure the progress of management towards the policy objectives for that ecosystem. In human health, an analogy for indices of ecosystem state might be body temperature and heart (pulse) rate which allow a rapid assessment of the immediate condition but without any indication of cause.

The PICES report on ecosystem indicators for the North Pacific (Kruse *et al.,* 2006, pp. 95–96) recognised a distinction between 'contextual' and 'management' indicators. Contextual, or 'audit', indicators provide information on the background conditions, which may include conditions over which humans have no control. Indicators of atmospheric and oceanographic climate such as temperature, salinity, sea ice, plus synthetic indicators such as the Southern Oscillation and Pacific Decadal Oscillation indices, are examples of contextual indicators. These have also been called 'descriptive' indicators by Degnbol and Jarre (2004). Management, or 'control', indicators summarise information on conditions over which humans have (some) direct control, and conceptually should be applicable to measure the results of management actions. Degnbol and Jarre (2004) call these 'performance' indicators which compare actual conditions with some desired set of conditions, such as a management goal. Degnbol and Jarre (2004) identify two additional classes of indicators which address mostly socio-economic conditions. These are 'efficiency' indicators, which relate environmental pressures to human activities, and which these authors suggest are highly relevant for policy-making. They provide an example of the volume of fuel per ton of fish caught as an indicator of energy efficiency. Vessel subsidies per revenue from fishing may be another example. The other class of indicators are 'total welfare' indicators which provide some measure of overall sustainability (which includes human social systems).

All these classes of indicators, with the exception of the contextual or descriptive indicators, are most useful (perhaps most meaningful) when applied in the context of specific objectives – *i.e.*, they indicate what the current conditions of the system are in relation to some desired state or condition. In this sense, indicators are best developed and applied within the broad concept of EBM, which should start with explicit statements of the objectives for management (*e.g.*, O'Boyle and Jamieson, 2006).

A framework that has gained broad acceptance in other fora, and which is beginning to be explored for marine systems, is the Driver-Pressure-State-Impact-Response (DPSIR) concept originally developed by the Organisation for Economic Co-operation and Development (OECD; *e.g.*, Smeet and Weterings, 1999; Rapport and Singh, 2006). In this framework Driving forces, such as climate change or human population growth, exert Pressures on the environment (*e.g.*, fishing effort) which change the State of the environment with possible Impacts to the functioning of the system. Societies may then provide a Response to these changes by modifying the Pressures (Degnbol and Jarre, 2004). Each of the levels in this DPSIR framework, with the possible exception of the Response (which is a policy action), use indicators to summarise their condition. Jennings (2005, p. 212) noted that "In a management framework supported by pressure, state, and response indicators, the relationship between the value of an indicator and a target or limit reference point… provides guidance on the management action to take". There needs to be a close relationship between indicators and clear policy objectives.

3.1.2 Characteristics of Good Indicators

Degnbol and Jarre (2004) and Rice and Rochet (2005) provide criteria for desirable indicators. Although directed towards EBFM, these criteria are sufficiently general to apply to ecosystem-based marine management more broadly. General principles are that the indicator should be sensitive (to the process being indexed), observable, acceptable, and related to the management objectives (Table 3.1.1). The best indicators would be those which are easily measured, cost effective, and easily understood (interpreted). In addition, Rice and Rochet (2005) provide a step-wise process for selecting the suite of ecosystem indicators:

Step 1 determine user needs,
Step 2 develop a list of candidate indicators,
Step 3 determine screening criteria,
Step 4 score candidate indicators against the screening criteria,
Step 5 summarise the scoring results,
Step 6 decide how many indicators are needed,
Step 7 make the final selection,
Step 8 report on the chosen suite of indicators.

However, as noted by Rochet and Rice (2005), the process of selection is not without difficulties. Experts may provide very different scores and these differences must be confronted through discussion in order to reach compromise on a final suite of indicators. One possibility is that test sets (data collected under known conditions) or simulations (*e.g.*, Fulton *et al.*, 2005) are used to challenge the indicators and verify their performance under a range of conditions. This can clarify the usefulness of candidate indicators.

3.1.3 Potential Indicators

In regard to the feasibility of developing indicators to assist with the management of marine resources, the 2004 Paris symposium allowed several conclusions to be drawn (Cury and Christensen, 2005):

- defining and implementing indicators is achievable with present knowledge, data, and frameworks;
- no single indicator describes all aspects of ecosystem dynamics; a suite of indicators is needed (covering different data, groups, and processes);
- environmental and low trophic-level indicators capture environmental change and bottom-up effects,
  - global effects of environmental change (*e.g.*, regime shifts) on higher trophic levels are not well captured by most indicators (at least individually, suites can elucidate these impacts);
- high trophic-level indicators (*e.g.*, birds, marine mammals) summarise changes in fish communities,
  - top-down effects can be quantified using trophodynamic indicators;

- size-based indicators are promising for characterizing fish community dynamics in a context of over-exploitation;
- ecosystem-based indicators are conservative,
  - they only show if the ecosystem is strongly affected, so trends and rapid changes must be evaluated by research and/or management;
- interpretation of indicators requires scientific expertise because of potential error and bias in their analysis;
- some indicators are better used for surveillance than for prediction. Regime shifts illustrate a situation where surveillance indicators may be useful;
- in an ecosystem approach to fisheries management, the objective is not to find the best indicator but rather a relevant suite of indicators with known properties;
- a strong feedback between scientific expertise and management is necessary to improve indicators and their practical use.

In terms of applications to *fisheries* management, a consensus is emerging on a core set of ecosystem indicators (*e.g.*, Degnbol and Jarre, 2004; Fulton *et al.*, 2004; Fulton *et al.,* 2005; Shin *et al.*, 2010). Ideally, this set should use species with fast turnover rates (to provide the potential for early warnings), species which are directly impacted (*e.g.*, by fishing, such as target species), species which are habitat-defining, and should include species at top trophic levels as these integrate and may be sensitive to a number of changes in their environments. Pelagic species that are highly variable (*e.g.*, in abundance) and which may track short-term environmental variability closely, may provide early warnings of changes but will have high noise-to-signal problems, *i.e.*, they may not indicate emerging trends well. Demersal and/or longer-lived species which dampen short-term variability may be better indicators of significant changes in system states. The emerging consensus list of core indicators (Table 3.1.2) includes the relative biomass of several groups of species; the biomass

Table 3.1.1 Desirable properties of indicators for marine ecosystem-based management (after Rice and Rochet, 2005).

Criteria	Sub-criteria
Concreteness	• Concrete property, or abstract concept? • Measureable units, or relative scale? • Directly observable, or output of models?
Theoretical basis	• Basis credible, or debated? • If derived from empirical observations, are the concepts consistent with established theory?
Public awareness	• Does it have high public awareness already? • Is its meaning readily understood? • Already enshrined in legislation somewhere?
Cost	• Uses measurement tools that are widely available and low cost?
Measurement	• Can variance and bias be estimated? Is it high or low? • Are the accuracy and precision of data collection methods known? • Is it subject to vagaries of different sampling gears? • Is it highly variable seasonally? Geographically? • Does it have high taxonomic specificity?
Availability of historical data	• Are historical data available? From how large an area? • Are the uncertainties of these historical data known? • Are these historical data freely available?
Sensitivity	• Does the indicator respond smoothly, monotonically, and with high slope?
Responsiveness	• Does the indicator respond rapidly (*e.g.*, within 1–3 years) of changes, or on longer (*e.g.*, decadal) scales?
Specificity	• How specific is the indicator to the processes being indexed?

ratios among these various groups; the extent of habitat defining epifauna and macrophytes; synthetic properties such as size spectra and diversity; various properties from the fisheries such as total removals, maximum length, size-at-maturity; and biophysical features such as temperature, chlorophyll *a* concentrations, nutrients, and contaminants. Note this list includes both contextual (descriptive) and management (control) indicators. The latter class of indicators, such as those from fishing activities, need to be related to the objectives (via target and limit reference points, directions, *etc.*; Fulton *et al.*, 2004; Link, 2005) in order to identify the management actions that must be taken to achieve that objective. The contextual indicators provide the background for these actions, and *may* suggest how the system might be changing. Many of these indicators are derived from fishery-independent surveys and several, in particular among the contextual indicators, are best interpreted as part of a time series. Both of these points suggest that a combination of fisheries-dependent and fisheries-independent information is required, which may not be available for all systems. The extent to which data are available in each of the PICES member countries to develop these sets of indicators is shown in Table 3.1.3.

Moving beyond the issue of fishing to embrace ecosystem-based marine management will require developing a broader set of objectives, and their associated indicators, to include other human uses and activities in marine systems. Examples are contaminants, marine transport, and coastal use issues such as aquaculture and development. These issues may be more appropriate for local- or regional-scale management plans although some, such as marine transport and non-indigenous invasive species, will have larger spatial scales similar to those for fishing. In addition, monitoring and indexing of atmospheric and ocean climate changes, and large-scale changes in ocean productivity, will also likely take a higher profile. The majority of these latter indices will be contextual, since humans are unlikely to have management control in the foreseeable future over climate variability. Much more work also needs to be done with developing indicators of these human uses and stresses on marine ecosystems, including socio-economic indicators that link to marine ecosystem status.

Table 3.1.2 Core set of consensus indicators for ecosystem-based fisheries management (from Fulton *et al.* 2004; Link, 2005).

1	Relative biomass	Example of gelatinous zooplankton, cephalopods, small pelagics, scavengers, demersals, piscivores, top predators
2	Biomass ratios	Piscivore:planktivore; pelagic:demersal; infauna:epifauna
3	Habitat-forming taxa	*e.g.*, proportional area covered by these epifauna and/or macrophytes
4	Size spectra	Slopes of community size spectra and their changes can be particularly strong indicators of community level changes
5	Taxonomic diversity (richness)	*e.g.*, based on species counts
6	Total fishery removals	Catch + discards + bycatch
7	Maximum (or mean) length	Maximum (or mean) length across all species in the catch
8	Size-at-maturity	Example of main target species, bycatch, and top predators
9	Trophic level or trophic spectrum of the catch	Average trophic level or spectra of the catch (*e.g.*, Gascuel *et al.* 2005) (may require that diet data be updated periodically)
10	Biophysical characteristics	*e.g.*, temperature, salinity, sea ice (where present), chlorophyll *a*, primary production, atmospheric indices (*e.g.*, PDO).

Table 3.1.3 Current data available among PICES member countries to calculate the Indicators in Table 3.1.2. Specific regions within countries are: Canada – Pacific North Coast Integrated Management Area; China – Yellow Sea; Japan – Kuroshio Current; Republic of Korea – Yellow Sea; Russia – Far-Eastern seas and adjacent Pacific Ocean waters; U.S. – Eastern Bering Sea.

		Have (at least) some of these Indicators been calculated regularly?						Are time series of data available to calculate more of these Indicators?					
		Canada	China	Japan	Korea	Russia	U.S.	Canada	China	Japan	Korea	Russia	U.S.
1	Relative biomass												
	- gelatinous zooplankton	–*	Y	–	Y	Y	Y	–	–	–	Y	Y	Y
	- cephalopods	–	Y	Y	Y	Y	–	–	–	Y	Y	Y	–
	- small pelagic fishes	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	- scavengers	–	–	–	some	Y	–	some	–	–	some	Y	Y
	- demersals	Y	Y	Y	Y	Y	–	Y	Y	Y	Y	Y	Y
	- piscivores	Y	Y	Y	Y	Y	–	Y	Y	Y	Y	Y	Y
	- top predators	Y	Y	Y	some	Y	Y	Y	Y	Y	some	Y	Y
2	Biomass ratios												
	- piscivore:planktivore	–	Y	Y	Y	some	–	Y	Y	Y	Y	Y	Y
	- pelagic:demersal	–	Y	Y	Y	–	–	Y	Y	Y	Y	Y	Y
	- infauna:epifauna	–	–	–	–	–	–	–	–	–	some	Y	–
3	Habitat-forming taxa												
	- nearshore	Y	some	some	some	Y	–	Y	–	some	some	Y	–
	- offshore	–	some	–	some	Y	Y	–	–	–	some	Y	Y
4	Size spectra	–	Y	–	Y	Y	Y	–	Y	–	Y	Y	Y
5	Taxonomic diversity	some	Y	some	Y	some	–	some	Y	some	Y	some	Y
6	Total fishery removals	Y	some	Y	some	Y	Y	Y	Y	Y	some	Y	Y
7	Maximum (or mean) length	–	Y	Y	Y	Y	–	Y	–	Y	Y	Y	Y
8	Size-at-maturity												
	- target species	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	some
	- bycatch	–	–	–	Y	Y	–	–	–	–	Y	Y	some
	- top predators	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
9	Trophic level or trophic spectrum of the catch	Y	Y	Y	Y	some	Y	Y	Y	Y	Y	Y	Y
10	Biophysical characteristics	some	Y	Y	Y	some	some	some	Y	Y	Y	some	some

* Dashed entries mean "No".

An example of developing indicators for this broader concept of EBM is the Ecosystems Considerations appendix prepared for the Bering Sea and Gulf of Alaska by the U.S. National Marine Fisheries Service (NMFS) to supplement their regional stock assessments (http://access.afsc.noaa.gov/reem/EcoWeb/index.cfm; see also Livingston *et al.,* 2005; Livingston, 2006). This report includes information on climate, fishing, and individual components such as nutrients and marine mammals. It also develops aggregate indicators of ecosystem production and composition from a variety of data sources. Ultimately, the report is planned to rely extensively on the indicators as well as outputs from ecosystem models; at present, however, these models remain in various stages of development and validation.

The report relies heavily on using multiple indicators to interpret ecosystem change and processes influencing change. For example, groundfish recruitment anomalies are evaluated relative to indicators of climate variability and harvest policies. Time trends in trophic level of the catch are weighed in evaluations of sources of change in groundfish production and size diversity. Broad-scale ecosystem management objectives have been expressed, such as maintaining pelagic forage availability to top trophic predators and maintaining diversity. However, more input is needed from policy-makers to define more specific ecosystem management objectives. Similarly, research is continuing to identify important ecosystem thresholds to define management actions. In the absence of such thresholds, a pilot effort to develop a more explicit ecosystem-based approach to management in the Aleutian Islands has incorporated indicators into a risk assessment framework as a tool for managers seeking to identify priority short- and long-term management activities (http://www.fakr.noaa.gov/npfmc/current_issues/ecosystem/AIFEP507.pdf).

As a caution, Kruse *et al.* (2006) note that most of the indicators mentioned above provide information on *current* conditions rather than predicting future states. Trends may be extended and forecasts provided for those indicators for which (sufficiently long) time series are available, but this assumes that future conditions (and indicator performance) will remain similar to past indicator performance. This may not be true under progressive climate change or significant regime shifts in which, for example, a lack of significant sea ice in the Bering Sea may make this indicator useless for that region. Similarly, not all indicators will be appropriate for all PICES regions. Hopefully a core set of common indicators can be developed, but careful selection and research on their application to, and appropriateness for, each region will be necessary.

The core set of indicators in Table 3.1.2 could be a starting point of discussion for information to incorporate into future PICES North Pacific Ecosystem Status Reports. In order for the indicators to be placed into a management context for a region, the main drivers of change will need to be identified since these may vary across regions. These drivers will identify what pressure measurements (*e.g.*, bottom trawling effort, catch removals, nutrient inputs, *etc.*) need to be included in addition to the ones already in Table 3.1.2.

3.1.4 Communicating Indicators

Developing indicators to assist with marine EBM will be pointless if the meaning of these indicators is not understood. Developing appropriate methods to communicate the results and interpretation of indicators to other scientists, marine managers, policy-makers, and the public is a central task of developing these indicators (*e.g.,* see the earlier section on "Characteristics of Good Indicators"). Kruse *et al.* (2006, p. 101) provide a group report with some thoughts on these issues, and the U.S. NMFS Ecosystems Considerations appendix explores different methods. A 'traffic light' approach (*e.g.,* Caddy, 2002; Choi *et al.,* 2005) provides a method to quickly tabulate a large number of indices and illustrate how they are changing in time, but it also removes what might be important nuances and details. Central considerations for communicating indicators must be to determine the intended audience, recognise whether the indicators are contextual (and therefore, mostly for information) or management (and therefore, potentially requiring a management action), and the extent of confidence in the indicator – *i.e.*, how certain are the input data and how good is the relationship between the indicator and the process it is indexing? Ultimately, it is important to recognise the subjective nature of this communication process, and not to expect any indicator to be simply a re-statement of data.

3.1.5 Recommendations

1. PICES should explore the use of the consensus suite of indicators (Table 3.1.2) in each of its regions to develop a common set of indicators to be included in each iteration of the PICES North Pacific Ecosystem Status Report;
2. PICES should use the WG 19 Ocean Management Activity reports and Fishery Science Committee (FIS) and Marine Environmental Quality Committee (MEQ) inputs to help identify region-specific drivers of change and pressure measurements in order to interpret status indicators in Table 3.1.2;
3. PICES should establish collaborations with social scientists to develop socio-economic indicators which include the effects marine EBM, such as cost-profit and employment in fishing activities. The ultimate goals should be to develop indicators which describe the coupled marine social-ecological system.
4. PICES should recommend a research activity to explore the use of additional indicators for marine EBM in each of its regions, building from those outlined here and in the U.S. Ecosystem Considerations appendix.

3.1.6 References

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4 National Approaches Used to Describe and Delineate Marine Ecosystems and Subregions in the North Pacific

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4.1 Introduction

With marine ecosystems facing increasing and often unsustainable human demands, the need for comprehensive, integrated cross-sectoral resource management becomes ever clearer (Duda and Sherman, 2002). Many hold that the most responsible strategy is ecosystem-based management (EBM), wherein factors such as ecological interactions, socio-economic forces and human impacts are explicit components of monitoring, assessment and policy. While EBM has been variously defined by many authors, some concepts are pervasive across all definitions: it is spatially discrete; it is adaptive; it incorporates dynamics, interactions and uncertainty associated with physical, chemical and biological constituents; it emphasizes sustainability; and it considers human objectives, activities and impacts to be essential components (Arkema *et al.,* 2006). Because accounting for spatially explicit trends, processes and relationships is a main component of EBM, it follows that the spatial characteristics of marine ecosystems should be identified in order to provide a context for identifying stakeholders, defining objectives, conducting research, and implementing policies focused on sustainable management of species, goods and services (Juda, 1999; FAO, 2003, NOAA, 2004).

The six member countries of PICES are all moving toward EBM of marine resources (section 2), and must therefore, identify and characterize discrete areas of marine waters at scales relevant to scientists, managers, policy makers and stakeholders. This challenge is complicated by several factors. First, abiotic and biotic components of ecosystems are inherently dynamic in space and time. This fact is especially important in ecosystems that are structured by major coastal or ocean currents, as is the case for many of the large marine ecosystems (LMEs) in the PICES region (*e.g.*, Sherman and Tang, 1999). Such spatio-temporal dynamics will likely be altered by global climate change, though in different ways in different areas of the North Pacific. Second, marine ecosystems typically extend hundreds of kilometers offshore and often beyond the exclusive economic zone (EEZ) of a country. In many cases, the EEZs of multiple nations occupy the same ecosystem, often adjoining along extensive international borders. This fact can limit the ability of a country to monitor the full spatial extent of the ecosystem beyond its own territory, which in turn limits understanding of overall ecosystem function, structure and change. A related problem is that different countries may have different monitoring practices or objectives within the same ecosystem, which complicates ecosystem-scale data synthesis and interpretation. Finally, because EBM is, by definition, a multisector endeavor (Arkema *et al.*, 2006), it must account for suites of diverse resources, some of which may have very different spatial distribution or organization than others.

The challenges outlined above must be addressed if integrated management of local and transboundary ecosystems is to be achieved by PICES countries. That necessity is underscored by the Food and Agriculture Organization (FAO) of the UN, which states that the first step of an ecosystem approach to fisheries management is to identify the fisheries and the geographic area in which they exist (FAO, 2003). The same general statement could be applied to EBM of any resource. In practice, the FAO (2003) acknowledges that identifying the geographic area is an adaptive and iterative process, given that ecosystems have 'fuzzy' boundaries, and can be defined and re-defined along a broad, subjective hierarchy of organization as information, objectives and management relationships evolve. Nevertheless, it is clearly important for PICES member countries to engage in defining the spatial extent of marine ecosystems in the PICES region.

In this section, we outline some of the current practices that PICES member countries use to delineate ecosystems and, in some cases, ecosystem subregions in their territorial marine waters. At the 2005 PICES Annual Meeting in Vladivostok, Russia, WG 19 members were asked to compile national approaches to delineating marine ecosystems and subregions and compare these to existing or planned management and data reporting delineations. National reports on this task are presented below, starting with the People's Republic of China and moving clockwise around the Pacific Rim. Members were also asked to identify cooperative and collaborative efforts by adjacent countries to study and manage cross-jurisdictional areas and resources, with the goal of establishing common spatial definitions. We describe such collaborations in the Discussion, and also examine factors that will both impede and facilitate future collaborations.

4.2 National Summaries

4.2.1 People's Republic of China

The territorial marine waters that lie east of the People's Republic of China are dominated by the Yellow Sea and the East China Sea. Both are large, relatively shallow seas that are semi-enclosed within an array of continental land masses, straits, peninsulas and islands (Fig. 4.2.1). Oceanic and coastal currents, intense storms, large river inputs and high human population densities add considerable dynamic complexity to these ecosystems and affect some of the world's most productive, heavily exploited fisheries (Chen and Shen, 1999). Both seas are shared by multiple nations.

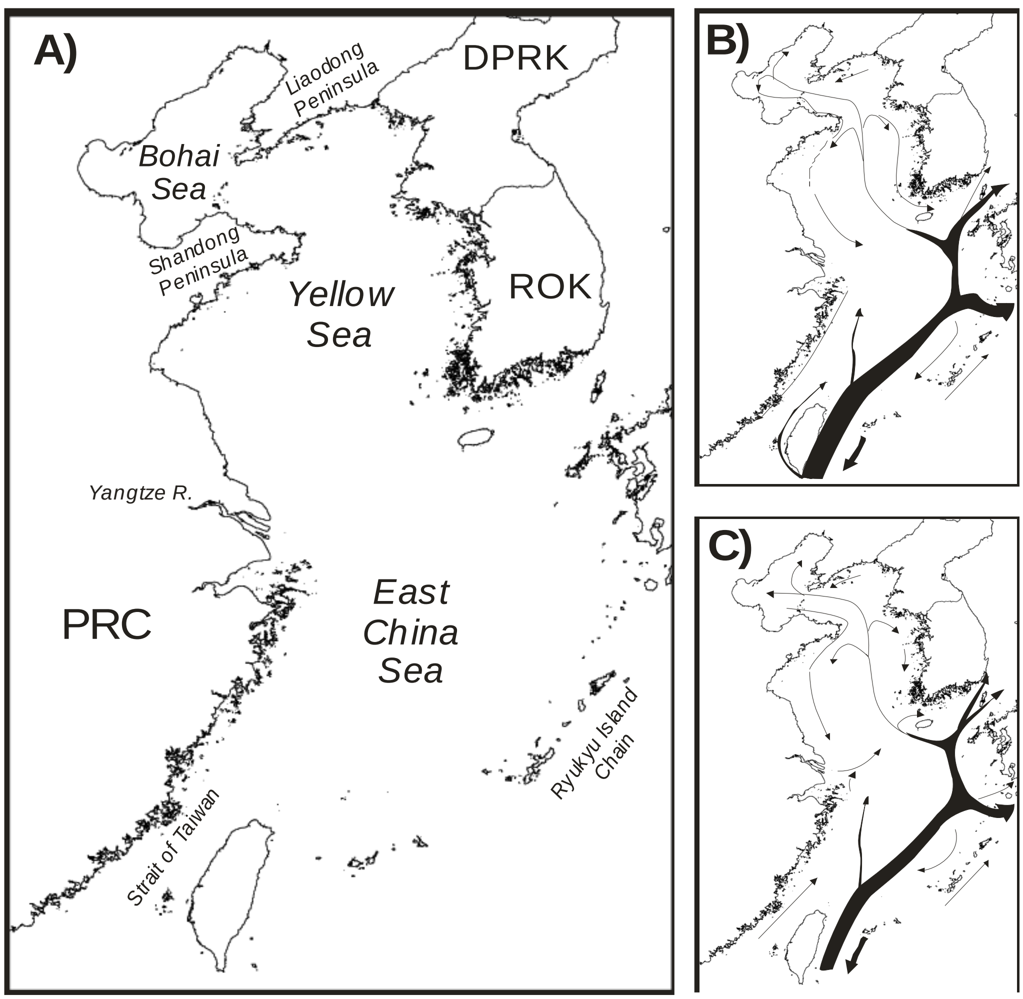

Fig. 4.2.1 Map of marine waters in PICES area waters off the coast of the People's Republic of China (PRC). Panel A shows general features; panels B and C show major currents in winter and summer, respectively (adapted from Chen and Shen, 1999).

Generally speaking, China has not formally defined or delineated marine regions or subregions, although its waters are broadly recognized as large marine ecosystems (LMEs) that are spatially defined by enclosing land masses (*e.g.*, Sherman and Tang, 1999; Sherman, 2006). The Yellow Sea LME is essentially bounded on the north and west by the Chinese mainland (north of the Yangtze River delta) and on the east by the Democratic People's Republic of Korea and the Republic of Korea. The Yellow Sea is quite shallow (mean depth $\bar{d}$ = 44 m) and lies entirely over the continental shelf. Its relatively cool, fresh waters are fed by several major rivers, including the Yangtze and Huang He. A major feature of the Yellow Sea is the Bohai Sea ($\bar{d}$ = 18 m), a large gulf formed by the Liaodong and Shandong peninsulas and heavily influenced by riverine inputs. The East China Sea LME is bounded approximately by the Yellow Sea, Korean Peninsula and Japanese island of Kyushu to the north, the Chinese mainland on the west, the island of Taiwan to the south, and the Ryukyu island chain to the east. At its eastern extent is the northerly flowing Kuroshio Current; its southern extent connects to the South China Sea LME through the Taiwan Strait. Compared to the Yellow Sea, the East China Sea is deeper ($\bar{d}$ = 270 m) and more variable bathymetrically, with 81% of its area over the shelf, 11% over continental slope, and the remainder over the deep Okinawa Trough to the west of the Ryukyu island chain. However, nearly all of China's Exclusive Economic Zone (EEZ) waters in the East China Sea are shallower than 150 m.

Although China has not formally delineated these waters, the spatio-temporal heterogeneity of physical, chemical and biological variables within the East China, Yellow and Bohai seas is well studied and widely documented (*e.g.*, Su, 1998; Chen and Shen, 1999). Fixed spatial delineations of these waters may be impossible due to the seasonal complexity of coastal and boundary currents in the Yellow Sea and East China Sea LMEs (Fig. 4.2.1). However, there are spatio-temporal generalizations that can be made. Li *et al.* (2006) examined over 70 years of oceanographic data from these waters and developed an index of 'spiciness' (the extent to which water is warm and salty); the equilibrium line (EL) of this index was intended to approximately differentiate the relatively cool, fresh, river-influenced Yellow Sea water mass from the East China Sea. Although the EL generally ran southwest from the southern coast of the Korean Peninsula to the Chinese mainland, its shape and stability were highly seasonal due to the dynamics of at least seven regional coastal and warm currents, the Kuroshio Current, and seasonal monsoons. Ultimately, they concluded that four major water masses (cold and dilute, warm and salty, mixed coastal, and mixed warm) exist in these two LMEs; the water masses are associated with certain currents and have distinct seasonal ontogenies (Li *et al.*, 2006). Su (1998) and Chen and Shen (1999) identified several other water masses within the East China Sea, seasonally defined by temperature, salinity and depth. Of note is a persistent mass of cool water near the bottom of the Yellow Sea (Su, 1998).

Similarly, empirical and statistical methods have been used to identify zones of distinct biological communities in relation to large-scale environmental variables. Chen and Shen (1999) concluded that zooplankton distributions in the East China Sea were controlled by the different water masses, with the highest zooplankton densities occurring near water mass convergences in the spring and summer. Jin *et al.* (2003) used a multivariate classification method to identify spatial and seasonal assemblages of commercially important fish in the Yellow and East China seas. They concluded that four distinct assemblages exist in spring, and four others in autumn. The assemblages were distinguished along two spatial axes: Yellow Sea *vs.* East China Sea and nearshore *vs.* offshore, based on environmental variables such as depth, temperature, salinity and dissolved oxygen (Table 4.2.1). The spatial arrangements, species compositions and dominance of pelagic *vs.* demersal species of the assemblages varied somewhat by season (Jin *et al.*, 2003), which underscores the spatio-temporally dynamic nature of these waters. Some of the differences in species composition relates to migratory species. For example, the aforementioned persistent cool water mass in the central to southern Yellow Sea (Su, 1998) provides an overwintering habitat for many commercially important, seasonally migratory species in the Yellow and Bohai seas, including small yellow croaker *Pseudosciaena polyactis*, largehead hairtail *Trichiurus lepturus*, Japanese anchovy *Engraulis japonicus*, penaeid shrimp *Penaeus orientalis*, and several mackerel species (Zhao, 1990). This water mass even supports large numbers of cold temperate species, including Pacific herring *Clupea pallasi* and a genetically isolated stock of Pacific cod *Gadus macrocephalus* (Grant *et al.*, 1987).

Table 4.2.1 Biological and environmental characteristics associated with major seasonal assemblages of commercially valuable fish in the Yellow and East China seas. The three most abundant species (by mass) in each assemblage are listed. Environmental data are means ± standard errors (Source: Jin *et al.*, 2003).

Assemblage	Key species	Depth (m)	T (ºC)	Salinity (psu)	DO (mg/L)
		Autumn, 2000			
AG1	*Harpodon nehereus, Pampus argentus, Setipinna taty*	33.4 ± 2.2	20.1 ± 0.3	31.8 ± 0.2	7.2 ± 0.1
AG2	*Engraulis japonicus, Liparis tanakae, Lophius litulon*	66.5 ± 3.7	11.5 ± 1.1	32.5 ± 0.1	6.6 ± 0.2
AG3	*Pseudosciaena polyactis, Trichiuris lepturus, Harpodon nehereus*	62.8 ± 2.9	20.7± 0.4	33.9 ± 0.1	6.0 ± 0.3
AG4	*Trachurus japonicus, Trichiuris lepturus, Psenopsis anomala*	104.0 ± 5.5	19.1 ± 0.5	34.4 ± 0.1	5.2 ± 0.2
		Spring, 2001			
SG1	*Lophius litulon, Pseudosciaena polyactis, Cleisthenes herzensteini*	50.6 ± 7.7	7.2 ± 0.3	32.2 ± 0.1	10.4 ± 0.1
SG2	*Pseudosciaena polyactis, Engraulis japonicus, Thryssa kammalensis*	57.4 ± 2.7	9.8 ± 0.3	32.9 ± 0.1	10.1 ± 0.1
SG3	*Acropoma japonicum, Engraulis japonicus, Trichiurus lepturus*	79.5 ± 3.4	17.7 ± 0.6	34.2 ± 0.1	7.7 ± 0.3
SG4	*Acropoma japonicum, Pagrosomus major, Seriola aureovittata*	116.6 ± 6.4	17.8 ± 0.4	34.5 ± 0.0	7.1 ± 0.3

4.2.2 Republic of Korea

The Republic of Korea is surrounded by three large, dynamic semi-enclosed seas, each of which is considered an LME (Sherman, 2006). East of the Korean Peninsula lies the East Sea, to the west is the Yellow Sea, and to the south is the East China Sea (Fig. 4.2.2; Huh and Zhang, 2005). All three ecosystems extend well beyond the EEZ of Korea. General characteristics of the Yellow and East China seas were outlined above in the National Summary for China. The East Sea is considerably deeper ($\bar{d}$ = 1700 m) than either of the other LMEs. Korean waters in the East Sea are strongly influenced by the North Korea Cold Current, part of the southerly flowing Liman Current that originates in the Sea of Okhotsk; and by the Tsushima Warm Current which moves north through the Korea Strait and causes upwelling along the east of the Korean Peninsula. These currents meet near the 40ºN parallel, creating a strong frontal region (Rebstock and Kang, 2003).

Delineation of Korean waters has been done primarily based on oceanographic characteristics. For decades, National Fisheries Research and Development Institute (NFRDI) researchers have surveyed seasonal oceanographic data (*e.g.*, temperature, salinity, seawater density, and zooplankton biomass at surface and 50-m depths) in the three seas (*e.g.*, Zhang *et al.*, 2000; Rebstock and Kang, 2003). Principal components analysis (PCA) and artificial neural network (ANN) analysis of these data revealed transitions among water masses (Zhang *et al.*, 2000; J. B. Lee, NFRDI, unpublished data). For example, the analyses spatially distinguished the relatively cool, fresh, river-influenced waters of the Yellow Sea from the warmer, saltier waters of the East China Sea and the even saltier, denser waters of the East Sea. Seasonal, interannual, interdecadal and stochastic climate variability is very important in determining the size and strength of current and frontal systems in this area (Zhang *et al.*, 2000; Rebstock and Kang, 2003). Surveys also reveal strong differences in the zooplankton communities; for example, chaetognaths have dominated the Yellow Sea zooplankton community since the 1980s, while copepods were most prevalent in the other seas (Rebstock and Kang, 2003).

Delineation of the LMEs in Korean waters has also been informed by the differences among fish communities (Kim, 2003; Rebstock and Kang, 2003). Importantly, many common fish species such as small yellow croaker and largehead hairtail move freely between the Yellow and East China seas. Thus, those regions may be most appropriately viewed as distinct but interconnected LMEs in terms of the conservation and management of some marine resources. In Korean waters of the East Sea, both cool water demersal and warm water pelagic fisheries are present, largely separated by the frontal region described by Rebstock and Kang (2003). Prominent fisheries in recent decades have included saury (*Cololabis saira*), Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*) and, more recently, mackerel and squid (*Todarodes pacificus*) (Park *et al.*, 1998; Zhang *et al.*, 2000) since an apparent regime shift in the late 1980s that brought warmer water into the East Sea.

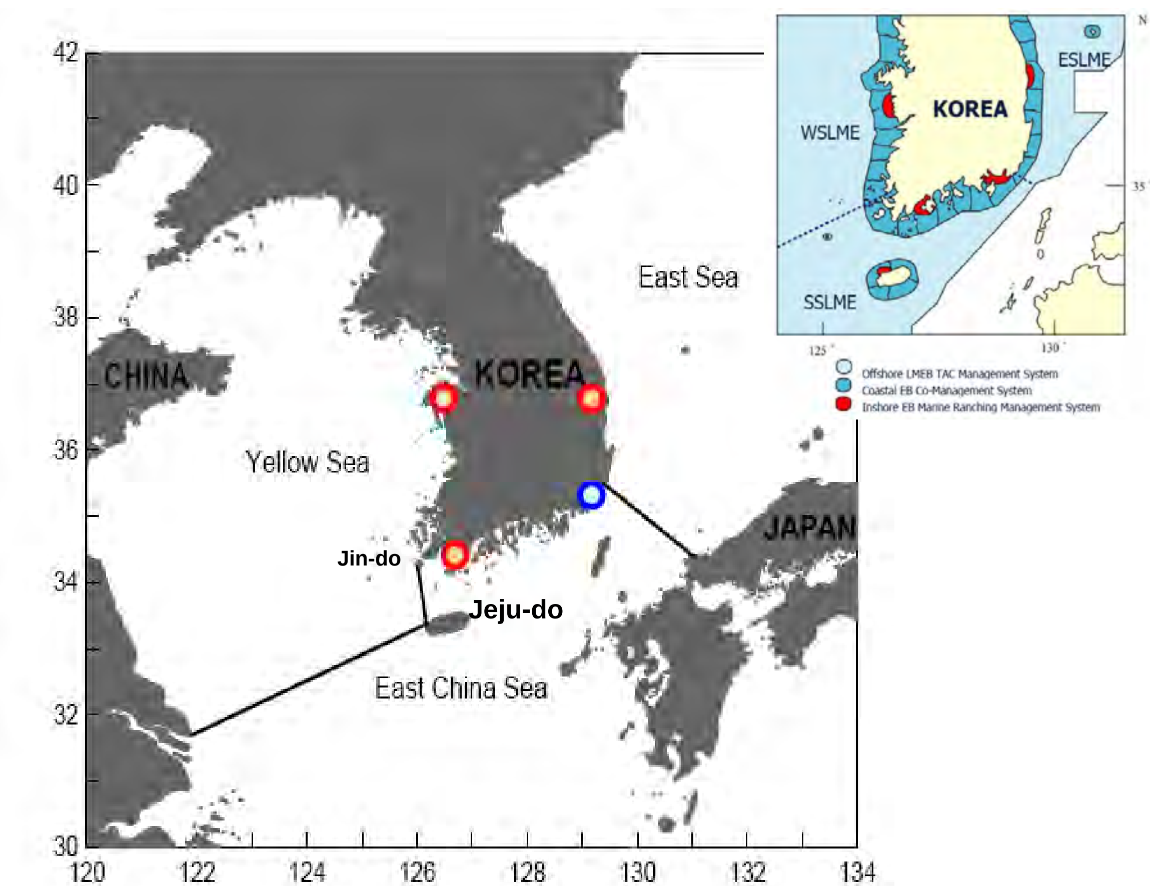

Fig. 4.2.2 Delineation of marine regions in the Republic of Korea waters. Inset represents offshore, coastal, and inshore regions proposed by Huh and Zhang (2005).

For management purposes, marine waters of Korea have been divided into subregional management zones by many different government agencies using geographic, meteorological, oceanographic and biological criteria. We will follow the management zonation scheme proposed by NFRDI. At the coarsest scale, NFRDI recognizes three general categories of management zones that are essentially defined by their distance from the coastline (Fig. 4.2.2): offshore zones, which extend to the EEZ limit; coastal zones around the mainland and large islands, such as Jeju-do and Ulleung-do; and inshore zones – tidal flats, bays and lagoons where marine ranching occurs. Further delineation of these zones is described below.

There are three offshore zones in Korean waters, which are spatially consistent with the three LMEs around the Korean Peninsula (Fig. 4.2.2). Resource management decisions in the offshore zones are made by the central government of Korea. Management in offshore zones is supported by scientific research by regional institutes of NFRDI, in the form of regular surveys of oceanographic and biological variables and quantitative assessments of fishery resources. In the Yellow and East China seas (Fig. 4.2.2; also see the People's Republic of China National Summary) the offshore zones extend from the coastal zone to the seaward extent of the EEZ. The NFRDI line that marks the transition from the East China Sea offshore zone to the Yellow Sea offshore zone extends from the island of Jin-do (near the southwest tip of the Korean Peninsula) to Chagui Island (near Jeju-do) and then across to the mouth of the Yangtze River (China). This line is geographically consistent with the transition between the two LMEs predicted by the ANN analysis (see above). NFRDI divides the waters in the Korea Strait between Korea and Japan along a line between Ulgi Lighthouse (southeast coast of Korea) and the southwest tip of Honshu (Japan). The remainder of this offshore zone is delineated by the extent of the EEZ.

Coastal zones around Korea (Fig. 4.2.2) are managed in a largely self-regulatory manner by local stakeholders in the adjacent metropolitan area or county. Management is supported with information provided by both local governments, which may conduct their own resource monitoring and assessment programs, and by the central government. The seaward extent of coastal zones (and thus of coastal management practices) may be on the verge of change: coastal zones have traditionally been defined as waters to which fishing vessels could sail and still return to their home port on the same day, but the speed of modern vessels necessitates a more concrete means of delineation. For example, some have suggested delineating the coastal zone as waters inside a fixed distance from the shore (analogous to the 3-nautical mile (~5.56 km) nearshore zone in U.S. waters which is primarily managed by individual states), although the distance that Korea would use is under debate.

Finally, there are several regions, designated 'inshore waters' by NFRDI, that are used for marine ranching (Fig. 4.2.2). Marine ranching in Korea began with the Tongyeong marine ranching project on the southeastern coast in 1998, following several decades of overfishing and environmental degradation related to intensive aquaculture and heavy coastal development (OECD, 2003). Marine ranching is a process by which specific coastal fisheries are enhanced through science-based restoration programs such as stocking key life history stages of target species, habitat enhancement, pollution control and prevention of overfishing. The management of inshore waters is self-regulatory. Management decisions are made by a fishery committee comprised of the leaders of local fishery cooperatives and advised by scientists and central government representatives (OECD, 2003). Scientists conduct regular surveys and assessments of the target resources to ensure that the decision process is well-informed. The spatial extents of marine ranching areas have been determined through negotiation and joint agreement by scientists, stakeholders, and fishery committees.

4.2.3 Japan

Marine waters around the perimeter of Japan are dominated by major ocean current systems, semi-enclosed seas, and open coast (Fig. 4.2.3). The Japanese approach to ecosystem definition and delineation explicitly distinguishes pelagic ecosystems, which are dominated by the dynamics of the circulation regimes, and demersal ecosystems, which are somewhat more fixed and characterized by the bathymetry of the seas and coastlines.

The coastal and ocean currents around Japan create four different pelagic regions that can be characterized generally in space (Fig. 4.2.3), although their inherently dynamic nature makes precise delineations difficult. Two pelagic regions derive

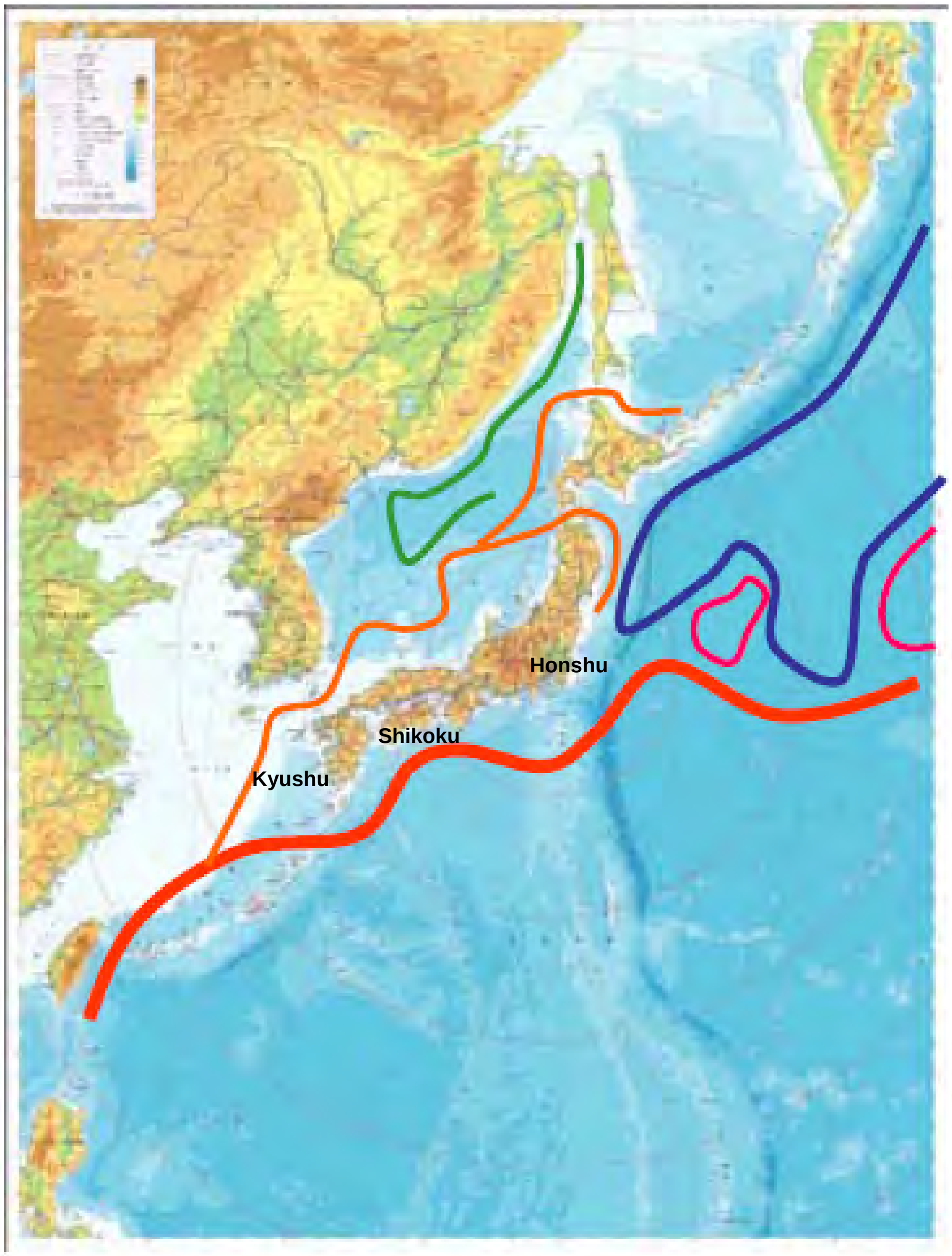

Fig. 4.2.3 Delineation of marine regions in Japanese waters (Tatsu Kishida, pers. comm.).

from the Kuroshio Current, which flows northeast from the East China Sea toward the island of Kyushu. Before reaching Kyushu, much of the current turns east-northeast and forms a boundary current, known as the Kuroshio Extension, that constitutes one pelagic region along the southeast coasts of Kyushu, Shikoku and Honshu. The smaller Tsushima Current breaks off from the Kuroshio Current and forms a second pelagic region. It flows northeast between Japan and the Korean Peninsula, moves along the west coast of Kyushu and Honshu, and then moves clockwise around the northern tip of Honshu, through the Tsugaru Strait, and southward along the east coast of Honshu. The Tsushima Current is warmer and more nutrient-poor than the southerly flowing cold currents on the western side of the Japan Sea, and exhibits 6-year cycles of variability in its flow path (Terazaki, 1999). A third pelagic region is formed by the Oyashio Current LME in northeastern Japanese waters. The Oyashio Current brings colder, fresher water southwest from the Bering Sea and Kamchatka regions to the east coasts of Hokkaido and Honshu, and then partly recirculates counterclockwise and back to the northeast (Yasuda, 2003). The fourth pelagic region is formed by a portion of the Oyashio Current that continues south and meets the Kuroshio Extension. This junction is known as the Kuroshio-Oyashio Transition Area, a complex mixed-water region influenced by numerous interacting currents, fronts and mesoscale eddies (Yasuda, 2003).

The distinctive oceanographic characteristics of the four pelagic regions support characteristic fauna that further help to distinguish the regions from adjacent waters. The spatial differences in the regions are not simply two-dimensional. Zooplankton species composition, a key indicator of the dominant current in an area, varies by depth as well as by latitude and longitude. In particular, there appear to be region-specific crustacean zooplankton communities above and below 200 m depth (Table 4.2.2); these communities are made up of species generally associated with particular ocean zones (neritic, oceanic, mesopelagic, bathypelagic) and/or climatic regions (subarctic, subtropical, tropical).

As with crustacean zooplankton, certain gelatinous zooplankton, squid, and pelagic fish are associated with the pelagic regions (Table 4.2.2), and their distributions can thus help to define the extent of the regions. For example, the giant jellyfish *Nemopilema nomurai* is most closely associated with waters of the Tsushima Current. Japanese common squid *Todarodes pacificus* which spawn during the fall are also common in the Tsushima Current, although the winter-spawning common squid population is spatially ubiquitous in Japanese waters. Several fish species associated with warmer currents spawn in the southwestern portion of the Kuroshio Current and then move either into the Tsushima Current or along the Pacific Ocean side of the islands. These species include Japanese sardine *Sardinops melanostictus*, chub mackerel *Scomber japonicus* and jack mackerel *Trachurus japonicus*; for management purposes, the Tsushima and Pacific groups are treated as separate ‘stocks’ although there is little evidence of genetic differentiation. The Pacific stock of chub mackerel uses northerly regions extensively, with large feeding grounds in the Oyashio and Transition Area regions. Yearling jack mackerel from the Pacific stock are highly dependent on food resources in the Transition Area.

Demersal zones around Japan are delineated into six regions which are defined in more precise spatial terms than the pelagic zones. These spatial delineations derive from bathymetric and zoogeographic features. Important among these are the channels that separate the major seas in the area (Fig. 4.2.3). The Tsushima/Korea Strait forms a natural separation between the demersal regions in the relatively shallow East China Sea and the western waters of Kyushu and Honshu. The east side of the Soya Channel in the north marks the beginning of the Sea of Okhotsk. Other significant large-scale zoogeographic features include Noto-hanto, a northward-pointing peninsula on the west coast of Honshu in the waters of the Tsushima Current, and Inobu-saki, a peninsula at 35º42′ N latitude on Honshu, which marks the point at which the island angles sharply to the north and the southwest and is considered the breakpoint between the two demersal regions on the east (Pacific) coast of the main islands. The significance of these two features as zoogeographic boundaries is clear from the differences in demersal fish and invertebrate communities that are targeted by commercial fisheries on either side of them (Table 4.2.3). On the east coast north of Inubo-saki, and on the west coast north of Noto-hanto, cold-water species are prevalent (in particular, walleye pollock *Theragra chalcogramma*). Southwest of these points, the composition of major commercial species shifts. The demersal community shifts further upon moving into the East China Sea, where shallow warm-water species prevail.

Table 4.2.2 Key indicator species associated with pelagic regions around Japan.

Fauna	Pelagic ecoregion: Tsushima	Kuroshio Extension	Oyashio	Transition Area
Zooplankton, < 200 m depth	ST/N, ST/O	T/O, ST/O, ST/N	SA	SA, ST/N, ST/O
Zooplankton, > 200 m depth	SA	MP, BP	MP, BP	MP, BP
Giant jellyfish	x	–	–	–
Common squid (fall stock)	x, spawn	–	–	–
Sardine (Pacific stock)	–	x, spawn	x	x
Sardine (Tsushima stock)	x	x, spawn	–	–
Chub mackerel (Pacific stock)	–	x, spawn	x	x
Chub mackerel (Tsushima stock)	x, spawn	–	–	–
Jack mackerel (Pacific stock)	–	x, spawn	–	x*
Jack mackerel (Tsushima stock)	x, spawn	–	–	–

Zooplankton are classified by climate zone (T = tropical, ST = subtropical, SA = subarctic) and/or ocean zone (N = neritic, O = oceanic, MP = mesopelagic, BP = bathypelagic). For other groups, ‘x’ indicates that the species is common, and ‘spawn’ signifies an important spawning area.
*Mainly a feeding ground for yearlings

Table 4.2.3 Key demersal fishery species in marine waters around Japan.

Coastal region	Geographic reference	Common name	Scientific name
East	N of Inubo-saki	Walleye pollock	*Theragra chalcogramma*
		Pacific cod	*Gadus macrocephalus*
		Saffron cod	*Eleginus gracilis*
	SW of Inubo-saki	Deep-sea smelt	*Glossanodon semifasciatus*
		Big-eyed greeneye	*Chlorophthalmus albatrossis*
West	N of Noto-hanto	Walleye pollock	*Theragra chalcogramma*
		Atka mackerel	*Pleurogrammus monopterygius*
	SW of Noto-hanto, inshore	Sailfin sandfish	*Arctoscopus japonicus*
		Pointhead flounder	*Cleisthenes pinetorum*
		Flathead flounder	*Hippoglossoides dubius*
		Korean flounder	*Glyptocephalus stelleri*
	SW of Noto-hanto, offshore	Deep-sea smelt	*Glossanodon semifasciatus*
		Snow crab	*Chionectes* spp.
		Pink shrimp	*Pandalus borealis*
Southwest	East China Sea	Swordtip squid	*Loligo edulis*
		Largehead hairtail	*Trichiurus lepturus*
		Lizardfish	*Saurida* spp.
		Japanese butterfish	*Hyperoglyphe japonica*
		Japanese meagre	*Argyrosomus japonicus*
		Small yellow croaker	*Larimichthys polyactis*

Thus, pelagic and demersal regions in the Japanese EEZ are generally defined by oceanographic patterns, bathymetry and species assemblages. However, in coming years it is possible that Japanese waters will be further (and more precisely) subdivided, based on jurisdictional boundaries. Fishery resource management in Japan was long handled by self-regulating limited-access fisheries, rather than formally managed by government management agencies, but that is changing. Science-based fisheries management advice is currently generated both at local scales, by prefecture governments, and at the national level, by the Ministry of Agriculture, Forestry and Fisheries (MAFF). Policy implementation at local scales may induce spatial changes in community structure or productivity within a region. For example, in the 1990s the Akita Prefecture (north of Noto-hanto) initiated several successful actions to rebuild the population of sailfin sandfish *Arctoscopus japonicus*, including fishery closures, stock enhancement and spawning habitat improvements.

4.2.4 Russia

Russian territorial waters in the Far Eastern seas (Fig. 4.2.4) and adjacent waters of Pacific Ocean occupy part or all of four LMEs in the PICES region: the Western Bering Sea, the Sea of Okhotsk, the Sea of Japan/East Sea and the Oyashio Current (Sherman *et al.*, 2007). The Far Eastern seas are critical to the nation's fishing industry, averaging over 70% of total Russian fish and shellfish production between 2000–2005 (Sinyakov, 2006) despite accounting for just under 43% of the whole of the Russian EEZ. Historically, a variety of criteria have been used to geographically delineate the Russian EEZ into fisheries management regions (FMRs) and ecological districts although the integration and overlap of those delineations is somewhat limited.

At the largest scale, Russian FMRs are based on FAO Major Fishing Areas, which delineate major geographic complexes of fisheries. Based on the spatial distributions of key commercial target species for Russian fleets (Karedin, 2001), the Major Fishing Areas were first divided into smaller FMRs and sub-areas in 1975, prior to global establishment of EEZs. The basic idea of FMR delineation was that a spatial unit would encompass the area inhabited by one commercial fishery stock, corresponding to a biological population. It was assumed that this method of delineation would also sufficiently encompass the key distributional features of other species about which less was known. Further study of population structure, seasonal migrations, and ontogenetic migrations of key commercial species led to a refinement of FMR delineations, first in 1980 and again in 1988, although to some extent they still reflected the original single-species framework. The refined FMR patterns were also established to account for the potential spatial limitations of fisheries following the establishment of EEZs. The current FMR pattern, established in 1989, is the most elaborate (Fig. 4.2.4), although the changes relative to prior FMR patterns were not done, based on scientific analyses or recommendations. Rather, they were adopted according to the initiative of the State Industrial Fisheries Association (Dalryba) to solve discrepancies between stakeholders in the Sakhalin, Kamchatka and Magadan regions.

Prior to the 1980s, Russian studies of commercially fished species were single species in nature. Biological and statistical information was primarily summarized and compared across existing FMR units, or was pooled at the scale of larger geographic regions (*e.g.*, regional seas). The concept of delimiting the Far Eastern seas into ecological districts arose in the 1980s, stemming from oceanographic studies of biological productivity. In early research on the ecological differentiation of global ocean habitats, Russian oceanographers introduced the term 'natural oceanic region' to describe an area with relatively homogeneous climatic, hydrologic and chemical conditions, which formed the backdrop for biological processes, community structure and ecosystem function (Muromtsev and Gershanovich, 1986; Gershanovich *et al.*, 1990; Shuntov, 2001).

In the 1980s, Dr. Vjatcheslav Shuntov of the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok suggested division of the Far Eastern seas and adjacent Pacific Ocean waters into biostatistical districts (Fig. 4.2.5) in order to better integrate community ecology, ecosystem and applied fisheries research. This system of delineation was facilitated by studies of surface water circulation patterns, bottom relief, and distribution of water masses, identified by thermal and salinity characteristics. The proposed system of biostatistical districts was broadly accepted by the scientific community, and has been permanently adopted for all TINRO-Center reports as well as in hundreds of scientific articles and at least five monographs on community and ecosystem themes (Shuntov *et al.*, 1993; Shuntov, 1998, 2001; Dulepova, 2002; Ivanov and Sukhanov, 2002).

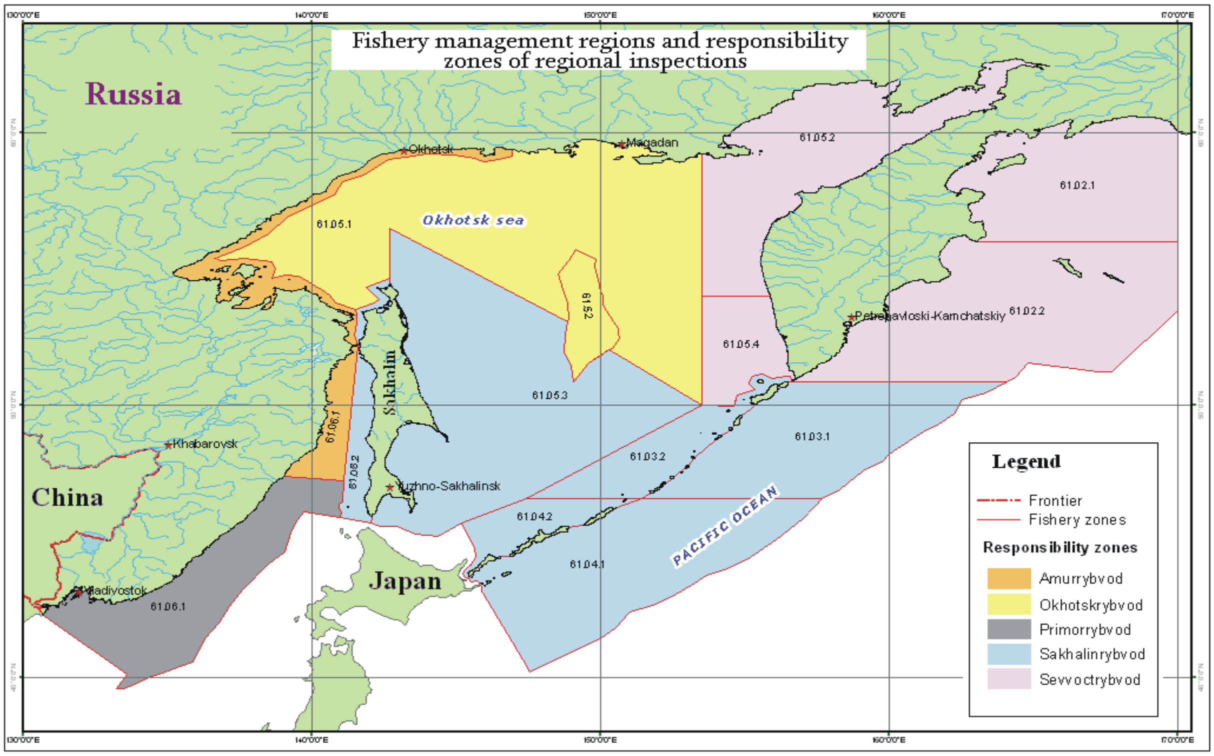

Fig. 4.2.4 Delineation of fishery management regions (FMRs) in the Russian Far Eastern seas, according to the 1989 delineation scheme (Karedin, 2001).

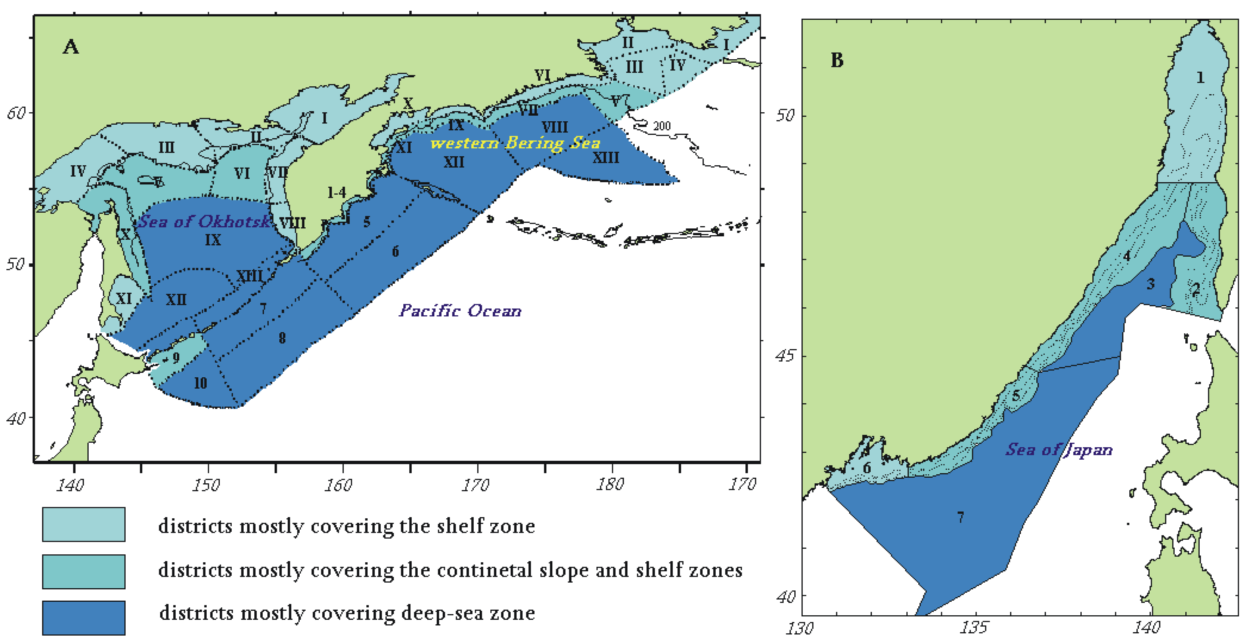

Fig. 4.2.5 Delineation of biostatistical districts in the Russian Far Eastern seas (Panel A, Vladimir Radchenko, pers. comm.; panel B, Volvenko and Kafanov, 2006).

The biostatistical districts in Russian EEZ waters can be pooled into three general groups: Western Bering Sea districts, Sea of Okhotsk districts and Pacific Ocean districts. The Western Bering Sea has 13 biostatistical districts that lie over the inner shelf (mean depth $\bar{d}$ <80 m), the outer shelf and slope ($\bar{d}$ = 209–356 m), and deep-sea domains ($\bar{d}$ = 2745–3577 m). Region XIII extends to a central portion of the sea, adjacent to a body of water that lies beyond the EEZs of either Russia or the U.S. (the so-called 'Donut Hole'). The Sea of Okhotsk has 14 districts, most of which cover continental shelf ($\bar{d}$ = 101–273 m) or slope ($\bar{d}$ = 343–503 m). Additionally, two districts adjacent to the Kuril Islands chain cover narrow insular shelf and slope but also a considerable amount of deep-sea waters ($\bar{d}$ = 1607 and 2171 m), and two districts in the central part of the sea have $\bar{d}$ of 1122 and 2934 m. The Pacific Ocean districts lie along the eastern side of the Kamchatka Peninsula and Kuril Islands (Fig. 4.2.5a), and also in Russian waters of the northwestern part of the Sea of Japan (Fig. 4.2.5b, Volvenko and Kafanov, 2006). Ten districts lie off the Kamchatka Peninsula and Kuril Islands, half of which cover shelf and slope ($\bar{d}$ = 107–420 m), and half of which cover deep-sea habitat ($\bar{d}$ = 2879–5118 m). Another seven districts in the northwestern portion of the Sea of Japan (Volvenko and Kafanov, 2006) correspond to shelf ($\bar{d}$ = 99–141 m), shelf/slope ($\bar{d}$ = 296–368 m), or deep sea ($\bar{d}$ = 1427–2879 m). Spatially aggregating data in these districts was faciliated by Volvenko (2003) who calculated the areas inside the 100-, 200-, and 500-m isobaths for all 44 districts. Quantitative information on the nekton species distribution and abundance in these waters has been calculated and published as a series of atlases and tables (most recently Shuntov and Bocharov, 2006a,b).

Although it was hoped that the biostatistical districts would be used to spatially integrate basic and applied research, in practice they have not been used for fisheries management despite their potential usefulness for applications such as area closure measures. The 1989 FMR delineations (Fig. 4.2.4) are still generally applied for that and other fishery management purposes. Some changes to the current FMR pattern were suggested by an ichthyofaunal zoning analysis by Karedin (2001) but were not adopted. Similarly, a recent ichthyofaunal zoning study of the northwestern Sea of Japan revealed spatial similarities to the biostatistical districts (Volvenko and Kafanov, 2006) and implied a much greater degree of spatial heterogeneity in the fish communities than that of the FMR pattern. There have been some recent changes to the existing FMR delineation, related to coastal fishery formalization. In late 2004, a new federal law allocated quotas to Russian coastal fisheries, distinguishing them from commercial fishery quotas; coupled with the new coastal allocation was the establishment of new coastal fisheries zones which extend from the coastline to just over 22 km (12 nautical miles) offshore within Russian territorial waters. Although fishers from coastal communities have appealed for the expansion of this zone, changes are not foreseen in the near future.

4.2.5 United States of America – Alaskan Waters

Continuing clockwise around the North Pacific Rim, we next come to the U.S. Because U.S. territorial waters are geographically separated by Canada, we will treat the northerly waters (Alaska) and the southerly waters (Pacific Coast) separately, with the Canada section in between. Before describing Alaska, we offer a brief overview of the U.S. approach to marine ecosystem delineation, which will serve as a backdrop for both reports from the U.S.

The U.S. is engaged in an ongoing process of developing criteria to facilitate management of ecosystem components that exist at different scales, are managed by multiple agencies, and are valued by diverse stakeholders. The National Oceanic and Atmospheric Administration (NOAA), which is the primary agency responsible for stewardship of coastal and ocean resources, appointed a working group to solicit guidance from within NOAA and from other federal, regional and state organizations on various science-based ecosystem delineation schemes (NOAA, 2004). This group generally supported the use of LMEs to delineate ecosystems in the U.S. EEZ (Fig. 4.2.6), and endorsed use of the main classification criteria that define LMEs (bathymetry, hydrography, productivity and trophodynamics). Ecosystems in the PICES area that result from this delineation approach are: Alaska ecosytem complex (Eastern Bering Sea/Aleutian Islands, and the Gulf of Alaska), the California Current, and portions of the Insular Pacific Islands, which are primarily in the central and eastern tropical Pacific and extend into the Southern Hemisphere. The NOAA working group explicitly recognized that international cooperation would be necessary to achieve an ecosystem approach to management in some of these areas (NOAA, 2004).

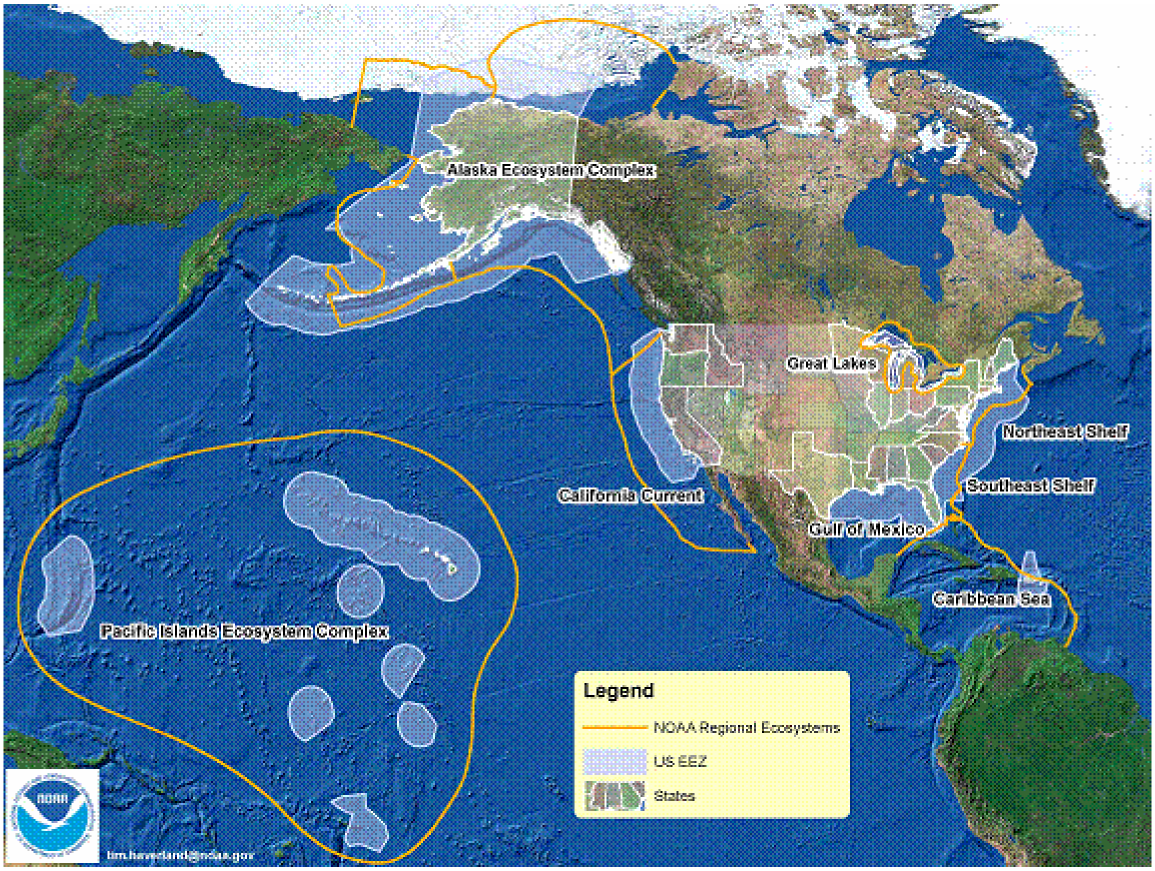

Fig. 4.2.6 U.S. large marine ecosystem (LME) boundaries derived from a regional ecosystem delineation workshop held by the NOAA Regional Ecosystem Delineation Working Group in Charleston, South Carolina, August 31–September 1, 2004 (NOAA, 2004; http://www.nmfs.noaa.gov/pr/sars/improvement/pdfs/ecosystem_delineation.pdf).

The working group also identified the need to delineate subregions in each of the LME-level ecosystems. A workshop convened in 2005 began the process of subregional delineation (Wendy Gabriel, NOAA, Northeast Fisheries Science Center, Woods Hole, MA, pers. comm.). It produced a draft list of four general criteria for defining and describing subregions: bottom topography and physiography; circulation and oceanography; biological characteristics; and characteristics of the coastal area, inland extent, watershed, and marine catchment. These criteria were similar to the LME boundary criteria, but also included the additional criterion of the inland extent of the marine ecosystem. The criteria were proposed to be established at two levels: a national minimum standard, such that a general level of consistency would be used to define subregions throughout U.S. LMEs, regardless of whether they are data-rich or data-poor; and regionally essential criteria that are relevant to specific LMEs. No further action has resulted from the initial workshop. However, there is wide recognition that final delineation will need to occur at the subregional level, and that delineation decision-making will include input from regional stakeholders.

Alaska is bounded to the north by the Arctic Ocean, to the south by the Pacific Ocean, and to the west by a large semi-enclosed sea (Fig. 4.2.7); the vast EEZ around Alaska extends into four different LMEs: the Eastern Bering Sea, Gulf of Alaska, Chukchi Sea and Beaufort Sea (Sherman, 2006), the first two of which are in the PICES region. Several major currents and frontal regions influence Alaskan waters, with intensity that varies seasonally, annually and decadally. Its highly complex coastline extends for nearly 10,700 km. In many places, its jurisdiction extends to international boundaries with Russia or Canada. For these and other reasons, defining and delineating subregions in Alaskan waters is particularly challenging.

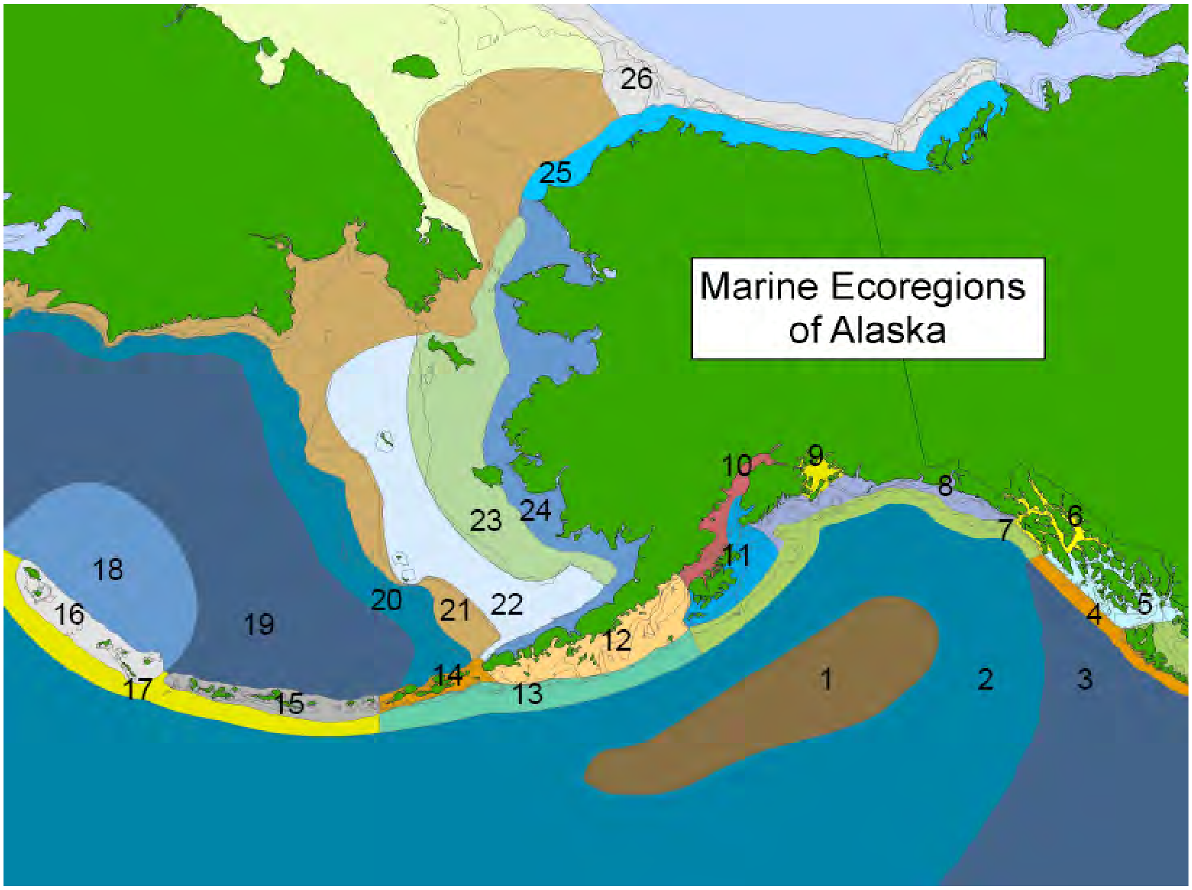

Fig. 4.2.7 Proposed delineation of ecosystem subregions in marine waters around Alaska, based on work by Piatt and Springer (2007).

There have been numerous efforts to define subregional boundaries in Alaska. In 1999, conservation groups (The Nature Conservancy and World Wildlife Fund) hosted a workshop to delineate Bering Sea subregions with a purpose to identify priority areas for conservation. Piatt and Springer (2007) evaluated known information on bathymetry and summer biological features and hydrography to derive 26 subregions for Alaska marine waters (Fig. 4.2.7). They acknowledged that these boundaries are likely variable but are determined mainly by bottom topography and current flow. Alongshelf boundaries were determined primarily from topographically defined fronts while cross-shelf boundaries were determined based on patterns in animal distributions. Piatt and Springer (2007) also concluded that coastal-shelf environments are much more heterogeneous than the open ocean, as is reflected by the finer spatial scale of subregions along the coast of the Gulf of Alaska, the Aleutian Islands, and the Eastern Bering Sea (Fig. 4.2.7).

In the meantime, a number of subregional boundaries have been defined to implement ecosystem-based protection measures designed to protect Steller sea lion (*Eumetopias jubatus*) foraging areas, corals in the Aleutian Islands, Eastern Bering Sea fish habitat, and a variety of closures to protect specific fish species from harvest during certain seasons (Witherell and Woodby, 2005). These subregions were based on biological information on species distribution and knowledge of fisheries activities in the area. The practical application of subregional boundaries by management authorities, such as the North Pacific Fishery Management Council, exemplifies the conclusion reached by the U.S. working group on regional ecosystem delineation that subregional delineation should be primarily the responsibility of the stakeholders in each region. The U.S.'s fishery management council system incorporates science-based decision making that brings together a cross-section of stakeholders in its design of management actions (see http://www.nmfs.noaa.gov/councils/).

4.2.6 Canada

Classifying marine systems is a main element of marine research and integrative resource management under Canada's national Ocean Strategy (Powles *et al.*, 2004). Thus, of all the PICES member countries, Canada has probably taken the most formal approach toward describing and delineating its marine waters. Their approach has involved dividing marine waters into adjacent 'ecoregions'; based on the hierarchical organization shown in Table 4.2.4 (based on Harper *et al.*, 1993), an ecoregion is an area on the scale of a marginal sea, distinguishable from neighbouring areas by physical and chemical conditions (*e.g.*, temperature, salinity), key systemic rates (*e.g.*, primary production), and community composition. An ecoregion can be a component of an 'ecoprovince' (*e.g.*, a major oceanic surface current), or a collection of several 'ecodistricts' (a localized mixing region). An ecoregion is assumed to be the most complex association of similar, connected areas for which clear, ecosystem-level research and management objectives can be devised and implemented.

Canada defined four ecoregions along its West Coast (Fig. 4.2.8), using nationally developed criteria (Powles *et al.*, 2004) that update earlier ecoregional delineations done by Zacharias *et al.* (1998). The criteria are geological (*e.g.*, degree of enclosure, bathymetry, surficial geology), oceanographic (*e.g.*, temperature, ice cover, freshwater influence, water masses, currents, mixing/stratification) and biological (*e.g.*, primary productivity, species distributions, population structure, community structure). These properties were used to classify an area of ocean only if data were available throughout that area, and they were considered jointly, not hierarchically. Although the ecoregional maps end at the limit of the Canadian EEZ for management purposes, the geological, physical, and biological properties inherent to an ecoregion very likely extend beyond the EEZ into adjacent waters (Powles *et al.*, 2004).

The four Canadian ecoregions are the Strait of Georgia, the Southern Shelf, the Northern Shelf and the Pacific Offshore ecoregion. The Strait of Georgia is primarily defined by its high degree of enclosure; it is bounded between Vancouver Island and the mainland of British Columbia on the west and east, and bordered by archipelagos and shallow depths in the north and in the south (Fig. 4.2.8). Its physical oceanography is characterized by strong tidal fronts to the north and south, along with significant freshwater influence coming from the Fraser River. The freshwater plume in the Strait of Georgia is generally restricted to the upper few centimetres of the water column.

The Southern Shelf ecoregion, located off the West Coast of Vancouver Island, is defined at its northern limit by Brooks Peninsula (northwest coast of Vancouver Island), which extends almost to the 200-m bathymetric contour and thus almost divides the continental shelf. The southern boundary was not defined under the Canadian process, as this ecoregion extends out of the EEZ into U.S. waters. Juan de Fuca Strait, between southern Vancouver Island and the northwest corner of the continental U.S., is a transition zone between the Strait of Georgia and the Southern Shelf. Biologically, the Southern Shelf ecoregion represents the northern distribution limit of many species, including Pacific hake *Merluccius productus*, some pandalid shrimp *Pandalus* spp., and the southern resident stock of killer whale *Orcinus orca*.

Table 4.2.4 Hierarchical levels of spatial organization used by Canada for classifying marine areas. This organizational scheme was originally developed by Harper *et al.* (1993).

Level	Basic descriptive scale
Ecozone	Ocean basins
Ecoprovince	Major oceanic surface currents
Ecoregion	Marginal seas
Ecodistrict	Local mixing processes, eddies, stratifications, small-scale currents
Ecosection	Bathymetric zones, habitat patches

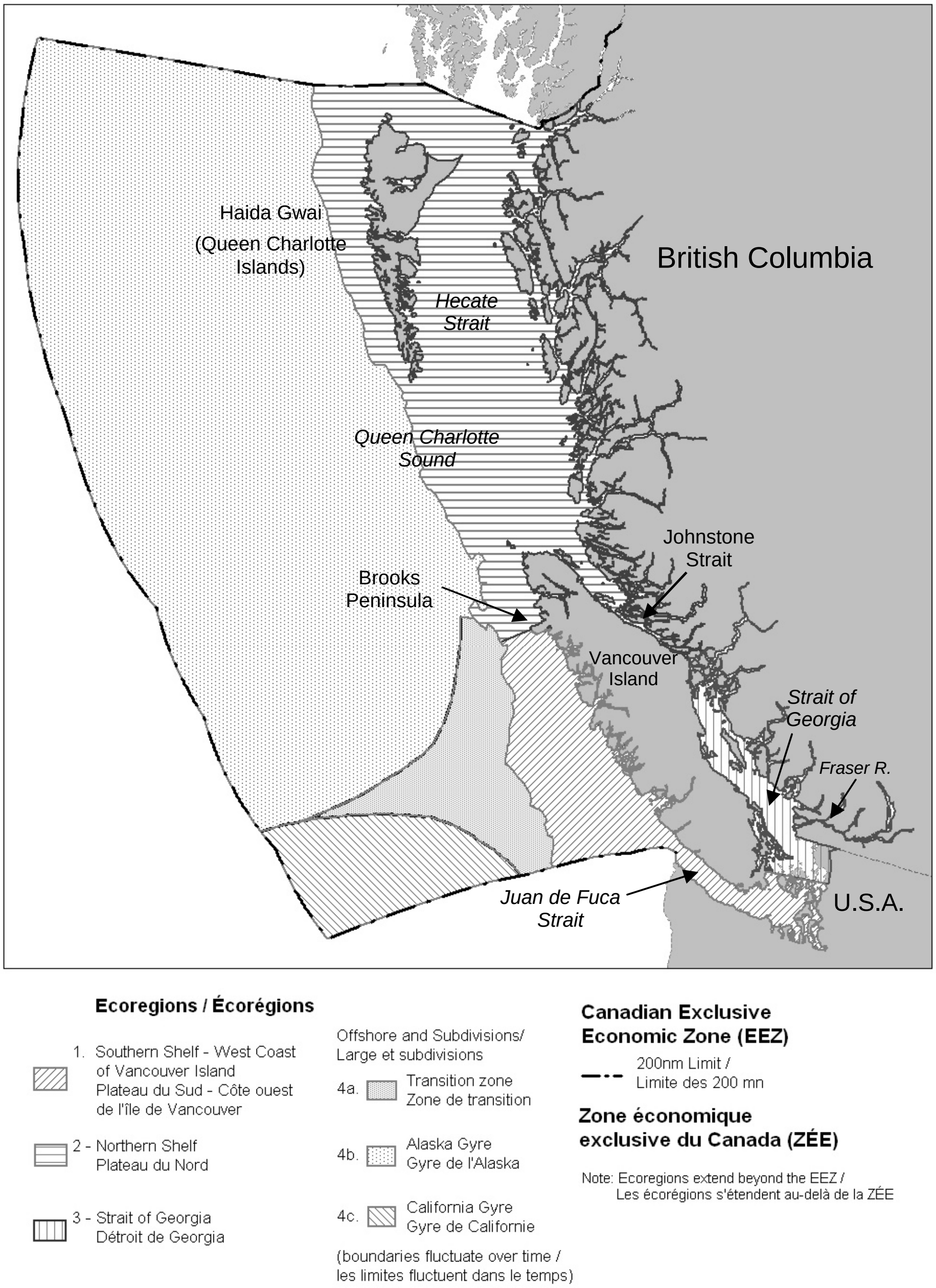

Fig. 4.2.8 Canadian Pacific Coast ecoregions (modified from Powles *et al.*, 2004).

The Northern Shelf ecoregion is bounded on the south by Brooks Peninsula, and extends northward into Alaskan (U.S.) waters. A distinctive geological feature of this ecoregion is the shallow water area located between the Queen Charlotte Islands (Haida Gwai) and the mainland coast. Oceanographically, shallow waters east of the Queen Charlotte Islands create a warm water front and strong mixing. Biologically, this ecoregion is roughly the southern range limit of many species, including the northern resident stock of killer whales. All major seabird colonies (colonies with >10,000 birds) on the West Coast of Canada occur north of Brooks Peninsula.

The Pacific Offshore ecoregion is the area seaward of the 200-m bathymetric contour, past the shelf break and to the west of the Northern and Southern Shelf ecoregions. Circulation patterns effectively divide it into three subregions, defined by the splitting of the easterly flowing North Pacific current as it approaches North America. This splitting results in part of the current going northward towards Alaska, and part turning south towards the continental U.S. This results in a northern subregion, the Alaska Gyre, associated with upwelling; a southern subregion, the California Gyre, characterized by downwelling; and a transition zone near the continental shelf boundary at the fork. The locations of these subregions move northward and southward seasonally and interannually with shifts in the current (Batten and Freeland, 2007). Biologically, the shelf break is an important boundary for seabirds. Species such as Laysan albatross *Phoebastria immutabilis* and many other Procellariiforms are found mostly seaward of the shelf break.

These four ecoregions provide spatial templates in which Canada plans to conduct EBM of marine resources. Canada recently began five ecoregion-scale pilot projects to implement integrated management (IM) plans; three of the pilot IM areas are in Atlantic waters, one in the Arctic and the fifth is the Northern Shelf region described above. The initial focus in the pilot projects is to provide managers and stakeholders with the best available scientific information on the ecoregion in order to support decision-making. To do so, scientists have conducted an Ecosystem Overview and Assessment (EOA; see appendix 4; Lucas *et al*., 2006). An EOA is a two-part document. The first part is a detailed description of the ecoregion's ecological status and trends, in the context of the region's geological, oceanographic and biological properties. The second part is an ecological assessment that reviews significant human activities and threats, links human activities with ecosystem functions, identifies ecologically significant areas and species, and makes recommendations concerning areas and activities that are high priority for management actions. Overall, the EOA also serves to engage stakeholders, and to assist in identifying ecosystem objectives, knowledge gaps, and ways to fill those gaps.

4.2.7 United States of America – Pacific Coast

Waters off the Pacific Coast of the continental U.S. are entirely within a single large marine ecosystem, the California Current LME (Sherman, 2006). The California Current is an eastern boundary current that crosses the northern and southern borders of the U.S. and extends seaward of the EEZ to roughly 1000 km from the coast. The surface current flows south, parallel to the coastline, from north of the U.S./Canada border until roughly Point Conception (Fig. 4.2.9) where it continues south-southwest to join with equatorial currents (Hickey, 1998). South-southeast of Point Conception and landward of the main body of the California Current is the Southern California Bight, characterized by a counterclockwise gyre that branches off the California Current and either recirculates (the Southern California Eddy) or rejoins the main current. The physical oceanographic features that define the Southern California Bight are most strongly developed in the summer and late fall in a normal year (Hickey, 1998; Hickey *et al.*, 2003).

At present, California Current waters off the Pacific Coast have not been formally subdivided for federal management purposes. However, a panel of federal and state scientists recommended delineating subregions within LMEs for the purpose of more effective resource management (NOAA, 2004). Several bathymetric and coastal features would be logical points for subregional delineation because they mark changes in physical and biological characteristics. Most notably, Point Conception (Fig. 4.2.9) is the point on the coastline where the main body of the California Current diverges, and is also considered the transition point between two biogeographic provinces – the Oregonian Province to the north and the Californian Province to the south (*e.g.*, Burton, 1998). Several other coastal features mark transitions in circulation, ecosystem function and community composition (*e.g.*, the Columbia River plume, Cape Blanco, Cape Mendocino, Point Arena and Monterey Bay). Some coastal areas are marked by strong upwelling, a critical driver of primary and secondary productivity in most years (Barth *et al.*, 2007). The U.S. GLOBEC program long ago recognized three major regions in the California Current. These regions, defined by patterns of circulation, coastal morphology, freshwater inputs and productivity, have break points at Cape Blanco and Point Conception (US-GLOBEC, 1992). One treaty-based international organization, the North American Commission for Environmental Cooperation (CEC), proposes three subregions on the U.S. Pacific Coast, with break points at Cape Mendocino and Point Conception; CEC subregion classification criteria are summarized in NOAA (2004).

Resource management in the California Current LME (especially for commercial species and species of concern) is already done based on subregional delineation in many cases, largely on the basis of distance from shore, depth, zoogeographic breaks and substrate/habitat types. Management responsibility for nearshore (<5.56 km, or 3 nautical miles, from shore) waters largely falls to individual states, and to the federal government from 5.56 km to the edge of the EEZ. Depth zones are a key basis for management of demersal species in federal waters over the relatively narrow continental shelf. This includes limits on the diameter of trawl footrope rollers (to prevent fishing on rocky substrates) and seasonal bottom trawling closures within certain bathymetric contours along the entire coast, in order to conserve depleted stocks of rockfish *Sebastes* spp. (PFMC, 2004). Coastal features mark differences in management strategies for some species; for example, many groundfish are managed more strictly to the

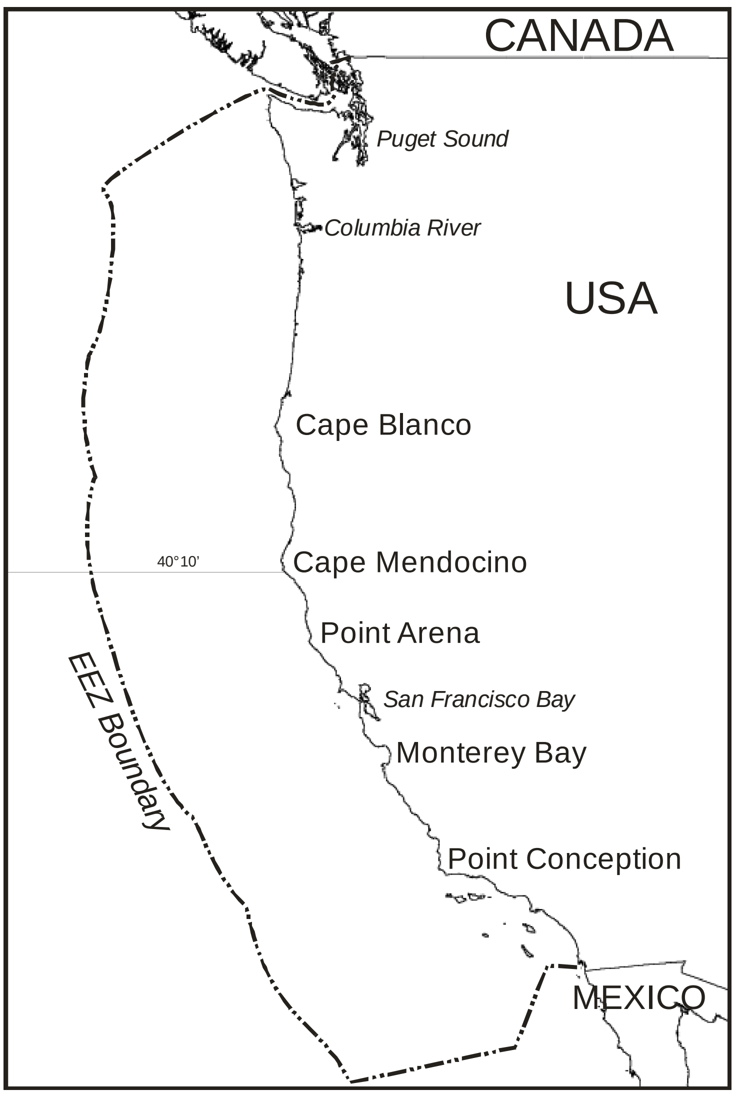

Fig. 4.2.9 Delineation of the Exclusive Economic Zone (EEZ) off the western coast of the continental U.S., along with some major coastal features. No ecoregions have been officially delineated within the EEZ, which lies within the California Current Large Marine Ecosystem (Sherman, 2006).

north of Cape Mendocino (PFMC, 2004). Other restrictions occur in areas where there is high likelihood of incidentally catching depleted or protected species (such as cowcod *Sebastes levis*, Klamath River fall Chinook salmon *Oncorhynchus tshawytscha* or leatherback turtles *Dermochelys coriacea*). Large-scale closures for bottom-contacting fishing gears have been established for unique offshore areas (*e.g.*, seamounts and banks identified by NOAA for groundfish conservation) and for vast areas believed to be rich in deep-sea invertebrates such as cold water corals, sponges, anemones and sea pens (*e.g.*, NOAA, 2005). It is likely that these species are distributed based on subregional differences in geology, oceanography and community structure, which may serve as bases for further spatial delineation as this process evolves.

4.2.8 Discussion

Comparison of National Approaches

In general, the National Summaries from the PICES member countries suggest a broad consistency in the criteria used to define and delineate marine ecosystems in their territories. In nearly all cases, spatial delineations were associated with major ocean currents, depth zones, and continental shelf/slope areas, all of which are obvious sources of spatial structuring. Many of these areas were further validated by statistical identification of distinct, characteristic species assemblages. Coastal features such as capes or peninsulas were frequently identified as key reference points for delineation, often because they represent zoogeographic barriers or points at which large-scale circulation patterns change markedly. Additionally, all member countries acknowledge cases where ecosystems extend beyond their EEZ, either into another country's EEZ or into international waters. Perhaps not surprisingly, the National Summaries contain less information about waters that lie beyond continental slopes and outside of their EEZs, even in cases where those waters are deemed part of the same ecosystem as (and are thus thought to be ecologically linked to) waters lying nearer to shore; this issue has been encountered in other spatial classification efforts (*e.g.*, Spalding *et al.*, 2007).

What is perhaps most interesting about the delineations is that PICES countries approached the issue in several different ways and yet came to comparable conclusions about the levels of ecological organization that constituted ecosystems and subregions. Delineation in some areas has relied primarily on an informal "Delphic" approach (*i.e.*, consensus of expert opinions) while other areas have added quantitative approaches (*e.g.*, neural network analysis or multivariate statistics). It is clear, however, that the PICES member countries vary widely in the formality of their approaches and the extent of their progress with respect to ecosystem delineation and subregionalization. The potential consequences of this are discussed in section on "International Collaborations".

There were several cases where member countries used the LME delineations as coarse-scale guides and defined finer-scale subregions. The coastal and inshore zones around Korea, the proposed conservation subdivisions around Alaska, the Canadian ecoregions, and the biostatistical districts around Russia occur at considerably finer spatial scales than the LMEs. Many countries noted the importance of variability in regional boundaries, such as the seasonal changes in water masses and fish assemblages described in the National Summary of China. That distinction is important because it recognizes that processes near the center of an ecosystem may be very different from processes at the margins, a principle that may help guide future refinements to delineations (*e.g.*, explicitly classifying some areas as transition zones, as was done by Japan and Canada).

Unique among the national approaches was the delineation scheme described by Japan. Acknowledging the inherent variability of the seasonally dynamic boundary and coastal currents, Japan loosely defined four pelagic zones based on three-dimensional oceanographic and biological patchiness relative to surrounding waters. In the demersal zone, however, Japan distinguished six zones, separated by distinct zoogeographic boundaries, such as shallow straits and peninsulas and supporting different benthic fish and invertebrate assemblages. This general notion, that the delineation of the pelagic zone does not necessarily precisely overlie delineations in the demersal zone, is potentially applicable in other parts of the PICES area.

Comparisons with Other Spatial Delineation Frameworks

Many other researchers and organizations have developed regional delineations of the oceans (see summaries in Longhurst, 1998 and Spalding *et al.*, 2007), and our work overlaps considerably with some and departs from others. Here, we draw comparisons and distinctions between our efforts and some prominent work by other individuals or groups.

As is clear from the National Summaries, the North Pacific LME framework (Sherman and Tang, 1999) strongly influenced our efforts. This implies broad acceptance of the LME-related suite of general structuring forces that define large, coastal marine ecosystems (bathymetry, hydrography, productivity and trophodynamics). One member country, the United States, explicitly identified the LME criteria as central to its plans for regional delineations. However, several countries clearly believe that managing marine resources will require finer-scale delineation of ecosystem subregions, as well as accounting for migratory species that move between LMEs (*e.g.*, largehead hairtail and small yellow croaker in the Yellow and East China seas). Two countries, Japan and Canada, also identified transition zones, where boundary current LMEs either converge or diverge, as distinct regions of ecological or management interest.

To a great extent, following the LME paradigm is sensible because the LME network is closely associated with the coastal, continental shelf regions of the world's oceans (Sherman, 2006) and hence is also associated with the EEZs of coastal nations like the PICES member countries. This also may explain why the much larger-scale oceanographic provinces defined by Longhurst (1998) do not correspond as well to the delineations described in the National Summaries. The Longhurst Provinces were developed to partition the entire world oceans, including the open pelagic regions far from continents, and hence processes at very different scales than those within coastal LMEs are being considered.

Recently, Spalding *et al.* (2007) developed a classification scheme known as the Marine Ecoregions of the World (MEOW), which defined 232 coastal marine ecoregions worldwide, based primarily on taxonomic criteria. MEOW ecoregions (areas with high taxonomic homogeneity, particularly at the level of sedentary species) are nested in a hierarchical analytical framework where ecoregions are components of taxonomic provinces and provinces are components of taxonomic realms. This system was designed to provide a basis for analyzing patterns and processes that characterize and influence marine biodiversity, and to inform management and conservation efforts in coastal waters. Its hierarchical framework enables analysis of changes and differences at multiple scales, and its basis in quantifiable taxonomic variables makes its classification criteria somewhat more concrete than qualitative, relative criteria. Spalding *et al.* (2007) described several differences between their network of ecoregions and the currently defined LME network (*e.g.*, Sherman, 2006), in part because the MEOW system covers considerably more coastal regions and, in part, because the criteria for delineation are different. However, Spalding *et al.* (2007) found that roughly half of their ecoregions, alone or in aggregate, were highly congruent with LMEs.

In general, the Northern Pacific Rim ecoregions identified by Spalding *et al.* (2007) were similar to our formally and informally delineated ecosystems. The congruence is highest in the western Pacific, where Spalding *et al.* identified separate ecoregions for the East China Sea, Yellow Sea, Sea of Japan, Sea of Okhotsk, Kuroshio Current and Oyashio Current (Spalding *et al.*, 2007). There were some minor differences; most notably, the MEOW system identified four separate ecoregions along the eastern side of Japanese waters, extending from seaward of the Ryukyu island chain northward to the east coasts of the main islands (Spalding *et al.*, 2007), as compared to the three areas (Kuroshio, Oyashio and Kuroshio-Oyashio Transition) identified in Japan's National Summary. MEOW also did not classify the central part of the Sea of Okhotsk because it lay beyond the MEOW criterion for 'coastal' waters (<370 km from a coastline).

In the Bering Sea and eastern Pacific waters, there was greater (but not insurmountable) incongruence between our approach and MEOW. MEOW delineations of the Western and Eastern Bering Sea ecoregions differed substantially from the Western and Eastern Bering Sea LMEs (Sherman, 2006), and the MEOW system did not include the Bering Sea Donut Hole, again because it lay beyond 370 km from a coastline. In U.S. waters, MEOW ecoregions were, in aggregate, similar to the LMEs of both the Gulf of Alaska (where MEOW defined two ecoregions: the Gulf of Alaska and Aleutian Islands) and the California Current (where MEOW defined three ecoregions, with break points at Cape Mendocino and Point Conception). These differences are related, in part, to the fact that the U.S. has yet to formally define subregions within the LMEs around its coasts. Finally, the four ecoregions defined in the National Summary of Canada were only partly captured by the MEOW process: MEOW did distinguish the Strait of Georgia from other Canadian territorial waters, and also distinguished the north–south break at Brooks Peninsula, but did not identify the Pacific Offshore ecoregion or its subregions as defined in Canada's National Summary. These differences likely reflect specific local knowledge or management priorities identified in the Canadian process that would not have been a part of the global classification criteria of the MEOW effort.

International Collaborations

A key goal of this summary was to identify opportunities for PICES member countries to collaborate in managing marine ecosystems that span international borders. Occurring on both sides of such borders are activities or conditions (*e.g.*, primary productivity, anthropogenic nutrient inputs, fishing pressure, habitat status) that affect resources on the other side. Ecosystem-based management explicitly accounts for the spatial distribution of processes and resources; thus, responsible collaborative management of an ecosystem by two or more countries requires that they share comparable ideas of how ecosystem resources and processes are arrayed in space and time (Juda, 1999; Duda and Sherman, 2002). Ecosystem delineation provides a useful spatial framework for developing national and international research and management plans and activities.

WG 19 identified several examples of international resource management (particularly of fisheries) in the PICES area. The U.S. and Canada have shared treaty-based cooperative management of several transboundary species, including Pacific halibut *Hippoglossus stenolepis* since 1923; sockeye salmon *Oncorhynchus nerka* and pink salmon *O. gorbuscha* bound for the Fraser River since 1985; and the abundant, highly migratory Pacific hake *Merluccius productus* since 2003. Japan and Korea share jointly fished zones in shared seas, and China and Korea share jointly fished zones in the East China Sea and Yellow Sea. The Convention on Conservation and Management of Pollock in the Bering Sea, signed in 1994, established a means for international management and conservation of walleye pollock in international Bering Sea waters; signatories include China, Japan, Korea, Russia and the U.S. China, Japan, Korea and the U.S. are also included in the membership of the Asia Pacific Fisheries Commission, established through the FAO in 1948. It has a broad agenda related to sustainable fisheries development, research, coordination and communication (see http://www.apfic.org). The United Nations and World Bank-funded Global Environmental Fund (GEF) recently endorsed a proposal entitled "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem" that will support the governments of China and Korea in cooperative efforts to sustainably manage fisheries and mariculture, reduce pollution, and promote responsible oil, shipping and tourism industries in the Yellow Sea LME (Duda and Sherman, 2002; GEF, 2004). The outcome of this project may provide a model for other international collaborations in the PICES region.

Ecosystem-based management will require more collaboration by PICES member countries in the multinational LMEs typical of the North Pacific. We suspect that international collaboration will be most complicated in the western North Pacific, owing to ecological structuring forces as well as socio-economic and governance issues. In the eastern North Pacific, where Canadian and U.S. waters intersect in two places, the borders cross a continental shelf that is very narrow relative to the longshore extent of the boundary current ecosystems. Thus, these cases involve two nations with comparable governance and socio-economic structures, similar marine resources, and small geographic areas that require co-management. This is not to say that the U.S. and Canada always practice cooperative, transparent management of transboundary marine resources. It does, however, represent a simpler condition than that of the western North Pacific, where several semi-enclosed ecosystems are shared by three or four member countries, often with profound differences in governance structure, economic development, levels of scientific involvement, and degrees of dependence on marine resources. Their EEZs often meet over continental shelf waters, which tend to be the most heavily exploited and stressed marine systems in this densely populated area. The political boundaries themselves may be uncertain due to territorial disputes. These complications further underscore the value of the generally similar science-based approaches to ecosystem definition and delineation used by China, Japan, Korea and Russia.

Several institutions and frameworks can support additional international collaboration. Clearly, PICES is a forum for scientists to exchange information, to identify critical data gaps, and to discuss elements of possible cooperative monitoring programs (*e.g.*, useful ecosystem and fishery indicators, optimal spatio-temporal allocation of monitoring effort, data reporting formats, *etc.*). Another significant resource is the experience gained from the 'five-module approach' to LME assessment (Sherman, 1995; Sherman and Duda, 1999; Duda and Sherman, 2002). In this process, variables and indicators in three focal science-based modules (productivity; fish and fisheries; pollution and ecosystem health) are monitored in support of gathering basic information, assessing risk, and making decisions. A socio-economic module links ecological dynamics and resource management to economic principles that might operate under various management regimes. A governance module considers national and international institutions, activities and mores that determine how resources are used, how constraints and opportunities are assessed, what behaviors are acceptable, and who is responsible for implementing policies and programs (Juda, 1999; Duda and Sherman, 2002). Finally, management strategy evaluation (MSE) provides an analytical framework for assessing the outcomes of potential management actions. MSE involves defining a set ecological and economic objectives, selecting management strategies that can achieve those objectives, quantitatively analyzing the trade-offs among management alternatives, and specifying performance measures that indicate management success (Sainsbury *et al.*, 2000). Spatially explicit ecosystem models, such as Atlantis (*e.g.*, Fulton *et al.*, 2005) or Ecospace (Christensen and Walters, 2004) which feature management routines, are often used in MSE, and may prove vital tools for synthesizing available information and developing holistic management plans for marine ecosystems that span international borders. International research organizations like PICES are ideally suited to develop, refine and distribute these types of large-scale, data-intensive modeling tools.

4.2.9 Conclusions

As PICES member countries move toward ecosystem-based management of marine resources at a national and international scope, they are undergoing the crucial step of partitioning marine waters into ecologically cohesive, manageable spatial units. Although some member countries have taken more formal approaches than others, all members seem to have embraced similar criteria for delineating ecosystems and ecosystem subregions. The outcomes described in the National Summaries are also encouragingly similar to widely accepted classification schemes such as the LME network (Sherman, 2006) and the MEOW network (Spalding *et al.*, 2007). At least two major challenges remain, however, for formal delineation of ecosystems and subregions in the PICES area. First, the member countries need to determine the priority of developing, defining and implementing a standardized template for ecosystem delineation. Currently, such a template does not exist and its priority, both within individual countries and within PICES, remains unclear. Second, the delineation schemes described above were largely prepared by fisheries ecologists and likely reflect biases of the authors. The limitations and consequences of those biases would need to be addressed, likely through inclusion of a broader family of disciplines. As these two challenges are addressed, PICES experts and member countries should carefully consider the advantages and disadvantages of existing delineation schemes and identify criteria (abiotic, biotic, economic, *etc.*) and structural frameworks (qualitative, quantitative, hierarchical) that will facilitate national and international marine resource management.

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5 Summary

This document expands in greater detail the progress each of the PICES member countries are making towards the implementaion of ecosystem-based management (EBM) within their EEZ. None of the countries to date have achieved full EBM, and it is readily apparent that because of differing national management objectives, EBM is being approached quite differently across the North Pacific. As discussed in the earlier Study Group report (Jamieson and Zhang, 2005), fishery management objectives in China, Japan and Korea are largely focused on maximising food production from the sea to meet the demands of their large human population's food needs, whereas in Canada and the United States, maintaining healthy populations of species in all trophic levels is recognized as the major EBM objective, even if this sometimes means closing fisheries to allow for population recovery. These different management approaches are perhaps best illustrated with respect to how invasive species are determined. There is broad agreement that invasive species are harmul to the 'desired ecosystem', and in the eastern Pacific they are defined as non-indigenous species. In the western Pacific, any species, non-indigenous or indigenous, whose abundance increases so that it becomes disruptive to existing fisheries is considered undesirable and invasive. This could therefore include significant increases in abundance of native jellyfish or harmful algal species, situations which, while also not desirable in the eastern Pacific, would not be dealt with by authorities focusing on what they define as invasive species. This difference may be subtle, but it serves to illustrate how different events or situations may be responded to differently by resource and research managers.

Through the process of documenting the diversity in EBM approaches shown by PICES member countries, it should be possible over time to discern which EBM approaches work well and which do not work under particular circumstances. This report establishes a baseline for each country against which future progress can be measured, and rate of achievment of objectives determined. We believe this is a key achievement, as it will assist in future studies, such as are being contemplated for PICES' new integrative science program on **F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems (FUTURE). There are three key questions that FUTURE will be addressing, namely:

1. What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
2. How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
3. How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

They all relate to or influence the ultimate success of achieving effective EBM, so it will be interesting to document over time how either marine systems and/or management approaches of human activities change. Because of information presented in this document, it should be possible to evaluate in the future the consequences of anthropogenic influences on regional marine ecosystems.

5.1 Recommendations for Looking beyond WG 19

We discussed how the findings and work of WG 19 could best be integrated and built upon within PICES in years ahead, particularly within the context of the new PICES integrative science program on **F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems (FUTURE); please see http://pices.int/members/scientific_programs/FUTURE/FUTURE-main.aspx). Development of ecosystem-based management is still very much in its early stages in each of the PICES member countries, and so we recommend that PICES continue to actively monitor progress into the foreseeable future. To provide a long-term forum for this process, we concluded that the issues addressed by WG 19 might justify the establishment of a new group, with emphasis on developing an integrative, science-based, ecosystem-scale understanding of the human dimension (across a diversity of sectors). This group will be closely associated with FUTURE as an Advisory Panel on *Anthropogenic Influences in Coastal Ecosystems* (AICE). We suggest that this new group's emphasis be on developing an integrative, science-based, ecosystem-scale understanding of the human dimension (across a diversity of sectors) in FUTURE, and suggest it be called *"PICES Understanding, Linking and Synthesis of Ecosystems"* (PULSE). A draft proposal for this proposed body with an objective, terms of reference and membership is:

Objective

To monitor and synthesize regional and basin-wide ecosystem-based management (EBM) studies and initiatives (ecosystem health) and to provide a forum for the integration of FUTURE-related EBM practices and their implementation.

Draft Terms of Reference

1. PULSE (*PICES Understanding, Linking and Synthesis of Ecosystems*) is the scientific body responsible for the promotion, coordination, integration and synthesis of research activities related to the implementation of EBM among PICES member nations. This goal would be accomplished by convening meetings, periodic scientific symposia or workshops, or by distributing information designed to foster cooperation and integration among existing or developing PICES programs, and possibly between and/or within member nations;
2. PULSE will provide the scientific body to identify and improve indicators to measure progress in the achievement of EBM. It will provide the forum to discuss the needs, impacts and responses of coastal communities in a changing marine environment, and to enhance the use of this information by governments and society at large. It will also provide a forum for the connection of ecosystem monitoring and status reporting of both environmental and social indicators (through linkage with MONITOR), and the subsequent implementation and adaptation of EBM;
3. Scientific collaboration and coordination with other international agencies, bodies and societies that are engaged in either EBM or human activities that are relevant to the achievement of EBM will be undertaken. This will engage expertise not previously active in PICES, such as social-scientists and policy makers;
4. PULSE will encourage establishment of other component activities, such as developing the basis for coupled human science-natural science models, and emerging approaches as needed to facilitate synthesis of the FUTURE Program.

Membership

We recommend a membership that will ensure core connection with PICES Committees, key expertise from the various disciplines involved in studying ecosystem approaches to management, and national representation. We advocate a nomination process that will closely connect this group to PICES Scientific Committees, such as ensuring that a member or designate from each Committee and perhaps from the current Study Group on *PICES Communications* in PULSE. There is also merit in having member participation from different sectors besides fishing (*e.g.*, mariculture) and ecoregions.

5.1.1 Advice on the Structure and Content of Future North Pacific Ecosystem Status Reports

The Working Group also considered advice on the structure and content of future North Pacific Ecosystem Status Reports (NPESRs), and specifically the inclusion of EBM-related topics in status reports. An incremental improvement version of NPESR is being recommended by Science Board, and we recommend that enhanced information on pollution and socioeconomics be considered for inclusion. We discussed the need to identify key pressures in each region, and on how indicators on status and trends describing human well-being should be determined, and concluded that further review on these topics is needed. Establishment of a PICES Study Group on *Indicators of Human Well-Being: Benefits and Health* is recommended to assist in this effort.

Criteria for selection of membership should include biophysical and social scientists, including in the latter those with strong economic, sociological and anthropologic expertise, with understanding of natural science, particularly marine science, and who are working on questions relating to marine ecosystem approaches and management issues. Terms of reference for such a group might include:

1. Identify potential indicators of human-well being and human impacts in relation to the PICES report on marine ecosystem status and trends; evaluate the Millennium Ecosystem Report indicators for their appropriateness.
2. Review how these measures might be quantified and standardized across member countries, and if the data are available to quantify these.
3. Review how these measures can be used in ecosystem models and management strategy evaluation frameworks.
4. Identify longer-term issues that might be covered by a working group on this topic (governance structures for implementation, *etc.*).

Criteria for selection of membership should include natural and social scientists, including in the latter those with strong economic, sociological and anthropologic expertise who are working on questions relating to marine ecosystem approaches and management issues.

5.2 Ecosystem-based Management in International Waters

In the above, all details and discussion presented have been focused on initiatives being undertaken within the Exclusive Economic Zones of PICES member countries. While significant progress is being made in these regions to address issues relates to EBM, the reality is that many species have spatial distributions in the Pacific Ocean that extend well beyond national jurisdictions. For these species, effective EBM can only be realized if national efforts to achieve EBM are harmonized with similar multinational efforts in international waters. To this end, many of the initiatives to determine appropriate EBM steps in national waters, such as identifying ecoregions (spatial areas with a basically similar mix of species and environment) and within them, ecologically and biologically significant areas and species need to be undertaken in offshore international waters of the PICES region.

5.3 Bibliography

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Appendix 1

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Appendix 2

Template for Ecosystem-based Fishery Management Country Profiles of Ocean Management Activities

1. Fishery Management	- General approach to management for target species	
	- For general approach or a representative selection of species/groups	- Ecological properties of the species (*e.g.*, where on r-K spectrum; top predator, intermediate predator–prey, prey species)
		- Level of natural variability (*e.g.*, 'usual' level of interannual recruitment variability → highly variable recruitment interannually → episodic recruitment and regime shifts)
		- Planned management responses (control rules and recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger if used)
	- General approach to management for non-target/bycatch	
	- For general approach or a representative selection of species/groups	- Ecological properties of the species or groups
		- Level of natural variability
		- Planned management responses (control rules, recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger if used)
2. Management of Threatened or Protected Species and Communities	- General approach to management of threatened or protected species/communities	
	- For general approach or a representative selection of species/communities	- Ecological properties of the species or groups
		- Level of natural variability
		- Planned management responses (control rules, recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger, if used)

3. Habitat Management	- General approach to management of habitats	
	- For general approach or a representative selection of habitats	- Ecological properties of the habitats
		- Level of natural variability
		- Planned management responses (control rules, recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger, if used)
4. Community/Trophic Structure Management	- General approach to management of food webs in general and of direct feeding interactions (predator–prey relationships involving the target species) specifically.	
	- For direct feeding interactions (*e.g.*, predator–prey relationships) that directly involve the target or other highly valued species	- Ecological properties involved
		- Level of natural variability
		- Planned management responses (control rules, recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger if used)
5. Management of Physical Environment (including Freshwater Discharge from Land)	- General approach to management of the physical environment	
	- For general approach or a representative selection of issues	- General properties of the aspect of the physical environment at issue (*e.g.*, fragility/robustness and reversibility /irreversibility of fishery effects)
		- Level of natural variability
		- Planned management responses (control rules, recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger, if used)
6. Management of Contaminants and Pollutants	- General approach to management of contaminants and pollutants	
	- For general approach or a representative selection of issues	- General properties of the aspect of contaminants, pollutants at issue (*e.g.*, toxicity and reversibility/ irreversibility of effects)
		- Level of annual/seasonal variability
		- Planned management responses (control rules, recovery rules and targets)
		- Level of information/uncertainty (elaborate as necessary)
		- Reference points (target, limit and trigger, if used)

	- Socio-economic considerations	- Size of local population and growth rate
		- Size of population dependent on the activity being considered
		- Cultural, social and economic values/importance of the activity
7. Management of Aquaculture	- Ecological properties of species	
	- Level of harvest variability	
	- Planned management responses	
	- Level of information/uncertainty	
8. Management of Enhancement Activities	- General properties of the enhancement activities (*e.g.*, stocking or releasing of fry/juveniles, establishing artificial reefs, making seaweed beds, *etc.*)	
	- Ecological properties of stocking species	
	- Planned management responses	
	- Level of information/uncertainty	

Appendix 3

Terminology

The ecosystem literature is rich with definitions and terms. The Canadian National Workshop on "Objectives and indicators for ecosystem-based management" (February 27–March 2, 2001, Sidney, B.C. Canada) spent considerable time discussing and debating those related to the ecosystem-level objectives (Jamieson *et al.*, 2001; see section 2.2). The terms and definitions given in the table below are based upon those currently in use in the literature as well as a few new ones added at the workshop.

Term	Definition
Characteristic	Some property of the ecosystem, separate from our measurement of it (*e.g.*, absolute biomass or recruitment measures for a population)
Delphic analysis	The Delphi Method is based on a structured process for collecting and distilling knowledge from a group of experts by means of a series of questionnaires interspersed with controlled opinion feedback.
Ecosystem	The spatial unit and its organisms and natural processes (and cycles) that is being studied or managed
Ecosystem-based management	A strategic approach to managing human activities that seeks to ensure through collaborative stewardship the coexistence of healthy, fully functioning ecosystems and human communities [towards maintaining long-term system sustainability] by integrating ecological, economic, social, institutional and technological considerations
Indicator (attribute)	Quantity that can be measured and be used to track changes over time with respect to an operational objective. Measurable part or process (property) of a system (*e.g.*, average weight of age 5 individuals of a species)
Metric	Indicator empirically shown to change in value along a gradient of human influence (*e.g.*, a population's biomass as a result of fishing activity; number of introduced (exotic) feral species)
Multimetric index	A number that integrates several metrics to indicate a "condition" factor
Reference point	Value of an indicator corresponding to a management target or threshold
Target reference point	An indicator reference point that is trying to be achieved (*e.g.*, an estimated biomass of 30,000 t)
Limit reference point	An indicator reference point that if crossed results in the implementation of a management action (*e.g.*, if the estimated biomass falls below 10,000 t, the fishery is closed)
Conceptual objective	General statements that are uniformly accepted by all stakeholders as desirable. They are specific enough that everyone will interpret them the same way, but do not specify how they will be measured.
Operational objective	Objective that has a direct and practical interpretation in the context of (fisheries, habitat) management and against which performance can be evaluated quantitatively. A specific statement that consists of a verb (*e.g.*, maintain), a specific measurable indicator (*e.g.*, estimated biomass), and a reference point (*e.g.*, 50,000 t), thus allowing an action statement for management (*e.g.*, maintain estimated biomass of a given forage species greater than 20,000 t biomass).

Reference

Jamieson, G., O'Boyle, R., Arbour, J., Cobb, D., Courtenay, S., Gregory, R., Levings, C., Munro, J., Perry, I. and Vandermeulen, H. 2001. Proceedings of the National Workshop on Objectives and Indicators For Ecosystem-based Management, Sidney, British Columbia, February 27–March 2, 2001. CSAS Proc. Ser. 2001/09.

Appendix 4

Department of Fisheries and Oceans Ecosystem Overview and Assessment (EOA) Report Format

Standard Table of Contents

GENERAL INFORMATION

7. Physical Oceanography (models)

- a. Freshwater inputs
- b. Sea level and Tides
- c. Water Masses and Currents
- d. Stratification and Mixing (Fronts, Gyres and Upwellings)
- e. Waves and Turbulence
- f. Ice (Permanent and Seasonal Coverage)
- g. Underwater Sound – Sources and propagation

8. Physical-Chemical Properties of Seawater

- a. Temperature, Salinity and Water Density
- b. Dissolved Oxygen – Areas of Hypoxia
- c. Suspended Matter – Light Availability
- d. Organic Carbon (DOC/POC)
- e. Nutrients – Flux and Budgets
- f. Biogeochemistry (Dissolved Trace-Metals and Natural Hydrocarbons)

Part C – BIOLOGICAL SYSTEM

9. Flora and Fauna

- a. Planktonic Communities
  - i. Bacterioplankton
  - ii. Phyto- and Zooplankton
  - iii. Ichtyoplankton
- b. Benthic Communities
  - i. Microalgae
  - ii. Macrophytes
  - iii. Infauna
  - iv. Invertebrates
    - a. Commercial Species
    - b. Non-Commercial Key Species
  - v. Ground Fish
    - a. Commercial Species
    - b. Non-Commercial Key Species
- c. Pelagic Communities
  - i. Invertebrates
  - ii. Marine Turtles
  - iii. Pelagic Fish
    - a. Commercial Species
    - b. Non-Commercial Key Species
  - iv. Marine Mammals
  - v. Sea Birds

10. Habitat Use and Functional Areas

- a. Mating / Spawning / Breeding Areas
- b. Rearing Areas
- c. Foraging / Feeding Areas
- d. Migration Routes
- e. Critical Habitats (under SARA)

Part D – ECOSYSTEM DESCRIPTION

11. How does the ecosystem work? Ecosystem Relationships

- a. Physical-Biological Linkages
  - i. Influence of physical factors on biology and species distributions
  - ii. Nutrient Cycles, Blooms, Upwellings
- b. Biological Interactions
  - i. Functional Processes
  - ii. Food Web and Trophic Structure
- c. Natural Variability – Seasonal, Inter-Annual and Long-Term Changes
- d. Resilience of the Ecosystem

VOLUME TWO. ASSESSMENT AND CONCLUSIONS

PART E – ECOLOGICAL ASSESSMENT

12. Areas of Concern (maps)

- a. Ecologically and Biologically Significant Areas (EBSAs)
- b. Conservation Areas (MPAs, NMCAs, Wildlife Conservation Areas, *etc.*)
- c. Heavily Impacted Areas (*e.g.* ‘hot spots’ of contaminants, habitat degradation)
- d. Ocean Space Uses (Fishing zones, Oil & Gas Licenses, Aquaculture sites, Corridors, *etc.*)

13. Impacting Activities and Stressors

- a. Major Human Activities of Concern
  - i. Land-Based Activities
  - ii. Harvesting of Renewable Resources
  - iii. Extraction of Non-renewable Resources
  - iv. Transportation and Communications
  - v. Recreational Activities
  - vi. Other Sea-Based Activities
- b. Anticipated / Emerging Activities
- c. Global Stressors (regional focus)
  - i. Global Warming and Climate Change
  - ii. Ozone and UV Radiations
  - iii. Long-Range Transport of Pollutants
  - iv. Aquatic Invasive Species

14. Threats and Impacts on Ecosystem Properties and Components – Cumulative Impacts

- a. Biodiversity and Species at Risk
- b. Productivity and Use of Oceans Resources
- c. Water/Sediment, Habitat and Biota Quality
- d. Integrity of Coastal Landscapes and Bottomscapes
- e. Cumulative impacts/effects

PART F – CONCLUSIONS AND RECOMMENDATIONS

15. Uncertainties, Unknowns and Limits of Science Support

16. Recommendations to Science Managers

- a. Identification of Knowledge Gaps *(may be discussed in appropriate sections above)*
- b. Monitoring and Research Needs

17. Recommendations to the Integrated Management

a. Summary of the Major Environmental Issues and Concerns for the Study area
b. Identification of Priority Areas and Actions Needed
   i. In the short-term (1 year)
   ii. In the medium term (2-5 years)
   iii. In the long term (> 5 years)
c. Best Practices – Examples of Interest

CITED REFERENCES

(Or may be listed at the end of each corresponding sections)

RESOURCES AND EXPERTISE

- List of regional experts in fields of expertise
- List of ongoing initiatives in topics of interest

Selected Bibliography and Web Resources

ANNEXES

- Glossary (technical terms used in the report)
- List of acronyms
- Supporting Technical Documents *(if needed)*

IMPORTANT NOTICE

How to use this standard Table of Content

The EOA Protocol is under development; it will give explanations on the content of each chapter and section proposed in the Standard ToC. In the interim, the aim of this standard ToC is to provide EOA project coordinators and authors with a guidance to organize the information in order to describe ecosystem features and discuss environmental issues that may be observed in all Canada's Oceans and regions. It must be noted that not all sections of the standard ToC may be necessary, according to the study area. Only those relevant to Ecosystem-Based Management should be detailed and discussed in the EOA for IM purposes. On the other hand, only overall chapters and sections are mentioned in the Standard ToC. Authors may want to re-organize the proposed chapters or add new sections to highlight specific features and/or regional issues that are considered important for meeting IM needs in the study area / at the regional scale.

Additional sub-divisions can be added into a given chapter/section if necessary.

Appendix 5

WG 19 Annual Reports

PICES Fourteenth Annual Meeting
September 29–October 9, 2005
Vladivostok, Russia

2005 Report of Working Group on *Ecosystem-based Management Science and its Application to the North Pacific*

Working Group (WG 19) on *Ecosystem-based management science and its application to the North Pacific* held its first meeting from September 28-30, 2005. The WG 19 Co-Chairmen, Drs. Glen Jamieson and Chang-Ik Zhang, welcomed the participants (*WG 19 Endnote 1*) and reviewed the agenda for the meeting (*WG 19 Endnote 2*). Ms. Patricia Livingston, the third WG 19 Co-Chairman, was unable to attend due to travel interruptions enroute to Vladivostok.

Making terms of reference useful to PICES (Agenda Item 2)

There seems to be a significant difference between regions: Japan, China, and Korea have relatively perturbed ecosystems, and much of the national emphasis is on fisheries and aquaculture; on the other hand, Russia, Canada, and the United States seem to emphasize maintaining less-impacted, historical ecosystem characteristics. Valuable perspectives were offered from other parts of the world (*e.g.*, ICES, Australia).

WG 19 proposes to produce a brochure on ecosystem-based management (EBM), following the template of the well-received approach used by the PICES Study Group on *Fisheries and Ecosystem Responses to Recent Regime Shifts.* The brochure would be an executive summary of the final report of the Working Group and would focus on (1) the need for EBM, (2) objectives for EBM, (3) consequences of not moving to EBM, and (4) research that is needed to move towards EBM.

Revision of ocean management reporting format (Agenda Item 3)

The draft management plan was reviewed and streamlined to increase the focus on the general characteristics at the eco-region level. For each section, a list of questions was prepared for members from each country to answer about the status of management in their respective jurisdictions (*WG 19 Endnote 3*).

National marine ecosystem monitoring approaches, plans and issues (Agenda Item 4)

All member countries represented at Vladivostok gave overviews of their existing ecosystem monitoring approaches (neither China nor Japan sent Working Group members to the meeting). Monitoring approaches exist in each country, although each identified many data gaps, difficulty with data accessibility, and a lack of integration among monitoring programs. Dr. Elizabeth Fulton summarized the Australian approach to EBM-based monitoring. Some member nations have monitoring programs, though not necessarily organized in an EBM conceptual framework.

WG 19 proposes to establish a standardized format for reporting monitoring in each country, focusing on biological monitoring, physical monitoring, human influences, modeling, and ecosystem status reporting (*WG 19 Endnote 4*).

Overview of the 2004 IOC/SCOR symposium on "Quantitative ecosystem indicators for fisheries management" (Agenda Item 6)

Dr. Ian Perry provided a summary of a symposium that was held from March 31 – April 3, 2004, in Paris, France. Selected papers from the symposium were published in the *ICES Journal of Marine Science* (2005, Vol. 62, No. 3). The symposium had two major themes: (1) to provide an overview of the range of indicators of exploitation and state of ecosystems developed for fisheries management; and (2) to examine scientific basis for incorporating indicators into ecosystem-based fisheries management (EBFM). Over 100 indicators were proposed, and some included reference points or reference directions. All papers advocated multiple indicators, and most indicators were derived from fisheries-independent surveys. The symposium did not achieve consensus on which indicators to use, but the general consensus was that the identification of indicators is an important task but it is work in progress.

Dr. Perry described the properties of good indicators, an eight-step procedure for identifying them, how to determine screening criteria, and the general approaches used in applying them (empirical *vs*. theoretical, which seem to converge on which indicators are strongest, according to ICES symposium papers by Drs. Jason Link and Elizabeth Fulton).

Dr. Fulton noted that indicators based on data from fishery-independent surveys are not available in all parts of the world because countries cannot afford them. Models and empirical studies suggest that restricting the choice of indicators to fishery-dependent data can result in incorrect conclusions being drawn from the indicator data. Therefore, priority should be placed on the use of fishery-independent data. There is optimism that this can be done, even in developing countries and new fisheries, because of increased capabilities of remote sensing and the power of coarse scale indicators (*e.g.*, body size, abundance of all individuals in a particular functional group) that may be relatively easy to monitor.

Discussion on eco-regions (Agenda Item 7)

WG 19 discussed how to define eco-regions, based largely on the Canadian experience. The "eco-region" definition includes a mixture of geological, biological and physical parameters. Eco-region boundaries tend to be fuzzy, not sharp, and indicate areas of commonality.

All countries reported on progress with eco-regional delineation. Canada has progressed farthest. Delineation of eco-regions is in progress in the United States and Russia. Korea has begun consideration of formal eco-regional delineation. All participants agreed that it would be beneficial to have regional plans that span national boundaries because many of the eco-regions in the North Pacific are trans-boundary or in international waters.

Dr. Fulton discussed the Australian approach to bio-regionalization, a hierarchical approach that is defined at large scale by information on circulation and temperature, and adds in finer scale, ecological processes as you move down the 5-level hierarchy.

To consider the scientific requirements for eco-region identification and review the existing Large Marine Ecosystem boundaries in the PICES area, WG 19 proposes to convene a 1-day MEQ/FIS Topic Session on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*" at PICES XV. Travel funds are requested for 1 invited speaker to attend the session.

NPRB/PICES Workshop on ecosystem indicators for the Bering Sea (Agenda Item 8)

Dr. Perry informed about a project that was funded by the North Pacific Research Board to integrate ecological indicators in the North Pacific, with an emphasis on the Bering Sea. Four activities were identified for a workshop to be held May 31 – June 2, 2006, in Seattle:

1. Involve Bering Sea and international communities in developing a set of operational objectives for southeastern Bering Sea ecosystem;
2. Evaluate the NOAA/Fisheries "*Ecosystem Considerations*" chapter that is prepared annually for the North Pacific Fishery Management Council and the PICES North Pacific Ecosystem Status Report, with the goal of integrating the results;
3. Investigate methodologies to monitor system-wide structural ecosystem changes within the marine ecosystem;
4. Identify steps in valuating indicator performance that improve the monitoring network, and integration into predictive models.

Findings from this workshop are important for identifying criteria for ecosystem indicators.

Action items to be completed prior to the next WG 19 meeting (Agenda Item 9)

1. Compile national and international (*e.g.*, PICES, LMEs, "Sea Around Us" project (D. Pauly), Longhurst) approaches (maps, processes used to identify area) to establishing science-based eco-regions, and compare these to existing or planned "management" regions.

Gather together all delineated areas (*e.g.*, fishery statistical areas, LOMAS, management areas, *etc*.) and digitize for GIS display. Identify areas of cooperation/collaboration between adjacent countries to jointly evaluate cross-jurisdictional areas with the goal of trying to establish common eco-regions. These deliberations may be useful in updates of the North pacific Ecosystem Status Report.
   - Lead – all countries
   - Submission deadline – January 1, 2006
   - Product – summary GIS chart and report; G. Jamieson and I. Perry for Canada; D. Fluharty and J. Stein for US; by July 1, 2006.

2. Consider a theoretical evaluation of the consequences of an artificial boundary that splits an ecological process and how that could affect management.
   - Lead – C. Harvey and E. Fulton (ghost collaborator)
   - Deadline – July 1, 2006
   - Product – report and presentation at next meeting, as well as a paper to be published in peer-reviewed literature.

3. Each country will complete at least one Ocean management activity report. The intent is to show the process and framework that each country is using to implement an ecosystem approach to management. In selecting a region, consider regions where there is more than one significant management issue (*e.g.*, fishing and oil and gas exploration).
   a. Leads – All WG members
   b. Deadline – June 1, 2006
   c. Product – reports

4. Describe national ecosystem monitoring approaches relevant to the eco-regions considered in #3 (above). Monitoring activities should be grouped by category.
   - Lead – all countries
   - Deadline – June 1 2006
   - Product – reports

5. Summarize the findings from the 2004 symposium on "*Quantitative ecosystem indicators for fisheries management*"
   - Lead – I. Perry and P. Livingston (with assistance from E. Fulton)
   - Deadline – January 1, 2006
   - Product – reports

6. Summarize findings from the upcoming PICES/NPRB workshop on the framework and criteria for identifying ecosystem indicators. Invite members of MONITOR to WG 19 meetings.
   - Lead – WG members that participate in the workshop
   - Deadline – October 2006, next WG 19 meeting
   - Product – preliminary report

7. Hold a mini-symposium at PICES XVI on "*Comparative analysis of frameworks to develop EBM and research needed to move towards implementation of EBM*" to build on products arising from the PICES/NPRB Bering Sea Indicators workshop. Each country would present their perspective. Invited speakers will address issues such as case studies, lessons learned, indicators, *etc*. WG 19 should invite participation by other PICES Committees (*e.g.*, MONITOR) and WGs/Sections. Consider "over-arching" questions such as the following (also proposed bases for a brochure-type publication):
   - scientific need for EBM and consequences of not moving to EBM,
   - objectives for EBM,
   - ways to move towards EBM,
   - research needs to move towards EBM.

   Co-Chairmen to present brochure concept to parent PICES Committees in 2006.

8. Next meetings:
   - A 3-day PICES/NPRB Workshop on "*Integration of ecological indicators for the North Pacific with emphasis on the Bering Sea*" to be held May 31-June 2, 2006, in Seattle, U.S.A.;
   - A 3-day WG 19 meeting prior to PICES XV (October 2006, Yokohama, Japan);
   - A 1-day MEQ/FIS Topic Session on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*" at PICES XV.

WG 19 Endnote 1

Participation list

Members

Elena Dulepova (Russia)
David Fluharty (U.S.A.)
Christopher Harvey (U.S.A.)
Glen Jamieson (Canada, Co-Chairman)
Jae-Bong Lee (Korea)
R. Ian Perry (Canada)
Vladimir Radchenko (Russia)
Inja Yeon (Korea)
Chang-Ik Zhang (Korea, Co-Chairman)

Observers

Vladimir Belyaev (Russia)
Robin Brown (Canada)
Elizabeth Fulton (Australia)
Melissa Haltuch (U.S.A.)
Yukimasa Ishida (Japan)
Tokimasa Kobayashi (Japan)
Phillip Mundy (U.S.A.)
Hak-Gyoon Kim (Korea)
Darlene L. Smith (Canada)
John E. Stein (U.S.A.)

WG 19 Endnote 2

WG 19 meeting agenda

Wednesday, September 28

1. Welcome and introductions
2. Review terms of reference
3. Revision of ocean management reporting format
4. National marine ecosystem monitoring approaches, plans, and issues

Thursday, September 29

5. Continue descriptions of relevant national marine ecosystem monitoring approaches, plans and issues
6. Overview of the 2004 IOC/SCOR symposium on "*Quantitative ecosystem indicators for fisheries management*"
7. Review existing definitions of "eco-regions" and identify criteria that could be used for defining ecological boundaries in the PICES area

Friday, September 30

8. Discuss ideas for a PICES/NPRB workshop on ecosystem indicators for the Bering Sea planned (May-June 2006) and an inter-sessional workshop to be held in Year 2 or 3 of the WG's mandate
9. Discuss objectives, site and date for the next WG 19 meeting

WG 19 Endnote 3

Revised ocean management reporting format

Ocean management activities

- Eco-region where defined or geographic location (*e.g.*, Korean portion of Yellow Sea);
- General description of oceanographic and biological setting; if appropriate, start with PICES North Pacific Ecosystem Status Report for the description of regions;
- Relevant management plan, policy, legislation (please provide copies of these or a source, such as a website or a contact point, so that we can obtain copies);
- General form of management or any other general comments on the management regime;
- What are overall ecosystem-based management objectives?
- How will these objectives be achieved?
- What is the timeframe to implement these objectives and meet goals?

Fishery management

- Management objectives for targeted and non-targeted species in fisheries;
- How is the ecosystem taken into consideration when managing fisheries?
- How selective is the gear (*e.g.*, bottom trawl; mid water trawl; purse seine; other gear, such

as long line and trap; gillnet) for the target species?

- Fishery gear targets certain sizes or life-history stage(s);
- Is fishery spatially concentrated, or not?
- Is fishery year round, or not?
- Are certain geographic areas excluded from the fishery? Explain reason for the exclusion.
- Are there catch limits on non-target species?
- Is the catch of non-target species recorded and accounted for?
- What is the environmental variability (*e.g.*, physical disturbance regime; El Niño, typhoon, changes in strength of currents) and how do species respond, if known?
- What is the spatial distribution of the fishery compared to the distribution of the target species?

<u>Management of threatened or protected species and communities</u>

- General approach to designation (legal/regulatory framework), management and recovery of threatened or protected species/communities (describe ecological properties of the species or groups that makes them vulnerable and needing protection);
- Is there legislation for designating species at risk?
- How are threatened species identified, and are there timeframes for developing recovery plans?
- Are recovery thresholds identified above which a species no longer needs legal protection?

<u>Habitat management (conservation/restoration)</u>

- General approach to management of habitats; this includes biological habitat, such as corals, sea-grass beds, *etc*., as well as physical habitat (describe ecological properties of the habitat that makes it significant.);
- Are specific habitats designated for protection, and what legislation allows for the designation?
- Are there monitoring and inventory activities in place?
- Are there restoration plans or activities underway?
- Are there ecologically or biologically significant habitat types/areas that can be identified and are they given special protection, and are there standards (*e.g.*, no activities allowed or just limitation of human activities in the habitat) for the level of protection?

<u>Community/trophic structure management</u>

- Are the characteristics of the community altered by human activities (*e.g.*, eutrophication, pollution, species introductions, sedimentation, altered coastal circulation, dredging and filling, altered hydrography of rivers, fishing, *etc.*)?
- Are management activities affecting food-webs or do existing food web perturbations constrain moving to a desired state.
- Does specific legislation address issues relevant to food webs?
- Are there monitoring and inventory activities in place?
- Are there restoration plans or activities underway?
- Are there ecologically or biologically significant species interactions that can be identified and are they given special consideration, and are there standards (*e.g.*, ballast water, coastal development, water quality, *etc.*) for the level of protection?

<u>Management of contaminants and pollutants</u>

- General approach to management of ecosystem-wide effects of contaminants and pollutants;
- Does specific legislation address issues relevant to contaminants?
- Are there monitoring and inventory activities and standards in place?
- Are there restoration plans or activities underway?
- Which aspects of the ecosystem are being most affected by the effects of contaminants?

<u>Management of aquaculture</u>

- General properties of the aquaculture activities (*e.g.*, stocking or releasing of seed/fry/juvenile, production of individuals in contained environments);
- Do specific regulations address issues relevant to species selection, scale of the operation, spatial distribution, and environmental impacts of activities?
- Are there monitoring and inventory activities in place?
- Are there mitigation plans or activities underway?
- Are there significant ecological and biological interactions that can be identified and are they given special consideration?

Management of enhancement activities (species and habitat)

- General properties of the enhancement activities (*e.g.*, stocking or releasing of fry/juvenile, putting in artificial reefs, making seaweed beds, *etc*.);
- Do specific regulations address issues relevant to species selection, scale of the operation, spatial distribution, and environmental impacts of activities?
- Are there monitoring and inventory activities in place?
- Are there mitigation plans or activities underway?
- Are there significant ecological and biological interactions that can be identified and are they given special consideration?

WG 19 Endnote 4

Standardized format for reporting national monitoring

- Habitat classification (biogeographic zone)
- Biodiversity
- Species population abundance (fish, HABs, *etc*.)
- Species spatial distribution and movements (migration routes) – ecologically and biologically significant areas
- Temporal changes (cycles and trends) in physical environment
- Human influences
  - Pollution level, sedimentation, exotics, habitat alterations
  - Spatial locations (*e.g*., vessel location monitoring (VMS))
- Modeling, predictions and forecasting (identification of key indicators or gaps in knowledge)
- Ecosystem status reporting (state of ocean report); planning for reporting
- Level of integration, monitoring systems and data management and access

WG 19 Endnote 5

Proposal for a 1-day MEQ/FIS Topic Session at PICES XV on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*"

The management of human activities that impact ocean ecosystems requires planning and engagement of stakeholders to meet the objectives of ecosystem-based management, which in turn requires identification of areas to determine which stakeholders need to be involved in each specific process. Area boundaries are typically based upon science (*i.e.* eco-regions), human community (*i.e.* coastal community composition), administrative (*i.e.* historical resource management areas) and international considerations (*i.e.* transboundary issues). This session will consider the science requirements for eco-region identification in the PICES area, and we solicit presentations that: 1) highlight national or regional experiences or frameworks in place for delineating marine sub-regions or eco-regions; 2) demonstrate the use of a variety of physical and/or biological criteria for region identification; or 3) explain the specific management purposes behind various sub-regional identification schemes. Session discussion will involve participants in reviewing the existing Large Marine Ecosystem boundaries of the PICES area and developing recommendations for criteria to be used in sub-regional identification in the North Pacific.

Recommended convenors: Glen Jamieson (Canada), Patricia Livingston (U.S.A.) and Chang-Ik Zhang (Korea).

PICES Fourteenth Annual Meeting Topic Session Summary

MEQ/FIS Topic Session (S8)
Ecosystem indicators and models

Co-convenors: Glen Jamieson (Canada), Xian-Shi Jin (China), Pat Livingston (U.S.A.), Tokio Wada (Japan), Vladimir Radchenko (Russia) and Chang-Ik Zhang (Korea)

Background

Ecosystem-based management (EBM) of resources will require ways to monitor current conditions and predict future states. Ecosystem indicators are single variables that reflect the status of broad suites of management activities or environmental conditions, and their assessment is key to monitoring the achievement of EBM. Predictive ecosystem models can be used to hypothesize the responses of an ecosystem to management actions, to assess the sensitivities of indicators, and to highlight gaps in current knowledge. This session brought experts together to identify criteria for suitable indicators and the utilities of predictive models, and to present candidates of indicators and models that are actively in use in PICES areas.

Summary of presentations

Thirteen of 15 scheduled oral papers were presented plus several posters. Presentations included reviews of indicators in simulation models that attempted to describe key elements of entire ecosystems, and the ecosystem behavior that might result from perturbation, indicators relative to describing the consequences of fishing and/or environmental features in particular, modeling of specific ecosystem energy pathways, approaches to the identification of indicators that track ecosystem characteristic shifts, identification of important spatial areas where monitoring activities might most cost-effectively be focused, and the utility of different bioindicators for monitoring specific impacts. Given this diversity of papers, discussion was wide-ranging and reflected the challenges in trying to identify relevant, cost-effective and conceptually easily explainable potential indicators for evaluation of success in achieving EBM.

List of papers

Oral presentations

Elizabeth A. Fulton, Michael Fuller and Anthony D.M. Smith
Management strategy evaluation and indicators for ecosystem-based fisheries management

Gordon H. Kruse, Patricia A. Livingston and Glen S. Jamieson
Evolution of ecosystem-based fishery management

Sang Cheol Yoon and Chang Ik Zhang
A comprehensive ecosystem-based approach to management of fisheries resources in Korea

James E. Overland, J. Boldt, J. Grebmeier, J. Helle, P.J. Stabeno and M. Wang
Multiple indicators track major ecosystem shifts in the Bering Sea

Michio J. Kishi, Ippo Nakajima and Yasuko Kamezawa
Fish growth comparisons around Japan using NEMURO.FISH

Vladimir I. Zvalinsky
Ecosystem parameters and stability: Theoretical considerations

Glen Jamieson and Cathryn Clarke
Identification of ecologically and biologically significant areas in Pacific Canada

Chuan-Lin Huo, Geng-Chen Han, Ju-Ying Wang and Dao-Ming Guan
EROD as bioindicator for monitoring of marine contaminants along the Dalian coast

Sun-Kil Lee, Jae Bong Lee, Chang-Ik Zhang and Dong Woo Lee
Comparisons in ecosystem effects of fishing in Korean waters

Zenyong Wang, Hao Wei and Zuowei Zhang
Application of modified NEMURO Model to Jiaozhou Bay

Thomas C. Wainwright, James J. Ruzicka and William T. Peterson
A biological production index for the northern California Current

Jie Li, Zengmao Wu and Xiaofang Wan
Modelling study of the new production and the microbial food loop impact in the Yellow Sea Cold Water Mass

Chris J. Harvey, Isaac C. Kaplan, Emily J. Brand, Elizabeth A. Fulton, Anthony D.M. Smith, Albert J. Hermann, M. Elizabeth Clarke and Phillip S. Levin
A spatially explicit ecosystem model to examine the effects of fisheries management alternatives in the California Current

Posters

Young-Min Choi, Kwang-Ho Choi, Yeong-Seop Kim, Jung Hwa Choi and Jong-Bin Kim
Ecosystem structure and fisheries resources status in the southern part of Korean waters

Jae Bong Lee, Chang-Ik Zhang and Dong Woo Lee
Ecosystem indicators for the recruitment of pelagic fish around Korean waters

PICES Fifteenth Annual Meeting
October 13–22, 2006
Yokohama, Japan

2006 Report of Working Group on *Ecosystem-based Management Science and its Application to the North Pacific*

The Working Group (WG 19) on *Ecosystem-based management science and its application to the North Pacific* held its second meeting from October 13–14, 2006, under the co-chairmanship of Drs. Glen Jamieson and Chang-Ik Zhang, and Ms. Patricia Livingston. Dr. Christopher Harvey served as rapporteur. A list of participants and the meeting agenda can be found in *WG 19 Endnotes 1* and *2*.

Review of national/international approaches to establishing science-based eco-regions (Agenda Item 2)

Dr. Ian Perry reviewed the definitions of North Pacific ecosystems put forth by PICES and other researchers and institutions, the different management zones defined by member nations, and how closely ecosystem boundaries and management boundaries matched one another. He concluded that:

- Ecosystem boundaries are often difficult to define due to the lack of fixed geography and due to long-term variability in non-static boundary-forming processes;
- The Large Marine Ecosystems (LMEs) as defined by Sherman appear to be the most useful conceptualization of ecosystems for PICES member countries;
- Management boundaries are generally consistent and complementary between nations, although perhaps less so in the Bering Sea and in the western Pacific;
- It will be difficult to change existing statistical areas due to the historic value and inertia placed upon their usage, so PICES must build on historical context rather than trying to change it;
- Management areas are generally much smaller than LMEs, but the management areas can generally be aggregated to reasonably approximate LMEs.

Theoretical evaluation of the consequences of an artificial boundary (Agenda Item 3)

Drs. Harvey and Elizabeth Fulton provided an update on efforts to use Atlantis, a spatially explicit marine ecosystem modeling software, to examine how different management strategies on either side of a jurisdictional boundary (*e.g.*, a national border) affect cross-border eco-systems. Harvey and colleagues are still in the process of completing an Atlantis model of the northern California Current, and therefore have yet to finish this task. It will be done by next year's Annual Meeting, either using the northern California Current model or one of Fulton's models for Australia.

National ocean management activity reports (Agenda Item 4)

Each member country outlined the processes and frameworks they are using to implement ecosystem-based management (EBM). A common problem among member countries is that the elements of EBM are often handled by different government agencies (for example, fisheries are managed by one ministry and environmental monitoring by another), and that there is often very little communication and collaboration between those agencies.

As it was noted last year, there are different conceptual frameworks among member countries. In Canada, Russia and the United States, EBM is mainly directed at maintaining or restoring ecosystems to relatively pristine status, while in China, Japan and Korea, EBM is described in the context of resource enhancement. In addition, there is a need for greater coordination and integration of management efforts, both within individual nations and between nations for resources that inhabit multi-national waters. As within nations, different aspects of EBM are handled by different agencies or ministries, frameworks may not exist for coordinating those activities. Across nations, all

PICES member countries manage resources that move into other EEZs (Exclusive Economic Zones), and the Working Group encourages PICES to support the development of regional management plans in these multi-national areas.

Two other concerns were raised by WG 19 on this agenda item. Firstly, certain words (*e.g.*, "ecosystem", "integrative") have different meanings and applications among different member countries, and a glossary of terms with agreed-upon definitions should be a part of the WG 19 final report. Secondly, written volumes describing marine eco-regions and science supporting EBM are crucial and should be living, evolving documents. However, they can grow very large and thus inaccessible to readers who need the information that they contain.

National ecosystem monitoring approaches (Agenda Item 5)

WG 19 members described highlights of their national monitoring plans. Each nation has devoted considerable resources to monitoring programs; Russia and Korea, in particular, have developed long time series and broad spatial coverage of a wide range of oceanographic and biological variables. Emerging issues that different nations are encountering include:

- the need to better define ecosystem objectives, so that monitoring programs can be used most effectively in management;
- the difficulty of getting managers, who are often in different agencies or ministries, to use monitoring data in decision-making;
- maintaining funding for monitoring programs.

Summaries of recent scientific meetings on ecosystem indicators (Agenda Items 6 and 7)

Two recent scientific meetings on ecosystem indicators were reviewed. Drs. Perry and Fulton revisited the 2004 Paris Symposium on "*Quantitative ecosystem indicators for fisheries management*", which was described at last year's WG 19 meeting. They broadened the discussion to include new thinking on indicators. Dr. Fulton stressed the value that several "types" of indicators have had in monitoring ecosystem change. They include: relative biomasses, biomass ratios (*e.g.*, piscivores to planktivores), size spectra, maximum fish length, total fishery removals (or some other total human impact), size at maturity, biodiversity, and biophysical variables (*e.g.*, Chl-*a*). These can be rapidly measured and do not require special expertise or modeling to quantify. She has concluded that monitoring pelagic ecosystems requires fewer total indicators, but signal detection is slow. By contrast, demersal systems require more indicators but signal detection is rapid.

Dr. Perry described the Bering Sea Ecosystem Indicators project, a PICES effort funded by NPRB to define objectives, a monitoring program, and effective indicators for managing the southeastern Bering Sea. The process featured pre-workshops with diverse experts and stakeholders to maximize participation. These meetings were preparatory to the PICES/NPRB Indicators workshop convened on June 1-3, 2006, in Seattle, U.S.A. The project has produced recommendations concerning ecosystem objectives, socio-economic objectives, and communication objectives for better disseminating the project's work within PICES, to the broader scientific community, and to the public. The final report will be published as *PICES Scientific Report No. 33* by the end of this year. It will include three white papers developed for the workshop (on "*Operational objectives for the southeastern Bering Sea*" by Gordon Kruse and Diana Evans, on "*Toward ecosystem-based management of the oceans: A perspective for fisheries in the Bering Sea*" by Andrea Belgrano, Jennifer Boldt, Patricia Livingston and Jeffrey M. Napp, and on "*Ecological indicators: Software development*" by Sergei N. Rodionov) and a summary of workshop discussions and recommendations. Outcomes of the workshop have been used by NPRB in developing an integrated ecosystem research plan for the Bering Sea.

It was recommended that WG 19 should focus not on choosing specific indicators, but rather on developing a scientific process by which proper indicators are defined for a given ecosystem, such that the process can be readily developed and implemented in an EBM framework.

Content of the WG 19 final report (Agenda Item 8)

The final WG 19 report, due prior to the 2008 PICES Annual Meeting, will include a general introduction, national definitions of EBM, and a glossary listing and defining key terms. It will then summarize activities toward meeting the WG 19 Terms of Reference (TOR). Reporting plans for TORs are detailed below:

TOR #1: Describe and implement a standard reporting format for EBM in each PICES country. The report will include: (1) national definitions of EBM; (2) national objectives for EBM; (3) descriptions of how objectives are made operational in each country; (4) reports on national ocean management activities; and (5) a synthesis that describes similarities and differences among national approaches. *The Working Group no longer feels it is practical to create a standard reporting format because it would be prohibitively labor-intensive, so this aspect of the term of reference will not be considered further.*

TOR#2: Review existing definitions of eco-regions and identify criteria used for defining ecological boundaries. The report will include national identification criteria as presented at the PICES XV MEQ/FIS workshop (W3) on "*Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*", with particular attention to how national definitions compare with other ecosystem definitions (*e.g.*, LMEs). The brief report of the workshop is included in the *Session Summaries* chapter of this Annual Report.

TOR #3: Evaluate indicators from the 2004 Symposium on "*Quantitative ecosystem indicators for fisheries management*". The report will present the WG 19 recommendations for types of indicators (and not specific indicators) that have been analyzed in publications generated since the 2004 symposium. *The Working Group feels that this term should be broaden to include and integrate findings from the NPRB-funded PICES Bering Sea Ecosystem Indicators project into the final report.*

TOR #4: Describe relevant national marine ecosystem monitoring approaches, plans, and models for predicting human and environmental influences on ecosystems. The WG is concerned that much of this Term of Reference has already been addressed, in the *PICES Scientific Report No. 18* on "*Impact of climate variability on observation and prediction of ecosystem and biodiversity changes in the North Pacific*" (2001). *The Working Group proposes to change this TOR to: Determine if national monitoring data currently being collected are sufficient to allow calculations of key indicators.* Each nation will summarize the monitoring approaches in one ecosystem or eco-region that are most representative of their implementation of EBM. Tentatively, those case studies will be: the Kuroshio Current (Japan), the Yellow Sea (Korea), the Okhotsk Sea (Russia), the Pacific North Coast (Canada), and the Bering Sea (U.S.A.). Key indicators will be calculated for each system and data gaps will be identified.

TOR #5: Hold an inter-sessional workshop that addresses the status and progress of EBM science efforts in the PICES region. For the purposes of the final report, we will summarize the content of a 1-day FIS/MEQ workshop on "*Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation*" proposed for PICES XVI in Victoria, Canada.

In addition, WG 19 will create an 8- to 10-page brochure that is essentially an Executive Summary of the final report. It will be published in 2008, with the foreseen target audience to be determined later. We hope that the brochure will be translated into the languages of all PICES member countries.

Planning for PICES XVI (Agenda Item 9)

WG 19 proposes a 1-day FIS/MEQ workshop "*Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation*" to be convened at PICES XVI (*WG 19 Endnote 3*).

The structure of the workshop would be:

- a keynote talk summarizing activities of the Working Group;
- invited talks from other PICES Working Groups and committees (*e.g.*, MONITOR, TCODE, or parent committees) that describe EBM-related tools and themes developed by other groups in PICES;
- invited talks from representatives of external institutions (*e.g.*, FAO) that describe EBM-related tools and themes developed outside of PICES;
- an invited talk on the constraints to implementation of EBM;
- an invited talk on governance issues and difficulties related to EBM;

- An invited talk on socio-economic issues related to EBM; and
- Contributed talks solicited through the general abstract submission process.

In the evening following the workshop, WG 19 would convene for 2 hours to discuss the content of the workshop and incorporate it into the final report.

The desired outcomes of this workshop are:

- to fulfill the Terms of Reference of WG 19;
- to promote general discussion on objectives, practices, and implementation of EBM in PICES member countries; and
- To generate papers for a special issue or theme section of a prominent marine science journal, such as *Marine Ecology Progress Series* or *Progress in Oceanography*.

WG 19 Endnote 1

Participation list

Members

Elena Dulepova (Russia)
David Fluharty (U.S.A.)
Christopher Harvey (U.S.A.)
Oleg Ivanov (Russia)
Glen Jamieson (Canada, Co-Chairman)
Tatsu Kishida (Japan)
Jae-Bong Lee (Korea)
Patricia Livingston (U.S.A., Co-Chairman)
R. Ian Perry (Canada)
Vladimir Radchenko (Russia)
Inja Yeon (Korea)
Chang-Ik Zhang (Korea, Co-Chairman)

Observers

Robin M. Brown (Canada)
K. Alexandra Curtis (U.S.A.)
Elizabeth Fulton (Australia)
Henry Lee (U.S.A.)
Jacob Schweigert (Canada)

WG 19 Endnote 2

WG 19 meeting agenda

October 13

1. Welcome and introductions
2. Review of national and international approaches (maps, processes used to identify area) to establishing science-based eco-regions, and compare these to existing or planned “management” regions
3. Theoretical evaluation of the consequences of an artificial boundary that splits an ecological process and how that could affect management
4. National ocean management activity reports: the process and framework that each country is using to implement an ecosystem approach to management
5. National ecosystem monitoring approaches relevant to the eco-regions considered above

October 14

6. Findings from the 2004 Paris symposium on “*Quantitative ecosystem indicators for fisheries management*”
7. Findings from the NPRB-funded PICES Bering Sea Ecosystem Indicators project
8. Content of the WG 19 final report
9. Planning for PICES XVI

WG 19 Endnote 3

Proposal for a 1-day FIS/MEQ workshop at PICES XVI on
“Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation”

An ecosystem-based approach to management (EBM) is an integrated approach to management of land, water, and living resources that promotes conservation and sustainable use over a broad range of human activities in an ecosystem. Implementation of an EBM for marine ecosystems in the North Pacific Ocean requires a number of steps and activities. An explicit framework that outlines the objectives, legal mandates, and institutional roles and responsibilities is essential. Data requirements and analytical tools need to be developed. This workshop invites papers to: 1) highlight existing national and international frameworks for implementation of an ecosystem approach to management; 2) outline the data requirements for such an approach; 3) describe the analytical tools being developed; 4) show the progress in communicating results of EBM activities; and 5) discuss outstanding research gaps for making progress. The workshop will be organized to allow time for keynote summaries of PICES Working Group 19 results, invited contributions from other PICES groups, insights by other organizations involved in providing integrated ecosystem advice, talks on governance issues and difficulties, socioeconomic issues, *etc*. During a discussion period, participants are welcome to advise the convenors on the desirability of publishing the results of the workshop in a leading primary scientific journal.

Recommended convenors: Glen Jamieson (Canada), Patricia Livingston (U.S.A.) and Chang-Ik Zhang (Korea).

PICES Fifteenth Annual Meeting Workshop Summary

MEQ/FIS Workshop (W3)
Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area

Convenors: Glen Jamieson (Canada), Patricia Livingston (U.S.A.) and Chang Ik Zhang (Korea)

<u>Background</u>

The management of human activities that affect ocean ecosystems requires planning and the engagement of stakeholders to meet the objectives of ecosystem-based management. This, in turn, requires identification of areas to determine which stakeholders must be involved in each specific process. Area boundaries are typically based upon science (*i.e*., eco-regions), human community (*i.e*., coastal community composition), administrative (*i.e*., historical resource management areas) and international considerations (*i.e*., transboundary issues). This workshop considered the science requirements for eco-region identification in the PICES area, and presentations were solicited to: 1) highlight national or regional experiences or frameworks for delineating marine sub-regions or eco-regions; 2) demonstrate the use of a variety of physical and/or biological criteria for region identification; or 3) explain the specific management purposes behind various sub-regional identification schemes. Discussion involved participants in reviewing the existing Large Marine Ecosystem boundaries of the PICES area and in developing recommendations for criteria to be used in sub-regional identification in the North Pacific.

<u>Summary of presentations</u>

The workshop had 11 presentations, 2 of which were invited, that focused on the science requirements for eco-region identification in the PICES area. Presentations highlighted national or regional experiences or frameworks in place for delineating marine sub-regions or eco-regions (Jamieson, Lee *et. al*.); demonstrated the use of a variety of physical and/or biological criteria for region identification (Fluharty, Harvey *et al*., Shtrik, Sydeman *et al*.); and/or explained the specific management purposes behind various existing sub-regional identify-cation schemes (Kishida, Livingston and Piatt, Seki and Makaiau). Invited speakers discussed: 1) a hierarchical classification scheme that has been successfully applied across multiple scales and in many system types and whose output is becoming an accepted component of management support packages – both as maps for use in defining coherent management areas, but also as part of ecosystem-level modeling tools (Fulton), and 2) issues associated with reconciling overlapping biogeochemical and fisheries-based ecosystem typologies, and the mesh of fisheries management and reporting areas which may, or may not, in turn be related to marine ecosystem typologies (Perry). The workshop concluded with a plenary discussion of issues raised from the presentations with respect to criteria for ecoregion determination.

List of papers

Oral presentations

Elizabeth Fulton, Vincent Lyne and Donna Hayes (Invited)
Bioregionalisation and ecosystem-based management in Australia

Glen S. Jamieson
Canada's ecoregion determination approach

Jae Bong Lee, Chang Ik Zhang, Dong Woo Lee, Jong Hwa Park and Jong Hee Lee
Marine sub-regions determined with physical and biological criteria in Korean waters

Chris J. Harvey, Isaac C. Kaplan and Phillip S. Levin
Selecting model domains and boundaries in ecosystem modeling of the U.S. West Coast: Process determines scale

David L. Fluharty
Aligning institutions with ecosystems for marine science

Patricia A. Livingston and John F. Piatt
Progress in U.S. ecoregion definitions for ocean ecosystems and an Alaskan example

R. Ian Perry (Invited)
Ecosystem typologies in the North Pacific – A useful concept for ecosystem-based management?

Michael P. Seki and Jarad Makaiau
Archipelagic fishery ecosystem plans for the U.S. central and western Pacific islands

William J. Sydeman, Sonia D. Batten, Michael Henry, Chris Rintoul, David W. Welch, Ken H. Morgan and K. David Hyrenbach
Meso-marine ecosystems of the North Pacific: Application to ecosystem-based management

Vadim A. Shtrik
Use of the classification and structure of coastal zone macro-vegetation for global and local eco-regional identification of coastal areas in the North Pacific

Tatsu Kishida
Physical and biological criteria for region identification around Japan

PICES Sixteenth Annual Meeting
October 26–November 5, 2007
Victoria, Canada

2007 Report of Working Group on *Ecosystem-based Management Science and its Application to the North Pacific*

The Working Group on *Ecosystem-based Management Science and its Application to the North Pacific* (hereafter WG 19) held its third meeting on October 27–28, 2007, under the co-chairmanship of Drs. Glen Jamieson and Chang-Ik Zhang, and Ms. Patricia Livingston. A list of participants and meeting agenda can be found in *WG 19 Endnotes 1* and *2*.

Description and implementation of a standard reporting format for EBM initiatives (Agenda Item 2)

Descriptions received from member countries were disparate and are being compiled into a summary. Still missing is a contribution from China. WG 19 discussed a conceptual spectrum of the ecosystem-based management (EBM) from single species fishery management to integrated (multi-sectoral) marine management and talked about trying to display national situations on the spectrum. Lists of government agencies involved in implementing EBM are being assembled.

Participants from each country were asked to provide Dr. David Fluharty a few paragraphs which outline where each nation is located on the Ecosystem Approach to Management (EAM) spectrum (*sensu* Sainsbury slide), including endangered species legislation, marine protected areas (MPA), or heritage site designations.

Dr. Fluharty discussed the possibility of incorporating a list of treaties dealing with transboundary stock management into the report. This document could be enhanced by adding aquaculture activities and their management. Categories in the report are expected to include: (1) definitions, (2) objectives, (3) legislation and agencies with marine management authority, (4) environmental assessment requirements in decision making, and (5) endangered species protection, marine sanctuaries, national heritage or other MPA designation processes. Target date for completion of this chapter of the WG 19 final report is the end of December 2007.

Definitions of "eco-regions" and criteria for defining ecological boundaries relevant to PICES (Agenda Item 3)

Dr. Christopher Harvey gave an update of the "eco-region" chapter of the WG 19 final report. Currently, the discussion section needs more work and regional figures are not yet in a common format. There was discussion about the World Wildlife Fund MEOW (Marine Ecosystems of the World) initiative and how this might overlap with PICES efforts to define eco-regions. It was determined that governments of member countries are pursuing individual definitions and frameworks for eco-regions, a situation that must be highlighted. It is not clear whether MEOW's system will be adopted, but national efforts could be compared with their regions. Some details and refinement of the discussion have to be finalized, but this chapter of the report is virtually complete, although lacking a contribution from China.

Dr. Elizabeth Fulton presented a report on the consequences of ocean management scenarios that ignore eco-region boundaries in favour of national boundaries. An artificial national boundary was generated between States in an existing model of southeast Australian waters, creating two artificial Exclusive Economic Zones (EEZs). Different management scenarios (loosely based on the range of management methods existing in the PICES region) were implemented, with contrasting options within these two EEZs. This meant that there were two management regions that spanned parts of a single eco-region – with some but not all species moving across the border between the two quasi-nations. Results for a range of indicators (drawn from the list constructed by Perry *et al.*) were presented. This gave insight into the state of the system overall and the relative performance of the management methods. Results included:

- different levels of production with different management approaches (although this result might not occur in regions with a dominant signal from upwelling);
- less biomass in forage groups if target species were managed sustainably and higher trophic levels were conserved;
- any kind of management helps maintain target species biomass (*vs.* an unconstrained baseline scenario);
- for species with even moderate degrees of mobility (or more), effective management in one "nation" subsidizes catches and biomass taken by the other, but is still beneficial as it also raises overall system state;
- top predators benefit from more prey but this signal can be diffused by large scale (including seasonal) movements following rich prey sources/locations;
- cephalopods dropped in biomass slightly because of increase in top predators;
- habitat has the potential to benefit from management, but success is not a given (it is sensitive to the magnitude and specific implementation and types of management);
- from an EBM perspective, management in one region is helpful but perhaps not as effective as if management was coordinated across the regions.

One question that has not been addressed in this modeling work to date is whether the benefits seen from implementing effective management in one nation's waters, even if the neighbouring country is not being as efficient, are cost-effective. This research will be targeted for publication by Drs. Fulton and Harvey in the peer reviewed literature, however, some illustrative examples and results will be incorporated in the WG 19 final report to highlight ecosystem issues arising from differential management across boundaries.

Evaluation of indicators and summary of monitoring efforts (Agenda Items 4 and 5)

An overview of the indicators chapter of the WG 19 final report was provided, and discussion points were outlined and agreed upon. The next step was for each member country to suggest whether the indicators listed in Table 2 of the chapter had been calculated yet for a particular region in each nation and whether there are data available to do so. Dr. Perry will coordinate this effort. Tables from some countries were finished at the meeting, but others will need input from national experts. Most indicators were related to effects of fishing and not to the broader types of impacts from other marine sectors. The participants expanded the third recommendation in the chapter to explore the development and use of socio-economic indicators. There was discussion about social indicators such as the spatial distribution and numbers of jobs. Those data are difficult to obtain in some countries. ICES examples in that regard can be found in the 2006 Report of the Ecosystem Effects of Fishing (Sections 4.2–4.4, pp. 92–106, Tables 4.2.4, 4.4.3). Indicator availability tables from each country will be completed by the end of December 2007 and will be added to this chapter of the report.

FIS/MEQ workshop at PICES XVI (Agenda Item 6)

A full report of the FIS/MEQ workshop on "*Comparative analysis of frameworks to develop ecosystem-based approach to management and research needed for implementation*" (W3) can be found in the *Session Summaries* chapter of this Annual Report. The workshop made progress in highlighting issues related to the implementation of EBM in PICES member countries. It was clear from the presentations that member countries are in different stages of EBM implementation. Some are still working on incorporating an ecosystem approach to fisheries management, while others have national legislation that provides a mechanism for implementing cross-sectoral approaches to the management of marine activities to ensure environmental protection. The degree of advancement might be related partly to the nature of the different human pressures being exerted on the marine environment. Even some of the countries that appeared to be more advanced in their implementation mentioned problems in actually making cross-sectoral management work in marine ecosystems. Overarching legislation that requires action may be needed. It was clear that more than one agency was involved in EBM activities in each country, and a challenge is to get agencies to work together in implementation. It was noted that the legislation that typically led to cross-sectoral implementation was some form of endangered species legislation.

Data requirements for EBM were discussed. The

Australian experience demonstrated that implementation could involve both highly quantitative approaches and models if data are available, but could also include methods to evaluate ecosystem status and potential impacts in qualitative ways. The ICES experience exhibited how highly-evolved data gathering for EBM advice could be, although it was noted that highly-evolved advice did not necessarily translate into the political will to follow such advice. MONITOR outlined some of the data requirements that would necessitate its involvement and that of all of the PICES Committees. The workshop noted particularly the lack of socio-economic data to assist in decision-making in an EBM context.

Analytical tools are being developed to aid in EBM, and these include the highly structured risk assessment framework of Australia that allows for both quantitative and qualitative evaluation of risks, and determinations of when action is needed. The MODEL Task Team described a suite of modeling tools that might be used to understand impacts of climate variability on marine ecosystems. Models such as ATLANTIS can help in the evaluation of management strategies, and these seem to be important tools to further decision-making.

Communicating the results of EBM activities is ongoing in member countries. Some are using highly-structured reporting instruments such as ecosystem assessment documents. The ICES advisory structure communicates EBM advice in a tactical way that is highly evolved, although its success in implementing EBM might not be so advanced. Reporting of ecosystem status is crucial but it was recognized that identification and reporting of ecosystem pressures and ecosystem responses to management are significant pieces in conveying EBM progress. Communicating measures of human health was noted to be essential in this regard. The role of PICES in communicating EBM was seen to be more of a strategic one. There is a variety of potential scales useful in reporting results.

A major outstanding research gap is the need for social science indicators and information. The advancement of risk assessment frameworks and tools seemed particularly important. Perhaps Working Groups on *Human Dimensions of Implementing EBM* or *Evaluation of Risk Assessment Tools and Frameworks* might be worthwhile to consider in the future.

WG 19 final report and 2008 inter-sessional meeting planning (Agenda Item 7)

National submissions of the above material are due to January 1, 2008, after which the lead authors and Co-Chairmen will begin merging the data into a final report. A major gap is a lack of Chinese submissions and lack of participation from this country to date. Options relating to finalization of the WG 19 report are thus:

- Get Chinese participation in an inter-sessional meeting in February 2008 (options Seattle or China);
- Extend the Working Group for one more year and meet with Chinese scientists at the next PICES Annual Meeting in Dalian;
- Finalize the report without Chinese input.

WG 19 hopes to have a draft of the final report by late January to send to the Chinese prior to the inter-sessional meeting, so they can see what contribution is desired from them.

After the meeting adjourned, it was realized that WG 19 originally intended to publish a brochure on EBM in 2008 but this topic was not discussed at the meeting. In hindsight, such a publication would have been premature as the final report has yet to be written. WG 19 still plans to produce a brochure (the concept was approved by Science Board last year), but after the final report is complete. Its contents would be a subset of information compiled in the final report. Discussion of contents of the brochure will be conducted either via email, at the inter-sessional meeting, or at next year's Annual Meeting.

Structure and content of North Pacific Ecosystem Status Report and EBM-related topics for inclusion (Agenda Item 8)

An incremental improvement version of the 2004 pilot report is being recommended by Science Board (*SG-ESR Endnote 2*). WG 19 suggests enhancing the next report with information on pollution and socio-economics. The discussion focused on the need to identify key pressures in each region, and on how should indicators on status and trends describing human well-being be determined. Further discussion on these topics will be required.

Establishing a PICES Study Group on *Indicators of Human Well-being: Benefits, Health* is recommended to assist in this effort. Terms of reference for this group might include:

1. Identify potential indicators of human well-being and human impacts in relation to PICES marine ecosystem status and trends. Evaluate the Millennium Ecosystem Report Indicators for their appropriateness.
2. How might these measures be quantified and standardized across member countries? Are the data available to quantify these?
3. How can these measures be used in ecosystem models and management strategy evaluation frameworks?
4. Identify longer-term issues that might be covered by a Working Group on this topic (governance structures for implementation, *etc.*).

Membership for this Study Group should consist of qualified social scientists, primarily those with strong economics background, with an understanding of natural sciences, particularly marine science, who are working on questions relating to marine ecosystem approaches and management issues.

Comments on FUTURE (Agenda Item 9)

The participants evaluated a draft Science Plan for a new PICES integrative scientific program on ***F****orecasting and* ***U****nderstanding* ***T****rends,* ***U****ncertainties and* ***R****esponses of North Pacific Marine* ***E****cosystems* (FUTURE) in the context of advancing science and communication in support of EBM. The communications aspect of this program is very important and should be discussed and outlined more clearly with a strategic view of identifying the audiences and appropriate methods of communication. The status and trends information is newsworthy and needs communication.

Models are important to project future ecosystem states, and the program has a heavy emphasis on that aspect. WG 19 members thought that the deliverables for the program also have to include status and trend indicators and an improved, coordinated monitoring system to support indicator data requirements. Society needs to hear about human health, food security, role of climate, and potential for unanticipated ecosystem change.

WG 19 Endnote 1

Participation list

<u>Members</u>

Elena Dulepova (Russia)
David Fluharty (U.S.A.)
Christopher Harvey (U.S.A.)
Glen Jamieson (Canada, Co-Chairman)
Jae-Bong Lee (Korea)
Patricia Livingston (U.S.A., Co-Chairman)
Mitsutaku Makino (Japan)
R. Ian Perry (Canada)
Vladimir Radchenko (Russia)
In-Ja Yeon (Korea)
Chang-Ik Zhang (Korea)

<u>Observers</u>

Elizabeth Fulton (Australia)
Xuewu Guo (PICES Secretariat)
Woo-Seok Gwak (Korea)
Oleg Katugin (Russia)
Kenji Konishi (Japan)
Skip McKinnell (PICES Secretariat)
Thomas Okey (Canada)
Jake Rice (Canada)
John Stein (U.S.A.)
Mikhail Stepanenko (Russia)
Zhaohui Xhang (China)
Mingyuan Zhu (China)

WG 19 Endnote 2

WG 19 meeting agenda

October 27, 2007

1. Welcome and introductions
2. National definitions of EBM, making sure to expand beyond EBFM and list agencies that are involved in broader sectors, other than fisheries. Brief description of each country's ocean management report contents

3. National reports: Review national definitions of “eco-regions” and identify criteria that could be used for defining ecological boundaries relevant to PICES
4. Evaluation of the indicators from the 2004 Symposium on “*Quantitative ecosystem indicators for fisheries management*” for usefulness and application to EBM in the North Pacific, but broaden the terms of reference to encompass not just Paris symposium, but also NPRB indicators project and the types of indicators summarized by Elizabeth Fulton
5. National reports on monitoring efforts that address the types of indicators described in item 4 above, as well as identify gaps. Member countries will focus on an eco-region that is most representative of their EBM efforts

October 28, 2007

6. Discuss content of FIS/MEQ Workshop on “*Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation*” (W3) at PICES XVI and incorporate into the report
7. Initiate discussion of structure of final report, deliverables and time frames; Planning for a 2008 inter-sessional meeting
8. Advice on structure and content of the North Pacific Ecosystem Status Report; suggest EBM-related topics for inclusion in the report
9. Discuss next major PICES scientific program, FUTURE, and provide comments

PICES Sixteenth Annual Meeting Workshop Summary

FIS/MEQ Workshop (W3)
Comparative analysis of frameworks to develop an ecosystem-based approach to management and research needed for implementation

Co-Convenors: Glen Jamieson (Canada), Patricia Livingston (U.S.A.) and Chang-Ik Zhang (Korea)

Background

An ecosystem-based approach to management (EBM) is an integrated approach to management of land, water, and living resources that promotes conservation and sustainable use over a broad range of human activities in an ecosystem. Implementation of an EBM for marine ecosystems in the North Pacific Ocean requires a number of steps and activities. An explicit framework that outlines the objectives, legal mandates, and institutional roles and responsibilities is essential. Data requirements and analytical tools need to be developed. This workshop invited papers to: 1) highlight existing national and international frameworks for implementation of an ecosystem approach to management; 2) outline the data requirements for such an approach; 3) describe the analytical tools being developed; 4) show the progress in communicating results of EBM activities; and 5) discuss outstanding research gaps for making progress. The workshop was organized to allow time for keynote summaries of PICES Working Group 19 results, invited contributions from other PICES groups, insights by other organizations involved in providing integrated ecosystem advice, talks on governance issues and difficulties, socioeconomic issues, *etc*. During a discussion period, participants were welcomed to advise the convenors on the desirability of publishing the results of the workshop in a leading primary scientific journal.

Summary of presentations

The workshop made progress in highlighting issues related to the implementation of EBM in PICES member countries. It was clear from the presentations that member countries are in different stages of implementation with respect to EBM. Some countries are still working on incorporating an ecosystem approach to fisheries management while others have national legislation that provides a mechanism for implementing a cross-sectoral approach to the management of marine activities to ensure environmental protection. The degree of advancement might be partly related to the nature of the different human pressures being exerted on the marine environment. Even where some countries appeared to be more advanced in their implementation, there were problems in actually making cross-sectoral management work in marine ecosystems. The need for overarching legislation that requires action may be needed. It was clear that more than one agency was involved in EBM activities in each country and a challenge is to get agencies to work together in implementation. It was also noted that the main type of legislation that forced cross-sectoral implementation was species-at-risk legislation.

Data requirements for EBM were discussed to some extent. The Australian experience demonstrated that implementation could involve both highly quantitative approaches and models if data are available but the framework could also include methods to evaluate ecosystem status and potential impacts even in qualitative ways. The ICES experience demonstrated how highly evolved data gathering for EBM advice could be, although it was noted that highly evolved advice did not necessarily translate into the political will to follow such advice. The Technical Committee on Monitoring outlined some of the data requirements that would require its involvement along with the involvement of all the PICES committees. The workshop particularly noted the lack of socio-economic data to aid in decision-making in an EBM context.

Analytical tools are being developed to aid in establishing EBM frameworks. Highly structured risk assessment frameworks in Australia allow both quantitative and qualitative evaluation of risks and definitions of when actions are needed. The MODEL Task Team described a suite of modeling tools that might be used to understand impacts of climate variability on marine ecosystems. Models, such as Atlantis, to aid in the evaluation of management strategies seem to be important tools to help EBM decision-making.

Communicating the results of EBM activities is ongoing in member countries. Some are using highly structured reporting instruments such as ecosystem assessment documents. ICES advisory structure for communicating EBM advice in a tactical way is highly evolved although reporting its success in implementing EBM might not be so advanced. Reporting of ecosystem status is important but it was recognized that identification and reporting of ecosystem pressures and ecosystem responses to management are important pieces of communication of EBM progress. Communicating measures of human health was noted to be important in this regard. The PICES role in communicating EBM was seen to be more of a strategic one. There seemed to be a variety of scales that are potentially useful for reporting results.

A major outstanding research gap is the need for social science indicators and information. The advancement of risk assessment frameworks and tools seemed particularly important. Perhaps working groups on the human dimensions of implementing EBM or evaluation of risk assessment tools and frameworks might be important to consider in the future.

List of papers

Oral presentations

R. Ian Perry, William R. Crawford and Alan F. Sinclair
Comparative analysis of Canadian Pacific North Coast and Strait of Georgia marine ecosystems

Phil R. Mundy
Data requirements for implementing an ecosystem approach to management from a PICES perspective

Jake Rice
Ecosystem approaches to management – Where to start?

Mitsutaku Makino and Tatsu Kishida
Ecosystem-based management in Japan: Its status and challenges

Vladimir I. Radchenko
Ecosystem-based principles in the contemporary fisheries management on the Russian Far East

Jake Rice
ICES frameworks and processes for science advice in an ecosystem approach

Glen S. Jamieson
Integrated management in Canada’s Pacific North Coast: Challenges in determining ecological objectives

Bernard A. Megrey, Michio J. Kishi, Shin-ichi Ito, Kenneth A. Rose, Francisco E. Werner and members of the MODEL Task Team and the NEMURO Mafia
Modeling multi-trophic level marine ecosystems using the NEMURO family of models: Climate change applications in the boreal North Pacific and scientific potential for ecosystem-based management

Chang Ik Zhang, Suam Kim, Donald Gunderson, Jae Bong Lee, Inja Yeon, Hee Won Park and Jong Hee Lee
Progress in the development of an ecosystem-based approach to assess and manage fisheries resources in Korea

David L. Fluharty
Realizing ecosystem based management through integrated ecosystem assessment and regional collaboration in the United States

Keith Sainsbury (Invited)
Sustainable use of marine ecosystems – The search for practical ways to support and implement ecosystem-based fisheries management and regional development

Inja Yeon, H.J. Whang, M.H. Shon, Y.J. Im, J.G. Myoung and WWF YSEPP project partners
Yellow Sea marine ecoregion for implementation of ecosystem-based management in marine capture fisheries

PICES Seventeenth Annual Meeting
October 24–November 2, 2008
Dalian, People's Republic of China

2008 Report of Working Group on *Ecosystem-based Management Science and its Application to the North Pacific*

The Working Group on *Ecosystem-based Management Science and its Application to the North Pacific* (hereafter WG 19) held its final meeting on October 26, 2008, under the co-chairmanship of Drs. Glen Jamieson, Chang-Ik Zhang, and Ms. Patricia Livingston. A list of participants and the meeting agenda can be found in *WG19 Endnotes 1* and *2*. *WG19 Endnote 3* contains the draft Executive Summary of the PICES Scientific Report currently being finalized. This Executive Summary contains the main recommendations of Working Group 19 at the conclusion of its work.

AGENDA ITEM 2
Discussion of Final Report

The primary item on the agenda involved discussion of the completeness of the final report and the recommendations of the Working Group. Status of the brochure was also discussed.

AGENDA ITEMS 3 AND 6
Description and implementation of a standard reporting format for EBM initiatives

Working Group members went over the country profile format and Ecosystem Approach to Management (EAM) typology contributions. Canada and Korea have newer contributions that need to be incorporated into the document. Each country should look to make sure its contribution is still accurate after English language editing. Also, WG 19 needs to decide if the country contributions should be made comparable in terms of length. Some contributions are longer than others. The Ecosystem-based Management (EBM) matrix that depicts each country's progress was not filled out by each country. Should this matrix still be shown? Members commented that it is difficult to report on a national basis because there are regional differences in implementation. There are several issues that are not in the table at present. For example, offshore wave energy generation, tourism and sportfishing are not outlined. Mariculture may need to identify intertidal, pen culture, and onshore locations of the activity. The text will be modified to describe the typology and sectors as examples. Offshore wave energy generation could be identified as an emerging issue in the text. Regional implementation of EBM should consider the most important sectors in a particular area. Another aspect is evaluating the social cost of EBM implementation. Dr. Mitsutaku Makino will provide a paragraph about this. Japan will contribute an example for one prefecture. WG 19 members from China and Russia will be contacted to see if they are able to contribute a national example to this table. Contributions will need to be made before the end of the year.

The Working Group consulted with Dr. Skip McKinnell about how to format the report with respect to location of references, appendices, and section formatting. For now, each section will have its own specific recommendations and the executive summary will provide a roll-up of all the recommendations from each section. Order of sections was discussed. EAM typologies and country profiles will come first. An ecoregion approach would then logically follow. Consistency in the names of countries needs to be checked and terms of reference need to be verified because they were modified later. Dr. Zhang will review the section on monitoring to see if anything could be added.

AGENDA ITEM 4
Discussion of recommendations

The relationship of PULSE (see *WG 19 Endnote 3*) to other potential task teams of FUTURE was discussed and more members were nominated. A potential Study Group or Working Group on *Indicators of Well-being* was mentioned. The Working Group recommended that the Convenors of Topic Session on "*Connecting the human and natural dimensions of marine ecosystems and marine management in the PICES context*" (S12) bring up this proposed group in the discussion part of their session. Potential members of the study group/working group could be some of the people presenting at S12. WG 19 members thought that this should be a study group initially to help focus the work and refine membership for a follow-on working group. A topic session for next year on spatial planning was discussed, and it was suggested that it be sponsored by MEQ and FIS.

AGENDA ITEM 5
Ecologically and biologically sensitive international marine areas in the North Pacific

Drs. Akihiko Yatsu and Jake Rice presented information on the current status of a Regional Fisheries Management Organization (RFMO) in international waters in the North Pacific and a joint Convention on Biological Diversity-International Union for Conservation of Nature (CBD-IUCN) effort that are both considering to look at the application of criteria for designating vulnerable marine ecosystems (VMEs) in North Pacific international waters. It appears that the RFMO is still being developed, and likely would not be able to initiate studies until the fall, 2009, at the earliest, while the CBD meeting to review progress on using the criteria in evaluation of VMEs will be in early fall, 2009. It was suggested by Dr. Rice that PICES might therefore be interested in considering addressing the usefulness of the criteria in the spring, 2009. WG 19 did not have any comment about PICES' possible role but agreed that species do not recognize national borders and EBM must extend to international waters. The proposed designation of VMEs in international waters would be a necessary step in the long-term achievement of EBM in the entire North Pacific.

AGENDA ITEM 7
Brochure

The brochure format was discussed. A figure depicting the differences between single sector management, ecosystem-based fishery management and multisector integrated managed was suggested. The terms EBM should be consistently used throughout the brochure although some mention could be made of the other terms that are in use. There was also support for translating into languages of the PICES member nations and making those available on the PICES website. There was some discussion on the possible perspectives and recommendations of the PICES Study Group on *Communications* about this brochure. Members were tasked with looking at various sections and provide edited text.

WG 19 Endnote 1

Participation list

Members

David Fluharty (U.S.A.)
Glen Jamieson (Canada, Co-Chairman)
Patricia Livingston (U.S.A., Co-Chairman)
Mitsutaku Makino (Japan)
In-Ja Yeon (Korea)
Chang-Ik Zhang (Korea, Co-Chairman)

Observers

Evgeny Barabanshchikov (Russia)
Ingrid Burgetz (Canada)
Oleg Katugin (Russia)
Skip McKinnell (PICES Secretariat)
Thomas Okey (Canada)
Jake Rice (Canada)
Steve Rumrill (U.S.A.)
Yasunori Sakurai (Japan)
Akihiko Yatsu (Japan)

WG 19 Endnote 2

Working Group 19 meeting agenda

1. Welcome and Introductions (Co-chairs)
2. Discussion of completeness of final report, deliverables and timeframe
3. Report by each country: Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem based management objectives of each country. Summary of compilation progress: Dave Fluharty
4. Discussion of recommendations – PULSE and SG on *Indicators of Human Well-Being: Benefits and Health*
5. Presentation by Jake Rice on SG on *Ecologically and biologically sensitive international marine areas in the North Pacific*
6. Overall review of final report
7. Discussion of brochure

WG 19 Endnote 3

Looking beyond WG-19

We discussed how the findings and work of WG 19 could best be integrated and built upon within PICES in the years ahead, particularly within the context of the FUTURE program. Development of ecosystem-based management is still very much in its early stages in each of the PICES countries, and so we recommend that PICES continue to actively monitor progress into the foreseeable future. To provide a long-term forum for this process, we concluded that WG 19 might most appropriately evolve into a Task Team rather than a Section because Task Teams report to Science Board and are more broadly distributed across all of PICES, rather than simply reporting to one or two committees. We suggest that the Task Team's emphasis be on developing an integrative, science-based, ecosystem-scale understanding of the human dimension (across a diversity of sectors) in FUTURE, and suggest it be called *"PICES Understanding, Linking and Synthesis of Ecosystems"* (PULSE). A draft proposal for this Task Team with a basic background statement, terms of reference and suggested co-chairs and members is:

Objective

To monitor and synthesize regional and basin-wide ecosystem-based management (EBM) studies and initiatives (ecosystem health) and to provide a forum for the integration of FUTURE-related EBM practices and their implementation.

Draft Terms of Reference

1. The PULSE Task Team is the scientific body responsible for the promotion, coordination, integration and synthesis of research activities related to the implementation of EBM among PICES member nations. This goal would be accomplished by convening meetings, periodic scientific symposia or workshops, or by distributing information designed to foster cooperation and integration among existing or developing PICES programs, and possibly between and/or within member nations;

2. The PULSE Task Team will provide the scientific body to identify and improve indicators to measure progress in the achievement of EBM. It will provide the forum to discuss the needs, impacts and responses of coastal communities in a changing marine environment, and to enhance the use of this information by governments and society at large. It will provide a forum for the connection of ecosystem monitoring and status reporting of both environmental and social indicators (through linkage with MONITOR), and the subsequent implementation and adaptation of EBM;

3. Scientific collaboration and coordination with other international agencies, bodies and societies that are engaged in either EBM or human activities that are relevant to the achievement of EBM will be undertaken. This will engage expertise not previously active in PICES, such as social-scientists and policy makers;

4. The PULSE Task Team will encourage establishment of other component activities, such as developing the basis for coupled human science-natural science models, and emerging approaches as needed to facilitate synthesis of the FUTURE Program.

Suggested members

We are seeking a structure that will ensure core connection with PICES Committees, key expertise from the various disciplines involved in studying ecosystem approaches to management, and national representation. We advocate a nomination process that will closely connect the Task Team to PICES Scientific Committees, such as ensuring that a member or designate from each of the Committees, and perhaps from the current Study Group on *Communications* is in PULSE. There is also perhaps merit in having member participation form different sectors besides fishing (*e.g.*, mariculture, *etc.*) and ecoregions.

1. *Suggested Co-chairs:* Mitsutaku Makino (Japan) and Gordon Kruse (U.S.A.)

2. *Suggested members:*

Janelle Curtis (Canada)
David Fluharty (U.S.A., SG-Communications)
Chris Harvey (U.S.A.)
Glen Jamieson (Canada, MEQ)
Xianshi Jin (China)
Patricia Livingston (U.S.A.)
Ian Perry (Canada)
Vladimir Radchenko (Russia, BIO)
In-Ja Yeon (Korea)
Chang-Ik Zhang (Korea, FIS)

EBM in International Waters

In the above, all details and discussion presented have been focused on initiatives being undertaken within the Exclusive Economic Zones of the PICES member countries, and while significant progress is being made in these regions to address issued relates to EBM, the reality is that many species have spatial distributions in the Pacific Ocean that extend well beyond national jurisdictions. For these species, effective EBM can only be realised if national efforts to achieve EBM are harmonised with similar national efforts in shared national ecoregions and with multinational efforts in international waters. To this end, many of the initiatives to determine appropriate EBM steps in national waters, such as identifying ecoregions (spatial areas with a basically similar mix of species and environment) and within them, ecologically and biologically significant areas and species, need to be undertaken in offshore international waters of the PICES region.

PICES Seventeenth Annual Meeting Topic Session Summary

MEQ Topic Session (S12)
Connecting the human and natural dimensions of marine ecosystems and marine management in the PICES context

Co-Convenors: David L. Fluharty (USA), Mitsutaku Makino (Japan), R. Ian Perry (Canada) and Chang-Ik Zhang (Korea)

A complete definition of marine ecosystems includes the human components. Consideration of ecosystem-based management, at least within the natural sciences, usually leaves out the human dimensions, or includes it only as fishing effort. For ecosystem-based management to succeed, however, humans need to be included. This session builds on the Science Board Symposium of 2003 titled *"Human dimensions of ecosystem variability"*. Human relationships and how humans interact with the ocean have been changing in nature and strength over time. Natural variability in marine systems can be large, but so are socio-economic pressures and considerations relating to marine environments. Determining appropriate socio-economic indicators to complement indicators of natural climate variability, *e.g.* for ecosystem-based management, is an ongoing challenge. This session will address these interactions between natural and socio-economic issues in the context of ecosystem-based management. Specifically, it will consider: (1) What are the criteria to determine relevant socio-economic indicators of human well-being related to marine issues for PICES member countries? (2) What are appropriate indicators to monitor changes in management objectives and human well-being relevant to changing ecosystem structure and production? (3) How might decisions that are made to enhance human well-being likely to impact (positively or negatively) the nature and functions of marine ecosystems? This session theme will continue to explore the many ways that humans interact with marine ecosystems and the scientific efforts to quantify and predict human impacts on the dynamics of such systems.

List of papers

Oral presentations

Mitsutaku Makino and Hiroshi Horikawa
Social-ecological conditions of fisheries and management by ITQs: A global review

Lawrence C. Hamilton (Invited)
Ecosystem, fishery and social changes in western Alaska

Chang Seung and Chang-Ik Zhang
Socio-economic indicators used in ecosystem-based assessment for the eastern Bering Sea trawl fishery

Peter S. Ross, T. Child and N. Turner
Caught in the crossfire: Environmental contaminants in Pacific food webs and implications for coastal First Nations

David L. Fluharty
Developing and using social science information in marine management processes in the United States

Hee Won Park, Chang-Ik Zhang and Jae Bong Lee
A comparative study on the structure and function of Korean marine ranching ecosystems

Shang Chen, Jian Liu, Tao Xia and Qixiang Wang
Change of ecosystem services of the Yellow River Delta Wetland, China

Olga N. Lukyanova and Ludmila V. Nigmatulina
The value of ecosystem services of Peter the Great Bay (Japan/East Sea)

Samuel G. Pooley, Ian Perry and Mitsutaku Makino
Socio-economic considerations of ecosystem approaches to fisheries management

Zhifeng Zhang
Effects of dredging on internal release of phosphate from marine sediments in Dalian Bay

Poster presentations

Jingfeng Fan, Hongxia Ming, Lijun Wu, Yubo Liang and Jiping Chen
Detection of human enteric viruses in shellfish in China

Peter M. Zhadan and Marina A. Vaschenko
Does pollution change the reproductive strategy of the sea urchin?

Natalia M. Aminina and Lidia T. Kovekovdova
Brown algae metabolism in polluted environments

Zhen Wang, Xindong Ma, Zhongsheng Lin, Guangshui Na, Qiang Wang and Ziwei Yao
Occurrence and congener specific distribution of polybrominated diphenyl ethers in sediments and mussels from the Bo Sea, China

Guangshui Na, Qiang Wang, Zhen Wang, Hongxia Li, Shilan Zhao, Tong Chen, Zhongsheng Lin and Ziwei Yao
Pharmaceuticals and Cersonal Care Products (PPCPs) in some river and sewage water of Dalian, China

Li Zheng, Xuezheng Lin, Zhisong Cui, Frank S.C. Lee and Xiaoru Wang
Phylogenetic analysis of indigenous marine bacteria with the ability to degrade oil pollutants in Bohai Bay

Liping Jiao, Liqi Chen, Yuanhui Zhang, Gene J. Zheng, Tu Binh Minh and Paul K.S. Lam
Polycyclic aromatic hydrocarbons in remote lake and coastal sediments from Svalbard, Norway: Levels, sources and fluxes

Qixiang Wang, Shang Chen and Xuexi Tang
Preliminary assessment of ecosystem services of the Yellow Sea

Petr V. Lushvin
The impact of anthropogenic activity (regime of hydroelectric power stations and technological explosions) on behaviour and reproduction of fish and crustaceans

Zhang Hongliang, Leng Yu, Xu Zijun and Li Jiye
Research on the generating and vanishing process of *Enteromorpha* bloom and the environmental controlling factors

Zhou Yan-Rong Zhang Wei Tang Wei Zhao Bei andYang Dong-Fang
Analysis of nutrients and organic pollution in Shuangdao Bay

Ji-Ye Li, Xiu-Qin Sun, Feng-Rong Zheng and Lin-Hua Hao
Screen and effect analysis of immunostimulants for sea cucumber, *Apostichopus japonicus*

Wang Xinping, Sun Peiyan, Zhou Qing, Li Mei, Cao Lixin and Zhao Yuhui
Compounds concentration analysis of oil and its application in oil spill identification

Appendix 6

PICES Press Article

The new PICES Working Group on Ecosystem-based management

Glen Jamieson
Pacific Biological Station
Fisheries & Oceans Canada
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Dr. Glen Jamieson is a research scientist at the Pacific Biological Station (Fisheries & Oceans Canada) who has 18 years' experience in shellfish stock assessment. His research and provision of scientific advice is currently centered in four general areas: 1) research in support of the establishment of marine protected areas (MPAs) and ecosystem-based management in British Columbia; 2) development of appropriate steward-ship and monitoring protocols; 3) evaluation of the population dynamics and responses of selected species, focusing on relatively sedentary species such as benthic invertebrates, rockfish, and lingcod; and 4) investigation and monitoring of the presence and impacts of exotic species. Glen is a member of the PICES MEQ Committee and the Chairman of the Study Group on Ecosystem-based management science and its application to the North Pacific.

Since the industrial revolution, man's impact on the oceans has increased dramatically, this being especially true in recent years. In near-shore coastal areas, human population growth has led to increasing pollution and habitat modification. Fishing effects have become increasingly severe, with many, if not most, traditionally harvested populations now either fully exploited or over-fished (Garcia and Moreno, 2003). Thus far, management of these activities has been primarily sector-focused. For instance, fisheries have generally been managed in isolation of the effects of other influencing factors, and have targeted commercially important species, without explicit consideration of non-commercial species and broader ecosystem impacts. However, there is now an increasing international awareness of the cumulative impacts of sector-based activities on the ecosystem (Jennings and Kaiser, 1998; Kaiser and De Groot, 2000), and the need to take a more holistic or ecosystem-based management (EBM) approach (Anon., 1999; Kabuta and Laane, 2003; Link, 2002) to ensure the sustainability of marine ecosystems. Globally, there is an emerging paradigm shift in our approach to ocean management and usage (Sinclair and Valdimarsson, 2003).

In response to the increasing awareness to look at cumulative environmental impacts, in October 2003, the PICES Science Board established, under the direction of the Fishery Science (FIS) and Marine Environmental Quality (MEQ) Committees, the Study Group on *Ecosystem-based management science and its application to the North Pacific*, with the following terms of reference:

1) Review and describe existing and anticipated ecosystem-based management initiatives in PICES member nations and the scientific bases for them;
2) Identify emerging scientific issues related to the implementation of ecosystem-based management; and
3) Develop recommendations for a Working Group to focus on one or more of the issues identified.

The first Study Group task was to reach a common understanding of what the terms ecosystem and ecosystem-based management meant. The following definitions were agreed to:

Ecosystem: The spatial unit and its organisms and natural processes (and cycles) that is being studied or managed.

Ecosystem-based management: A strategic approach to managing human activities that seeks to ensure through collaborative stewardship the coexistence of healthy, fully functioning ecosystems and human communities [towards maintaining long-term system sustainability] by integrating ecological, economic, social, institutional and technological considerations.

Representatives from each country then submitted a summary of their country's approach to EBM, and it became immediately obvious that challenges were different between China, Japan and Korea *vs.* Russia, Canada and the United States. The greater coastal populations in the former three countries, coupled with their much longer history of full exploitation of most harvestable renewable resources, meant that EBM was, initially at least, focused on 1) minimising existing impacts, 2) rebuilding depleted stocks to more acceptable levels, and 3) in near-shore areas in particular, minimising widespread impacts in the marine environment from land runoff from both industrial and urban developments. In contrast, in the latter three countries, human coastal populations and development were generally much less, with fishing impacts and offshore oil and gas development identified as the major impacts. In many instances, relatively unimpacted, pristine habitat and biological communities still existed, and so the challenges there were often how to maintain them while permitting appropriate new economic activity to occur.

When the Study Group met at PICES XIII (Honolulu, October 2004), there was much discussion around three issues:

1) What would be an appropriate standard format to document environmental impacts and initiatives to minimise them;
2) How could the PICES region be subdivided into what the Study Group termed eco-regions; and
3) What indicators would be most appropriate to evaluate progress in achieving EBM.

While it is recognised that many human activities impact the marine environment (*e.g*., fishing, mariculture, oil and gas exploration and development, pollution from land-based activities, disruption of freshwater discharges by urbanisation, *etc*.), the most comprehensive databases (*e.g*., target species landings, bycatch and discard characteristics, habitat disruption, *etc*.) as to how these impacts are affecting marine ecosystems are related to fishing activities. Hence, much initial reporting of ecosystem impacts is likely to be focused on documenting and addressing fishery impacts. Alternate reporting formats may need to be assessed or developed that capture the ecosystem effects resulting from other human activities, and that describe how these ecosystem effects are being monitored. Ecosystem parameters already, or potentially, being monitored may capture environmental change, without linking this change back to the specific human activity, or activities, that in fact might be causing the change (*e.g*. increasing sea water temperature may be the result of many causes, some of which relate to human activities). In some cases, additional research may then be required to determine linkages. It was thus proposed by the Study Group that a standardised reporting framework that describes human activity impacts be progressively applied to all fisheries in PICES member countries, and that the adopted reporting framework be robust enough to address an increasing number of environmental and other requirements imposed by legislation, certification schemes, and consumer and community demands.

Eco-regions have been defined by Canada as "*a part of a larger marine area (eco-province) characterized by continental shelf-scale regions that reflect regional variations in salinity, marine flora and fauna, and productivity*". Biological communities between each region are somewhat different, but within a region, they are generally similar, at least on the large scale. There would obviously be differences between habitats (*e.g*., estuarine, rocky, soft substrate, *etc*.) within an eco-region, but overall, the same mix of species could be expected to occur. EBM approaches within an eco-region should thus strive to achieve the same broad conceptual objectives of trying to preserve the natural species mix, proportions across trophic levels, water quality, and so on. Since some eco-regions might transgress national boundaries, this might mean that different countries would be trying to address the same ecological objectives in their own waters within the same eco-region. The Study Group thus indicated that it would be of value to have a collective evaluation of where different eco-region boundaries are located.

It was generally agreed that while achievement of EBM was a common objective, only through monitoring could the level of progress be actually measured. For cost-effectiveness, existing monitored parameters should be first assessed as to their utility here, but it was recognised that new parameters, many associated with non-commercial species, will also have to be monitored. Different national approaches to achieving such monitoring were briefly discussed, mostly in the context of initiatives to develop a process to determine an optimal mix of parameters to monitor.

In finalising its report, the Study Group made the recommendation to its two parent Committees, FIS and MEQ, to establish a Working Group on *Ecosystem-based management*, with a 3-year duration and the following terms of reference:

- Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem-based management objectives of each country;
- Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges;
- Evaluate the indicators from the 2004 Symposium on "Quantitative Ecosystem Indicators for Fisheries Management" for usefulness and application to the North Pacific;
- Review existing definitions of "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES;
- Hold an inter-sessional workshop that addresses the status and progress of EBM science efforts in the PICES region, with the deliverable being either a special journal issue or a review article; and
- Recommend to PICES further issues and activities that address the achievement of EBM in the Pacific.

The parent Committees and Science Board accepted these recommendations, and the proposed Working Group on *Ecosystem-based management science and its application to the North Pacific* was established in October 2004. The Science Board also suggested that the full report of the Study Group be published as soon as possible in the PICES Scientific Report Series.