PICES Scientific Report No. 29
2005

REPORT OF THE STUDY GROUP ON ECOSYSTEM-BASED MANAGEMENT SCIENCE AND ITS APPLICATION TO THE NORTH PACIFIC

Edited by

Glen Jamieson and Chang-Ik Zhang

January 2005
Secretariat / Publisher
North Pacific Marine Science Organization (PICES)
c/o Institute of Ocean Sciences, P.O. Box 6000, Sidney, B.C., Canada. V8L 4B2
E-mail: secretariat@pices.int Home Page: http://www.pices.int

Table of Contents

Executive Summary

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 issues identified. This is the final report of the Study Group.

Summaries of each country's approach to ecosystem-based management (EBM) are provided, and in reviewing these summaries, it is immediately obvious that EBM challenges are 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 is, 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 and transport 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.

Many human activities are documented as impacting 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*.), but 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 has been focused on documenting and addressing fishery impacts. A standardised PICES reporting framework that describes human activity impacts is needed for comparative purposes. Ideally, its format should be robust enough to address the increasing number of environmental and other requirements imposed by legislation, certification schemes, and consumer and community demands. It should also capture ecosystem effects resulting from most human activities, and describe how these ecosystem effects are being monitored. Ecosystem parameters already, or potentially, being monitored may be capturing 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 need to be undertaken to determine linkages.

The Study Group recommended to establish, under the direction of FIS and MEQ, a Working Group on *Ecosystem-based management and its application to the North Pacific* (WGEBM) with a 3-year duration and 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 "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES;
5. 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
6. Recommend to PICES further issues and activities that address the achievement of EBM in the Pacific.

1. Introduction

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 world-wide is now recognised as both timely and necessary because 1) in many environments, individual ecosystem components are presently being utilised, harvested or impacted with limited attention to the maintenance of the integrity of the overall ecosystem, and 2) the scale of these impacts is now such that there is real danger of overall negative ecosystem change to the detriment of human society. The concept of an EBM Working Group within PICES was first proposed at the PICES Eleventh Annual Meeting in Qingdao, in 2002. At that meeting, the PICES Science Board indicated that the preferred first step would be to hold a Topic Session on ecosystem-based management and use recommendations from session participants as advice for future direction.

Many new national and international legal agreements use some form of the term "ecosystem-based approaches" when describing new methods to assess and manage marine living resources. These are usually understood to include objectives related to maintaining and monitoring ecosystem features such as biodiversity, productivity and the physical and chemical properties of an ecosystem. However, it is often unclear what this means in practice, what new information will be required, and in fact whether scientific or management actions will actually change under these new approaches. A PICES EBM Session (convenors: Glen Jamieson (Canada), Patricia Livingston (U.S.A.), Vladimir Radchenko (Russia), Takashige Sugimoto (Japan), Qi-Sheng Tang (People's Republic of China) and Chang-Ik Zhang (Republic of Korea)) was subsequently held at the Twelfth Annual Meeting in Seoul, in 2003, and recommendations were provided to establish a Working Group to focus on how both natural variability and changes arising from fishing and other activities on ecosystem characteristics could be monitored. Determining how biological communities can be effectively measured and monitored was deemed a necessary prerequisite to the meaningful assessment of how organisation of a community might be being altered by any proposed human activity. However, the Science Board felt that these objectives were still too broad, and to facilitate the development of acceptable terms of reference for a Working Group, established instead a 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;
3. Develop recommendations for a Working Group to focus on one or more issues identified.

This is the final report of the Study Group.

2. Overview of international EBM history

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. 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 (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).

The roots of this change can be found in the 1992 UN Conference on Environment and Development (UNCED) in Rio de Janeiro, itself emanating from the 1982 UN Conference on the Law of the Sea, which, in turn, resulted in the 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 (UNFA), 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 were reviewed in Johannesburg at the Rio +10 meeting in August 2002. Thus, there is a growing body of international legislation in support of ecosystem-based management.

One of the major challenges of Integrated Management (IM) is harmonization of the activities of various ocean sectors (*e.g.*, fisheries, oil and gas development, aquaculture, recreational tourism *etc*.). Past management approaches have tended to manage such sectors in isolation of one another. Integrated Management requires that management of all sectors work towards commonly defined goals that guide the activities of all industries within an area. This puts all sectors on the "same rules" basis.

There is an emerging consensus that management goals need to be considered at both the conceptual and operational level (Garcia and Staples, 2000, Sainsbury and Sumaila, 2003). Conceptual objectives (Jamieson *et al.*, 2001; Sainsbury and Sumaila, 2003) are stated in broad, general terms intended to be understandable by a general audience, and tend to be valid for long time periods (O'Boyle, 1993). Policy statements by a government or organization, for instance, can be considered conceptual objectives. Given that they are broad statements, there is, however, a possibility that they will be interpreted differently by different people. In addition, they lack the specificity to be operational, *i.e.,* result in a particular management action based upon the degree of divergence of a measurable indicator from a pre-determined reference point (more on this below). Operational objectives are the strategies by which the conceptual objectives are actually implemented. Jamieson *et al*. (2001) considered that an operational objective consisted of a verb (*e.g.*, maintain), a specific measurable indicator (*e.g.*, biomass), and a reference point (*e.g.*, 50,000 t), thus allowing an action statement for management (*e.g.*, maintain biomass of a given forage species greater than 50,000 t biomass). This extends current definitions of operational objectives in the literature (Anon., 2003; Sainsbury and Sumaila, 2003).

2.1 References

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

Anon., 2003. Fisheries Management. The Ecosystem Approach to Fisheries. FAO Technical Guidelines for Responsible Fisheries. 4 (Suppl.2). 112 pp.

Garcia, S. and Moreno, I. 2003. Global Overview of Marine Fisheries. pp. 1-24. *In* Sinclair, M. and Valdimarsson, G. (eds.) Responsible Fisheries in the Marine Ecosystem. FAO & CABI Publishing. 426 pp.

Garcia, S.M. and Staples, D.J. 2000. Sustainability reference systems and indicators for responsible marine capture fisheries: A review of concepts and elements for a set of guidelines. Mar. Freshwater Res. 51: 385-426.

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, BC, 27 February – 2 March 2001. CSAS Proc. Ser. 2001/09. 140 pp. (http://www.dfo-mpo.gc.ca/csas/Csas/Proceedings/2001/PRO2001_09e.pdf)

Jennings, S. and Kaiser, M.J. 1998. The effects of fishing on marine ecosystems. Adv. Mar. Biol. 34: 201-352.

Kaiser, M.J. and de Groot, S.J. 2000. Effects of Fishing on Non-target Species and Habitats. Biological, Conservation and Socio-economic Issues. Blackwell Science, Oxford, England.

Kabuta, S.H. and Laane, R.W.P.M. 2003. Ecological performance indicators in the North Sea: Development and application. Ocean Coastal Management. 46: 277-297.

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

O'Boyle, R. 1993. Fisheries management organizations: A study of uncertainty. pp 423-436. *In* Smith, S.J., Hunt, J.J. and Rivard, D. (Eds.) Risk Evaluation and Biological Reference Points for Fisheries Management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Sainsbury, K. and Sumaila, U.R. 2003. Incorporating ecosystem objectives into management of sustainable marine fisheries, including 'best practice' reference points and use of marine protected areas. pp. 343-361. *In* Sinclair, M. and Valdimarsson, G. (Eds.) Responsible Fisheries in the Marine Ecosystem. FAO & CABI Publishing. 426 pp.

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

3. Canada

3.1 Overview

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 *Fisheries 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. Responding to both international legislative changes, as well as concerns for the impacts of human activities on its marine ecosystems, Canada enacted the *Oceans Act* in 1997. The *Oceans Act* outlined a new approach to managing oceans and their resources based on the premise that oceans must be managed as a collaborative effort amongst all stakeholders that use 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) 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, the Canada's Oceans Strategy was published (Anon., 2002a), a key element of it being a nationally co-ordinated Integrated Management program, in which interested stakeholders and regulators 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. For instance, 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 (CCIM) project in another IM thrust. 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 eco-region 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 EOs to be met for a specific LOMA in the eco-region.

3.2 Activities to date

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 counties. 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 summarise the Canadian perspective on Integrated Management, based on our experiences with EBM in Canada (O'Boyle and Jamieson, 2004).

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 interrelationships that exist among different uses and the environments they potentially affect (Anon., 2002b). It thus involves many facets relating to both what activities are undertaken and to how these are undertaken.

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 stated above. In this 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. For example, they stated 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 to intent of the associated conceptual objective.

Jamieson *et al*. (2001) translated each of the sub-objectives into operational objectives through a process termed "unpacking" (Fig. 3.1). 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, can a measurable indicator and reference point (see Appendix 10.2 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 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 Marine Environmental Quality objectives. Both of these terms are synonymous with the operational objectives that would go in management plans.

3.3 Integrated Management implementation in Canada

Integrated Management is still in its initial stages in Canada. While progress has been made in some

Conceptual Objectives		**Operational Objective**

Objective
• Sub-objective
  • …
	Maintain Productivity
	• Trophic Transfers
	  • Forage Species
	    • Target Escapement
	      • (Maintain) Biomass
		Consists of a Verb, Indicator & Reference Point
		
		Maintain Biomass of Forage Species > 50,000 t

Fig. 3.1 The link between conceptual objectives and operational objectives. With the "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.

areas, much remains to be done. Jamieson *et al*. (2001) summarized the recommended next steps to achieving IM in Canada.

3.3.1 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.

3.3.2 Assessment approaches

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

3.3.3 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 form background variability, cost of measurement, and so on. 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 on our knowledge to supply this information. This research needs to build on international initiatives such as the SCOR WG 119 on *Quantitative Ecosystem Indicators for Fisheries Management*.

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 is being undertaken on the Eastern Scotian Shelf (O'Boyle *et al*., 2004), where a number of ocean sectors - fishing, oil and gas exploration, transport, defense - 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 ESSIM area to address biodiversity, productivity and habitat issues. Operational objectives, which identify an indicator and reference point, associated with each conceptual objective, have then been proposed. Utilizing Canada's conceptual objectives unpacking protocol, individual ocean sector plans and activities can then 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 addressed as required and comment is made on how progress against the suite of objectives could be reported.

Based on these experiences, it is suggested that the following sequential steps are 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 relevant to the IM area;
2. Identification of the ecosystem components to be conserved and the associated conservation objective;
3. Determination of the appropriate ocean sectors to implement the conservation objective;
4. Definition of operational objectives for the IM area; and
5. Definition of operational objectives for each ocean sector.

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

3.3.4 Management directions for the future

Before Integrated Management can be implemented in Canada, concepts and approaches need to be "tested" in pilot-scale initiatives. Only through a nationally co-ordinated 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 of all currently available information, including socio-economic data;
- Practical experiences in actually compiling ecosystem-level data and their utilisation 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 realised and to determine how the concepts and approaches discussed by Jamieson *et al*. (2001) can be implemented over the long-term.

3.4 References

Anon., 2002a. Canada's Ocean Strategy. Fisheries and Oceans Canada. Oceans Directorate, Ottawa, ON. 30 pp. (http://www.cos-soc.gc.ca/doc/publications_e.asp)

Anon., 2002b. Policy and Operational Framework for Integrated Management of Esturaine, Coastal and Marine Environments in Canada. Fisheries and Oceans Canada. Oceans Directorate, Ottawa, ON. 36 pp. (http://www. cos-soc.gc.ca/doc/im-gi/index _e.asp)

Anon., 2003. A Strategic Planning Framework for the Eastern Scotian Shelf Ocean Management Plan. A Discussion Paper prepared for the ESSIM Forum. ESSIM Forum Secretariat. Oceans and Coastal Management Division. Maritimes Region, DFO. 37 pp.

Garcia, S.M. and Staples, D.J. 2000. Sustainability Reference systems and indicators for responsible marine capture fisheries: A review of concepts and elements for a set of guidelines. Mar. Freshwater Res. 51: 385-426.

Jamieson, G.S, Bauer, B. and Vandermeulen, H. 2003. Proceedings of the Central Coast Integrated Management Marine Environmental Quality Workshop, June 5-7, 2002, Parksville, BC CSAS Proc. Ser. 2002/013: 86 pp.

Jamieson, G.S. and B. McCorquodale. 2004. Proceedings of the Central Coast Marine Environmental Quality Indicators Workshop, March 10-12, 2004, Parksville, BC. CSAS Proc. Ser. (submitted)

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, BC, 27 February – 2 March 2001. CSAS Proc. Ser. 2001/09: 140 pp. (http://www.dfo-mpo.gc.ca/csas/ Csas/ Proceedings/2001/PRO2001_09e.pdf)

O'Boyle, R and Jamieson, G.S. 2004. Observations on the implementation of ecosystem-based management: Experiences on Canada's east and west coasts. Can. J. Fish. Aquat. Sci. (submitted)

O'Boyle, R. and Keizer, P. 2003. Proceedings of Three Workshops to Investigate the Unpacking Process in Support of Ecosystem-based Management. CSAS Proc. 2003/004.

O'Boyle, R., Sinclair, M., Keizer, P., Lee, K., Ricard, D. and Yeats, P. 2004. Indicators for ecosystem-based management on the Scotian Shelf: Bridging the gap between theory and practice. *In* Quantitative Ecosystem Indicators For Fisheries Management International Symposium Proceedings, 31 March - 3 April, 2004, Paris, France. (submitted)

Pajak, P. 2000. Sustainability, ecosystem management, and indicators: Thinking globally and acting locally in the 21st century. Fisheries 25: 16-30.

Sainsbury, K. and Sumaila, U.R. 2003. Incorporating ecosystem objectives into management of sustainable marine fisheries, including 'best practice' reference points and use of marine protected areas. pp. 343-361. *In* Sinclair, M. and Valdimarsson, G. (Eds.) Responsible Fisheries in the Marine Ecosystem. FAO & CABI Publishing. 426 pp.

4. Japan

4.1 Overview

Ecosystem-based management is a backbone of current Japanese ocean and fisheries policies. These policies are mainly focusing on the following two points: (1) environmental conservation and sustainable development of Japanese coastal zones, including coastal waters and land along the coast; and (2) conservation of biodiversity and sustainable use of marine living resources around Japan. However, there has been no single government agency that jointly plans and implements these policies, as does the National Oceanic and Atmospheric Administration in the United States of America and the Department of Fisheries and Oceans in Canada. Therefore, various policies including water quality control and waste regulation in coastal waters, mitigation for degraded and destroyed ecosystems, and the sustainable development of capture fisheries and aquacultures have been independently planned and implemented by different agencies. A lack or insufficiency of interaction among relevant agencies has often created political conflict between agencies advocating economic development versus environmental conservation. This is a particularly serious problem in coastal areas where many industries and human settlements occur.

As part of international discussions in the 1990s on conservation of biodiversity of species and ecosystems, the Japanese government passed the *Basic Environmental Law* in 1993. Since then, more essential discussion and some actual implementation of ecosystem-based management for fisheries and the ocean have started. Under the authorities of the *Fisheries Basic Law* of 2001 and related laws, marine capture fisheries and aquacultures have been regulated to meet the goal of sustainable development in harmony with environmental protection and ecosystem conservation. To harmonize sustainable development and environmental conservation in coastal zones, regulations to minimise various environmental impacts from land-based activities are being developed, along with simultaneous actions to minimise environmental degradation in coastal waters. Recently, the idea of integrated coastal zone management, which jointly addresses issues in both coastal waters and on land, has been proposed by relevant governmental and non-governmental organizations.

To achieve success with ecosystem-based management in Japan, it is essential to promote scientific activities that allow for a better understanding of ecosystems, *i.e.*, structure, function, and resilience to human activities; and responses to natural environmental variability, such as from periodic ocean climate change. Recently, the Fisheries Agency and the Fisheries Research Agency of Japan have expanded research activities to seek mechanistic linkages between fishery stocks and ambient ecosystem parameters. International discussions on this topic are also essential. Invasions and settlement of non-native and harmful organisms from the introduction of aquaculture species and ballast water discharge have adversely affected Japanese coastal ecosystems and the biodiversity of native populations. Recent environmental issues in Japanese coastal waters include severe harmful algae and jellyfish blooms, invading non-native species, and the expanded spread of diseases, and these issues are also increasingly common to countries around the marginal seas of the North Pacific. Collaborative effort is needed for monitoring ecosystem changes, detecting causal factors, and coordinating counter measures among these countries.

4.2 Conservation and sustainable use of marine living resources

Sustainable use is a traditional objective of Japanese fishers. Based on this, they have practiced community-based fisheries management in coastal common areas and even, to some extent, in offshore fisheries. During recent decades some stocks around Japan have nevertheless become depleted by overexploitation. After the ratification of the United Nations Convention on the Law of the Sea (UNCLOS) in 1996, the Fisheries Agency has restructured domestic management institutions and has started practicing a more conservative management in the Japanese Exclusive Economic Zone (EEZ). Present management approaches include harvest control by regulating total allowable catch (TAC), effort regulations based on stock recovery plans, and stock enhancement by releasing hatchery produced juveniles.

4.2.1 Harvest control by TAC system

Harvest control by a TAC system was introduced into Japanese domestic fishery management in 1997. More than 80 stocks of nearly 40 species found largely in the EEZ are assessed every year and an acceptable biological catch (ABC) with precautionary management options is calculated. Since 1998, TACs have been set for eight species: Pacific saury (*Cololabis saira*), walleye pollock (*Theragra chalcogrammus*), jack mackerel (*Trachurus japonicus*), Japanese sardine (*Sardinops melanostictus*), chub mackerel (*Scomber japonicus*), spotted mackerel (*Scomber australasicus*), Japanese common squid (*Todarodes pacificus*), and snow crab (*Chinoecetes opilio*). The total catch of these eight species was 1.5 million tons in 1998, about 30% of Japan's total harvest from marine capture fisheries and 50% of the landings from offshore fisheries. Adopted TACs values consider both socio-economic conditions in related fisheries and ABC projections.

TAC setting tries to take into account interactions among species. With present stock assessments, environmental factors are considered because most TAC species have large population fluctuations with ocean climate variations. In addition, mass-balance model analyses of food web structure and specific prey-predator interactions, including some marine mammals, have been developed for the northern Pacific region and the East China Sea. However, these analyses are still too preliminary to be included along in stock assessments and ABC calculations. It is hoped that the recent expansion of studies to seek mechanistic linkages between fishery stocks and ambient ecosystems by the Fisheries Agency and the Fisheries Research Agency will improve this situation.

4.2.2 Stock Recovery Plan and effort regulation system

The TAC system described above is largely aimed to regulate offshore stocks and fisheries. Since 2002, the Fisheries Agency has begun a new management approach called the Stock Recovery Plan to recover depleted coastal stocks and fisheries. By April 2004, plans have been established for recovering 13 depleted species in seven regions.

In these plans, fishing effort regulation is a major component. In consultation with scientists and administrators, fishers themselves recommend on actual regulating measures, such as time and area closures, fishing net mesh size, limitations of vessel number, and gear type restrictions. National and local governments support these plans through stock enhancement activities, such as establishing new sea grass and algal beds on spawning and nursery grounds and releasing hatchery produced juveniles. Environmental subsidies include compensation for economic losses associated with time and area closures and the development and introduction of improved gears.

There are already signals of some stock recovery for some species. However, in some cases, introduced regulations were not severe enough, resulting into insufficient and slow recoveries of those stocks. Most recovery plans target one or only a few species in a certain region, and only mildly consider other species or ecosystem functions. The time and area closures in the plans also only protect target species in a certain season, *i.e.*, not all species through the year, as would might be the case if effective marine protected areas (MPAs) were established.

4.2.3 Stock enhancement by hatchery-produced juvenile release

Juvenile release of hatchery-produced individuals is a traditional approach to stock enhancement in Japan, with Pacific salmon as a typical example. This approach has been conducted under the initiative of national and local governments.

Target organisms usually are higher-valued species including fishes, crustaceans and molluscs. With these species, landings from hatchery-produced released juveniles may substantially supplement naturally-produced landings in coastal capture fisheries. Hatchery-originated adults also contribute to the population fecundity of the wild population in some cases, such as with red sea bream (*Pagrus major*) and scallop (*Patinopecten yessoensis*).

There are some ecological concerns about the enhancement approach described above that include food web consequences, genetic influence on wild populations, and the spread of diseases. In recent years, sufficient numbers of spawning adults have been used to maintain the genetic diversity of released juveniles. Stocking efficiencies and ecological consequences of this approach are being considered with respect to vital population parameter rates and predation rates of juveniles after their release, and with respect to food web structures in release areas prior to juvenile releases.

4.3 Conservation and sustainable development on coastal waters

In Japan, coastal waters are well exploited as fishing and aquaculture grounds. The total landing from coastal fisheries and aquaculture production was 2,820,000 t in 2003, almost half of the total Japanese marine fisheries landing. Natural water purification by tidal flats and salt marshes is an essential ecosystem function required to sustain biological production in coastal waters. However, Japanese industries and human populations are dense in coastal areas, where about 50% of the first sale price of industrial products is generated. Since the 1970s, Japan has enacted several laws that aim to control environmental land-sourced impacts to maintain water quality in the coastal environment. With the increase of human activities, however, environmental degradation arising from eutrophication, water pollution, and lost of tidal flats and salt marshes has been recognised as a common problem in Japanese coastal waters.

Environmental degradation results in loss of habitats for organisms and frequent outbreaks of toxic red tides, resulting in a reduction of fishery and aquaculture landings. In addition, some coastal fisheries adversely affect coastal ecosystems through destruction of bottom faunas and floras and the bycatch and discarding of small-sized target and non-target species in various stages of their life cycles. Aquaculture also has adverse effects including contamination of coastal environment by fish waste deposition, pesticides, and antibiotics; spread of diseases; and escapement of non-native cultured species. Fishing effort regulations under the Stock Recovery Plans described above are attempting to remedy the adverse effects of fisheries. Since 1999, a new legal subsidy system has been developed to help avoid intense aquaculture and to reduce the aquacultural use of pesticides and antibiotics. Another legal approach is being planned to prohibit or strongly regulate the introduction of non-native species.

As mentioned above, there are many conflicts between development and conservation in coastal zones. An Integrated Management approach that jointly manages coastal waters and lands for sustainable development in harmony with environmental protection of coastal zones is needed. There have been some attempts to evaluate the economic value of goods and services from coastal ecosystems, as well as the need to restrict and regulate coastal development. In Tokyo Bay, a coastal environmental recovery plan has started with the participations of local government and citizens.

To address common environmental issues in coastal waters of East Asian countries, collaborative efforts among relevant countries are needed to monitor ecosystem changes, detect causal factors, and to coordinate countermeasures. PICES may be able to assist in the organisation of discussions and actions. In 2004, Japan held an international workshop with China and Korea on jellyfish, *Stomolophus nomurai*, blooms to allow the exchange of information and to discuss possible future collaboration among these countries.

4.4 The implementation of ecosystem-based management

In Japanese waters, scientific knowledge on food web dynamics is still insufficient to develop and apply a quantitative multi-species model for fisheries management. Alteration in dominant species occurs among small pelagic fishes with decadal ocean climate changes, and these changes affect food web structure around Japan. At present, a practical management approach is conservative single species management, but taking decadal ocean climate changes into consideration. In addition, the following approaches should be introduced to the present TAC system for incorporating ecosystem considerations: (1) a shift of target species with species dominance alteration; and (2) a set ceiling for the TACs in a region that corresponds to biological productivity that varies with decadal ocean climate changes. We also need quantitative evaluations of predation mortalities for major stocks to assess fishing impacts. Recent expanded research activities to seek mechanistic linkages between fish stocks and ambient ecosystems will support development of ecosystem-based fisheries management system in Japan.

There have been substantial reductions in number of fishing vessels in the Japanese offshore and far seas fisheries during the last several decades. However, excess fishing capacity and over-fishing are still major problems for sustaining marine living resources and fisheries, especially in coastal waters. The development of techniques and devices for reducing bycatch and discards is needed to help reduce the effect of an excess fishing capacity and over-fishing. Studies on the establishment of an effective MPA network are also necessary. Examination of the effects of economical incentives, such as individual transferable quotas (ITQs) and environmental subsidies, on stock recovery would be useful for developing an integrated management system that incorporates socio-economic considerations.

Finally, to harmonize development and implementation of an Integrated Management plan, agreements are necessary among existing government agencies on priorities. Systematic approaches should also be explored to better educate the public on these issues and to allow for greater citizens' participation in discussions and decision-making.

5. People's Republic of China

5.1 Overview

The Chinese government has promulgated and put into effect fishing closures for motorized trawlers in coastal waters, seasonal fishing closures and area closures on major fish spawning grounds; and has restricted licensing and established minimum mesh size regulations since the 1950s. These have had a significant positive effect on the conservation of fishery resources. The promulgation and enforcement of the *Law of Fisheries of the People's Republic of China* was a milestone in 1986 in the development of China's conservation of fishery resources. Since then, Chinese fisheries have developed rapidly. The *Law of Fisheries* defined a fishery development policy suitable for China's situation. It was a significant adjustment of fisheries activities since both enforcement capability was strengthened and the conservation and rational utilization of fishery resources was advanced. The *Law of Fisheries* was amended in 2000, and quota management was established. The *Law of Marine Environment Protection* was enacted in 2000 and the *Law of Sea Use Management* was enacted in 2002.

Due to the effects of global climate change and increasing human activities, inshore fishery resources in Chinese coastal waters are now mostly fully or over-exploited. Existing fisheries largely depend on small-size, low-value species. With the recent rapid development of land-based industries and aquaculture along populated coastal areas, pollution and habitat degradation are now serious problems. In addition, frequent occurrences of harmful algae blooms and introductions of non-native species from aquaculture and probably, accidentally through ballast waters, have adversely affected communities in Chinese coastal waters, and threaten the health of ecosystems and the maintenance of a natural biodiversity.

For the sustainable utilization of marine living resources and maintenance of biodiversity, ecosystem-based management is needed, and sustainable economic development is now a management target in Chinese ocean and fisheries management policies. In China, ecosystem-based management of marine fisheries is of interest to the Ministry of Agriculture (for fisheries), the State Oceanic Administration (oceanic affairs excluding fisheries), and the State Environmental Protection Administration. There is presently no single governmental agency that coordinates the implementation of integrated ecosystem-based management.

5.2 Current actions

Except for the above-mentioned passive measures, the following regulations have been applied in order to conserve living resources and restore ecosystems.

5.2.1 Output control

Because of high fishing pressures caused by many fishermen, single species Total Allowable Catch measures are not practical at present. Instead, limiting the total catch is used, with the 1999 landing as the maximum. Future total marine catches are to be equal or less than the catch in 1999 (zero growth policy).

5.2.2 Input control

In order to reduce fishing mortality, the Chinese government has allocated 270 million CNY each year to subsidize the scrapping of older fishing boats and to assist fishermen in leaving fishing. In addition, the building of new fishing boats is now strictly controlled.

5.2.3 Summer fishing ban

In order to conserve and protect fishery resources, China began in 1985 to close all fishing in the Yellow, Bohai and East China Seas for 2-3 months in the summer. The scale and duration of these closures has been expanded and enlarged over time. In 1999, closures were for 2.5 months in the region north of 35ºN, three months south of 35ºN, and two months on the continental shelf of the South China Sea. These measures are effectively protecting juveniles, allowing catches and quality of product to increase and improve.

5.2.4 Enhance ecosystem health

Stock enhancement has been undertaken for more than 20 years. The main species involved are high-valued species, particularly penaeid shrimp (*Penaeus chinensis*) in the Bohai, Yellow and East China Seas. Juveniles of other cultured shellfish species such as scallop, abalone and jellyfish, are released in coastal waters. Some cultured juvenile fishes have also been released, notably red seabream (*Pagrosomus major*), *Pseudopleuronectes yokohamae* and *Liza haematocheila.* In recent years, juvenile large yellow croaker (*Pseudosciaena crocea*) were released in the East China Sea to rebuild the depleted stock. Artificial reefs have been established in some coastal areas. Established marine protected areas (MPAs) have been limited to coastal waters.

Coastal Chinese waters are now mostly fully or over-exploited, for both fishing and mariculture. High fishing intensity, increasing pollution and climate changes have caused both stock depletions of some commercially high-valued, large-sized species and environmental degradation, with loss of habitats and frequent outbreaks of toxic red tides. The adverse effects of mariculture include contamination of 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 and from land sources, and is functionally dividing coastal areas through zoning to re-arrange areas designated for either mariculture or MPAs.

For ecosystem-based management, obtaining a better understanding of ecosystems is essential. Food web dynamics and species interactions have been studied in China's GLOBEC (Global Ocean Ecosystem Dynamics) programmes in the Bohai, Yellow and East China Seas. However, available scientific knowledge is still insufficient, especially with respect to coastal zones and the effects of releasing new species into the ecosystem. To create a functional integrated management system, not only fisheries but other impacting factors must be considered, and all resource management agencies need to participate.

6. Republic of Korea

6.1 Initiatives and actions of ecosystem-based management in Korea

Elements of ecosystem-based management (EBM) may be (1) sustainability of yields, (2) maintenance of biodiversity, (3) protection from the effects of pollution and habitat degradation, and (4) socio-economic benefits. Based on these elements of EBM, Korean initiatives with 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*. Most of the Korean Acts with the spirit of EBM are focused on the maintenance of biodiversity and/or protection from the effects of pollution and habitat degradation, rather than on sustainability of yields and achieving 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 ecosystem-based management.

6.2 Current ecosystem-based management initiatives in Korea

Current initiatives in support of EBM include the establishment of (1) precautionary TAC-based fishery management, (2) closed fishing season/areas, (3) fish size- and sex-controls, (4) fishing gear restrictions, and (5) marine protected areas (MPA). The details of these actions follow.

6.2.1 Precautionary TAC-based fishery management

Recognition of uncertainty and its potential consequences has 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 total allowable catch (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.

6.2.2 Closed fishing season/areas

Fishing seasons for 24 species during their main spawning seasons are closed in Korea. Fishing (trawl, purse seine, gill net, stow nets, and dredged net) for 12 offshore species is not allowed in coastal areas at any time of the year.

6.2.3 Fish size- and sex-controls

Fish size or weight regulation is applied for 27 species, based on each species' 50% spawning length or weight. Females of two crab species (tanner crab and snow crab) are not permitted to be caught.

6.2.4 Fishing gear design restrictions

Gill nets of more than two layers of nets are prohibited in Korean waters. The sizes of nets and meshes are restricted in 19 fisheries. Gear restrictions are set for fishery openings in 18 fisheries to conserve spawning and juvenile stocks and their habitats. The size of offshore and coastal fishing vessels is limited in gross tonnage. The number of licences for five kinds of aquaculture farming and set net fisheries are 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 nets; and for seed production fisheries.

6.2.5 Marine protected areas (MPA)

To ensure opportunity for the propagation and conservation of fisheries resources, spawning and nursing areas are protected from fishing. 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 wet lands, a total of 5 areas (83.54 km^2) along the west coast and 7 areas

(44.48 km^2) around mountains, lakes and estuaries are designated and managed by Acts, and 9 more areas along the coastal line 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 being planned for the enhancement and efficient management of fisheries resources, and thus requires an understanding of ecological interactions among major species with respect to predation, competetion 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. With such an understanding, fisheries management should prevent significant and potentially irreversible changes in marine ecosystems caused by fishing. The Tongyoung Marine Ranching Program has been underway since 1998 as a pilot program for comprehensive ecosystem-based management in Korea.

7. Russia

7.1 Existing and anticipated ecosystem-based management initiatives

Significant expansion of commercial fisheries in the Far Eastern region of Russia began in the 1950s. Legislation was then needed to regulate enhanced fishery activities on living resources. In 1962, *Regulations for Fishery* were developed and adopted, where among other things, time and area openings for commercial fishing, minimal commercial sizes of harvested species, and fishing gear type regulations were specified. However, most estimates of allowable catch for commercial species were still then devoid of strict quantitative assessments of their biomass and abundance. Weak enforcement of fishing operations together with an absence of data for accurate assessment of allowable catch resulted in excessive catches of a number of marine animals (some populations of flounder, rockfish, king crab, *etc*.). At the same time, commercial fishing impacts on many abundant smaller-sized species (squids, capelin, several species of the family *Macrouridae*) were not being considered in commercial fishery regulations.

Further development of a rational fishery concept resulted in a number of changes being made with the *Regulations for Fishery*, where requirements concerning separate species in fishery operations were refined and/or changed. The latest edition of these regulations was accepted in 1989. This was an integrated document that regulated harvest of fish and non-fish species in the economic zone, territorial waters and continental shelf of the Russian Federation. A large amount of data on the biology and ecology of commercial species collected during the years before 1989 made it then possible to provide initial quantitative estimates of species abundance, and hence to allow estimation of sustainable allowable yields. Final appraisal of total allowable catches (TACs) is now made by experts from the Ministry for Natural Resources of the Russian Federation.

However, such data can indicate only general population estimates of major commercial species and conditions for their harvest. To incorporate annual and seasonal variability in abundance estimates, spatial distributions and life history aspects, annual adjustments of dates and locations for fishery openings as corrections of TAC are now part of the process of determining annual fishery regulation. These adjustments are normally based upon survey data and assessments of population parameters, but also consider information about quantity and quality of catch reported directly from fishing vessels. These multiple databases now enable fishery scientists from regional research institutes to keep track of fishery operations and to provide recommendations on the optimal location of vessels to maximize their catches, or to immediately close a fishery for a particular species to address changing circumstances. Such fishery management is now used for walleye pollock, turbot, halibut, Pacific salmon, saury and many other species.

It is impossible to conduct effective fishery management without a solid long-term database of individual stock dynamics. Years of practice have shown that when forecasts of marine biological resources and their trends are based solely upon direct counts of eggs, juveniles, spawners, *etc*., that is, environmental considerations are not included, then estimates are frequently incorrect for long-term periods. In order to provide better long-term assessments, a variable array of ecosystem relationships need to be considered. To accomplish this goal, on-going research into the macro-ecosystems of the Far Eastern Seas and adjacent Pacific Ocean was commenced in the 1980s, and these studies continue today. Annual surveys include meteorological, hydrological, hydrobiological, trophological, nektonic and nektobenthic monitoring, and provide a solid background for ecosystem-based management of commercial species and populations subjected to modern fishing. Large-scale monitoring on species composition and structure of pelagic and bottom communities makes it possible to estimate ecosystem health, and to produce predictions of possible ecosystem changes, including those emerging from fishery impacts. For example, in the early 1980s, a general downward productivity trend was suggested for the Far Eastern Seas due to certain changes in climate and oceanographic conditions in the North Pacific. These expectations were later confirmed by a drop in fish productivity by more than one third, primarily due to a decrease in abundance of pollock and sardine, both major commercial species. Investigations suggested that in most cases, variability in natural factors such as climate, oceanography and resulting trophic level relationships (competition, predation), rather than anthropogenic factors, was the main reason for the observed dynamics in marine communities. At the same time, anthropogenic influence, mostly illegal fishery (poaching), led to decreases in abundance of a few species, *e.g.*, several populations of crabs, trepang, scallop, rockfishes, and several southern populations of salmonids.

Overall, fishery landings remained strong. Increases in the commercial harvests of herring, squids, some salmon populations, Japanese anchovy, atka mackerels and several non-commercial species made up for decreases in abundance of other major commercial species, such as pollock and sardine.

During such a course of events, and in order to maintain stable commercial harvests with an objective to even increasing landings when possible, it seems appropriate to be able to shift fishing effort within a multi-species fishery. A multi-species approach towards fisheries should favor expanding the number of harvestable species and possibly stabilize overall catch, while redistribution of fishery impacts on as many species as possible should provide optimal utilization of aquatic renewable resources.

Such changes in a fishery strategy need regular, rapid updating, and this approach is being advocated for the whole structure of commercial fisheries in Russia. This and related items were discussed at the “Far-Eastern Fishery Forum” held in Vladivostok, in July 2004.

7.2 Issues related to the implementation of ecosystem-based management

A major fundamental research study that will provide a solid basis for fishery regulation is ecosystem-based management of resources that includes assessment of the carrying capacity of marine ecosystems. Thorough investigation of factors that may limit species abundance is necessary. It seems productive to continue regular large-scale surveys of communities within ecosystems using modern equipment and techniques. The large amount of knowledge obtained by Russian scientists suggests that research on the following is still needed:

- production and population biology;
- trophologic investigations;
- studies on the dynamics of abundance of commercial species.

Such studies can provide the necessary parameters for ecosystem modeling and for enhancement of rational fisheries, particularly multi-species fishing. Ecosystem studies should significantly contribute to applied goals such as determining the optimal scale and interaction of fishery, aquaculture and natural area protection. Whether ecosystem-based fishery regulation is ultimately effective will largely depend upon the development of new, or well-known but modified, methods of fishery management, and upon the development of new technology for the capture of marine organisms.

8. United States of America

Recent, worldwide calls for an ecosystem-based approach to fisheries management imply that the necessary framework for protecting ecosystem components and structure and function has been lacking in present-day fishery management systems. These global interests are echoed in the report of the official U.S. Commission on Ocean Policy (2004) and a private report issued by the Pew Ocean Commission (2003). The U.S. Commission on Ocean Policy recommends, "to refine the existing fishery management system to strengthen the use of science and move toward a more ecosystem-based management approach." Emphasis on ecosystem and multi-species management approaches is predicted to improve sustainable yields of harvested stocks while maintaining biodiversity and ecosystem function.

8.1 Definitions and approaches to ecosystem-based fishery management in the United States

An ecosystem is a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics. The environment comprises the biological, chemical, physical, and social conditions that surround organisms. Therefore, when appropriate, the term environment should be qualified as biological, chemical, physical, and/or social. These environments are dynamic over various temporal scales.

Ecosystem-based management attempts to administer policies for natural resource exploitation that consider these various environments. Traditional resource management generally focuses on single species in isolation. By putting organisms in an ecosystem context, we may better anticipate changes in abundance or distribution of species as they respond to exploitation and changes in their environments. Primary management issues addressed in an ecosystem approach to fishery management are: (1) bycatch or fishery interactions, including mortalities of non-target and protected species, (2) consideration of the indirect effects of harvesting (food web interactions and habitat alteration), and (3) interactions between biological and physical components of ecosystems (environmental variation and human effects such as energy development activities, toxics, runoff, *etc*.).

An ecosystem approach to management of marine fisheries in the U.S. needs to: (1) be adaptive, (2) be regionally directed, (3) take account of ecosystem knowledge, (4) take account of uncertainty, (5) consider multiple external influences and (6) strive to balance diverse societal objectives. Transition to an ecosystem-based approach needs to be incremental and collaborative. In addition, it is imperative that there is accurate catch and bycatch accounting as well as consideration of such measures as dedicated access privileges (share-based management programs, *etc*.) to assist in providing greater incentives to the fishing entities to promote the conservation of the marine resources on which they depend (*i.e.*, decreasing the tendency to "race for fish").

8.2 Present U.S. legislative mandates relating to ecosystem-based fishery management

Several U.S. laws presently provide protection to marine ecosystems and these laws have been in existence for over 20 years (Table 8.1).

8.2.1 Target species

Management of target fish species in federal marine waters in the U.S. is governed primarily by the *Magnuson-Stevens Fishery Conservation and Management Act* (MSFCMA), originally passed in 1976 and amended in 1996 by the *Sustainable Fisheries Act* (http://www.nmfs.noaa.gov/sfa/magact/index.html). National standard guidelines (http://www.afsc.noaa.gov/refm/stocks/nsgfinal.pdf) for implementing the requirements of the MSFCMA have been developed to guide regions in development, review and amendment of fishery management plans and regulations prepared by Regional Fishery Management Councils and the Secretary of Commerce under the Act. These guidelines specify that maximum sustainable yield determinations consider the amount of yield that can be taken from a stock or stock complex under the prevailing ecological and environmental conditions.

8.2.2 Bycatch species

With respect to protection of bycatch species, National Standard 9 was added to the *Magnuson – Stevens Fishery Conservation and Management Act* when it was amended in 1996. It 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". The national bycatch website is http://www.nmfs.noaa.gov/bycatch.htm. At the national level, a plan for dealing with bycatch has been developed. This plan is available at http://www.nmfs.noaa.gov/bycatchplanonline.pdf. A national strategy for dealing with bycatch was also recently developed and can be found at http://www.nmfs.noaa.gov/bycatch_images/FINALstrategy.pdf.

8.2.3 Threatened or endangered species

Other legislation that impacts fishery management is the *Marine Mammal Protection Act* (MMPA) (http://www.nmfs.noaa.gov/prot_res/laws/MMPA/MMPA.html) and *Endangered Species Act* (ESA) (http://www.nmfs.noaa.gov/prot_res/laws/ESA/ESA_Home.html). The MMPA establishes a federal

Table 8.1 Major national laws governing the management and protection of U.S. marine resources.

National law	Acronym	Main legislative intent
National Environmental Policy Act of 1969 (as amended)	NEPA	Environmental protection is provided through a process of outlining the environmental consequences of human activities to guide decision-makers to take actions that protect, restore, and enhance the environment.
Clean Water Act of 1972 (as amended)	CWA	To restore and maintain the chemical, physical, and biological integrity of U.S. waters through the elimination of point and non-point sources of pollution.
Marine Mammal Protection Act of 1972 (as amended)	MMPA	Protection and conservation of marine mammals through strict limits on both the taking of marine mammals in U.S. waters and the importation of marine mammals and mammal products into the U.S.
Endangered Species Act of 1973	ESA	Provides for the conservation of species that are in danger of endangerment or extinction throughout all or a significant portion of their range and the conservation of the ecosystems on which they depend.
Coastal Zone Management Act of 1972	CZMA	Comprehensive management of the nation's coastal resources, ensuring protection for future generations while balancing competing national economic, cultural and environmental issues.
Marine Plastic Pollution Research and Control Act	MARPOL	Restricts dumping of plastics, including synthetic ropes, fishing nets, plastic bags, and biodegradable plastics, into U.S. EEZ waters. Also controls dumping of other types of refuse within 25 nautical miles of shore.
Magnuson-Stevens Fishery Conservation and Management Act of 1976 (as amended)	MSA	Conservation and management of fishery resources off the coasts of the U.S. through the establishment of national standards and regional fishery management plans and councils.

responsibility to conserve marine mammals, with a goal of obtaining an optimum sustainable population of marine mammals within the carrying capacity of the habitat. This law also specifies a goal that the level of incidental mortality and serious injury of marine mammals be reduced to insignificant levels approaching a zero rate, which is commonly referred to as the *Zero Mortality Rate Goal* (ZMRG). 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. The ESA provides protection for fish and wildlife species that are listed as threatened or endangered.

The MMPA defined Potential Biological Removal (PBR) rates to be used to set allowable takes of marine mammals in fisheries. These rates are the product of the minimum population estimate, one-half the maximum theoretical net productivity rate, and a recovery factor. These PBRs define a maximum level of take that would still allow the species to attain its optimum sustainable population. This management approach was instituted with the understanding that direct human-related mortalities would be the primary reason for observed declines, which may not be the case for some species. Fisheries report direct takes of animals. If PBRs are exceeded or the marine mammal stock is threatened or endangered (or has some potential for being listed in the near future), a take reduction team is formed to develop a plan that will reduce the take within 6 months of its implementation to levels less than the PBR and over the span of 5 years to reduce the levels in commercial fishery operations to levels approaching zero. See the following web site for more information on this management approach: http://www.nmfs.noaa.gov/prot_res/PR2/Fisheries_Interactions/TRT.htm.

Another management process for reducing interactions between fisheries and threatened or endangered species is the Section 7 consultation under the ESA. First, informal consultation takes place in which the agency contemplating an action (such as fishing) must contact either the U.S. Fish and Wildlife Service or U.S. National Marine Fisheries Service Protected Resources to get a list of endangered or threatened species and habitats in the action region. If the action agency determines (and the protection resource agency agrees) that the project may adversely affect the species, then a formal consultation is required. The protection agency then determines if the action will jeopardize the continued existence of the species or adversely modify its habitat. If either of these is judged to be occurring, then the Biological Opinion must identify reasonable and prudent alternatives that would remove jeopardy and adverse habitat alterations, and allow the action to go forward. For more complete description of the consultation process, see http://endangered.fws.gov/consultations/consultations.pdf. Jeopardize the continued existence is defined as "engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers or distribution of that species". Destruction or adverse modification of habitat means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical. These definitions lack clearly articulated quantitative standards for decision-making.

8.2.4 Habitats

At the federal level, the *Magnuson-Stevens Fishery Conservation and Management Act* calls for direct action to stop or reverse the continued loss and degradation of fish habitats. Congress mandated the identification of habitats essential to all life history stages of managed species and measures to conserve and enhance this habitat. The Act requires cooperation among NOAA Fisheries (NMFS), the regional Fishery Management Councils, fishing participants, and Federal and State agencies to protect, conserve, and enhance essential fish habitat (EFH). The amended *Magnuson-Stevens Act* requires NMFS to minimize damage to EFH from fishing practices, to the extent practicable.

Additionally, the Act requires Federal agencies that authorize, fund, or conduct activities that "may adversely affect" EFH to work with NMFS 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 NMFS to develop EFH conservation measures if the action may adversely affect EFH. While NMFS does not have veto authority over federal projects adversely affecting EFH, this mandate enables NMFS 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 *Magnuson-Stevens Act* ensures that NMFS takes a more holistic approach to fish habitat protection. Laws and regulations on EFH can be found at http://www.nmfs.noaa.gov/habitat/habitatprotection/essentialfishhabitat6.htm.

Aside from the consultation requirements above, NMFS is presently working on the designation of EFH and development of protection measures for each of the fishery management regions in the U.S. NMFS and five regional Fishery Management Councils are preparing new environmental impact statements (EISs) for the EFH components of many fishery management plans. In response to a court order, NMFS will prepare EISs to evaluate the designation of EFH, the identification of Habitat Areas of Particular Concern (HAPCs), and the minimization of the adverse effects of fishing on EFH. In the meantime, NMFS is actively researching gear effects on habitat.

8.2.5 Food webs

The general approach to management of food webs in general and of direct feeding interactions (predator-prey relationships involving the target species) specifically has several facets. First, the *Magnuson Stevens Fishery Conservation and Management Act* defines optimum yield 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". The amount 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 to modify maximum biological yield targets to account for ecological factors such as predator/prey relationships.

Scientific information provided to U.S. Fishery Management Councils includes the SAFE reports (Stock Assessment and Fishery Evaluation), which, according to national standards, should contain the most recent biological condition of the stocks and the marine ecosystems in the fishery management unit. It summarizes, on a periodic basis, the best available scientific information concerning the past, present, and possible future condition of the stocks, marine ecosystems, and fisheries being managed.

8.2.6 Ecosystems

An even broader piece of legislation, the *National Environmental Policy Act* (http://ceq.eh.doe.gov/nepa/regs/nepa/nepaeqia.htm), 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.

8.3 Integration of legislative mandates into an ecosystem approach

Historically, marine research and management under each of these laws has tended to be fairly separate. Although marine fishery managers attempted to meet the requirements of the *National Environmental Policy Act* (NEPA), the production of environmental assessments and impact statements under this law were viewed more as an administrative task than as a useful tool for scientific evaluation and mitigation of ecosystem impacts of fishing.

A key characteristic of recent environmental assessments relating to fisheries is the involvement of a broad range of scientific expertise and the use of NEPA requirements to guide the analysis. Instead of being viewed solely as an administrative burden, the original spirit and intent of NEPA to provide an open, public process to advise decision-makers on alternatives for the protection of the environment is now the essential framework for implementing ecosystem-based fisheries management. Originators of NEPA recommended that implementation be integrated with other planning and environmental review procedures so that all such procedures run concurrently. Thus, this law also provides the means for integrating the disparate requirements and reviews required by other U.S. laws governing specific aspects of the marine environment into a common, overarching ecosystem-based assessment framework.

Historically, NEPA assessments have been constrained mainly to analysis of specific management decisions at the federal fisheries level that are likely to have a significant effect on the environment. Thus, there has been a tendency to focus on the particular decision to be made and its likely effects, *e.g.*, setting of the total allowable catch or a change in a management measure. More recently, these NEPA assessments have been done at a broader policy level, examining the whole suite of fishery management measures and policy goals in a region, which provide a framework for implementing ecosystem-based improvements to the region's fishery management.

Currently, the U.S. Congress is considering legislation for revamping U.S. fisheries law that calls for:

- each of the regional Fishery Management Councils to prepare a report outlining a prioritized list of information and research needs to support ecosystem-based management of the fisheries within its jurisdiction;
- these efforts to be supported by the Secretary of Commerce with additional resources;
- for a process to select a pilot program for ecosystem-based management in one region;
- for concerted efforts to perform research needed to develop the information required;
- for a Fishery Ecosystem Plan to be submitted for approval by the Secretary of Commerce. [Senate Bill 2066, 108th Congress, 2nd Session; http://thomas.loc.gov/cgi-bin/query/C?c109:/temp/~c1086cPgVx]

These provisions follow on the recommendations to Congress made by the Ecosystem Principles Advisory Committee in its 1999 Report to Congress (NMFS EPAP, 1999) that Fishery Ecosystem Plans form the basis for advancing ecosystem-based management in U.S. regional fisheries. In addition they incorporate the experience with the development of a demonstration Fishery Ecosystem Plan for Chesapeake Bay [Chesapeake Fisheries Ecosystem Plan Technical Advisory Panel. 2004. Fisheries Ecosystem Planning for Chesapeake Bay. NOAA Chesapeake Bay Office, Baltimore, MD.].

Details of the present state of implementing ecosystem-based fishery management in the U.S. North Pacific regions of Alaska and West Coast of North America are contained in Appendices 10.3 and 10.4, respectively.

8.4 Scientific issues in implementing ecosystem-based approaches

There are a number of scientific challenges ahead with respect to implementing ecosystem-based fishery management in the United States. These include the need to:

- Improve predictive capability with regard to climate and human impacts on ecosystems: model refinement and regime shift analysis to drive recruitment scenarios;
- Develop a more explicit definition of ecosystem-based management objectives: may require public involvement in defining specific regional objectives for management;
- Develop objective criteria and sensitive indicators to measure the success in achieving desired ecosystem state or condition (or avoidance of undesirable states);
- Develop a more formalized decision-making framework, including standardized tools for objective analysis.

In particular, an important aspect of implementing an information-rich, ecosystem-based approach to fishery management is the development and validation of predictive models that include climate, predator-prey interactions, and habitat and which consider the effects of fishing on the ecosystem. A description and listing of some of the models that have been developed or are under development in the U.S. North Pacific region that might be used to predict effects of fishing on ecosystems are contained in Appendix 10.5.

8.5 References

NMFS Ecosystem Advisory Panel (EPAP). 1999. Ecosystem-based fishery management. A Report to Congress. U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, April 1999, 54 pp.

Pew Oceans Commission. 2003. America's Living Oceans: Charting a Course for Sea Change. Pew Oceans Commission, 2101 Wilson Blvd., Suite 550, Arlington, VA 22201, 144 pp. (http://www.pewoceans.org/oceans/)

U.S. Commission on Ocean Policy. 2004. Preliminary Report of the U.S. Commission on Ocean Policy. Governor's Draft, Washington, D.C., April 2004. 156 pp. (http://www.oceancommission.gov)

9. Discussion and recommendations

In considering the summaries of each country's approach to EBM, it is 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 is, 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 developments were generally much less, with fishing impacts and offshore oil and gas development and transport 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.

Many human activities are documented as affecting 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.*), but 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 has been focused on documenting and addressing fishery impacts. A standardised PICES reporting framework that describes human activity impacts is needed for comparative purposes. Ideally, this format should be robust enough to address the increasing number of environmental and other requirements imposed by legislation, certification schemes, and consumer and community demands. It should also capture ecosystem effects resulting from most human activities, and describe how these ecosystem effects are being monitored. Ecosystem parameters already, or potentially, being monitored may be capturing 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 need to be undertaken to determine these linkages.

The Study Group recommended:

1. **The establishment of a Working Group on *Ecosystem-based management and its application to the North Pacific* (WGEBM) under the direction of the Fishery Science (FIS) and Marine Environmental Quality (MEQ) Committees with a 3-year duration and the following terms of reference:**

Terms of reference with additional information:

1. Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, plus a listing of the ecosystem-based management objectives of each country.

Review and describe in detail existing and anticipated ecosystem-based management objectives and initiatives in PICES member countries and elsewhere globally, and the scientific bases for them (this will be in more detail than is summarized in this report of the Study Group). Common elements, gaps and critical issues will be identified, particularly for areas such as monitoring, in which concerted international (*e.g.,* PICES) efforts might help in the achievement of progress. A standard reporting format, such as the attached Australian outline (Appendix 10.6), would be developed for summarising the approach each country has adopted for all human impacts affecting the marine environment, including fishing.

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.

The most important emerging scientific issues related to EBM appear to be the identification of sensitive ecosystem indicators and development of predictive models that can tell managers how ecosystem state might change in response to human or climate forcing. A major challenge in the achievement of EBM is determining what are the most relevant and cost-effective ecosystem parameters to measure in the monitoring of whether EBM is actually being effectively achieved. The details of such parameters can be expected to be ecosystem-specific, but evaluation is required of whether there are underlying basic parameters that need to be monitored in all systems. Within PICES member countries, efforts would be described that explore science evaluation of potential components of ecosystem monitoring (measurements, indicators). Another key aspect of EBM to be examined would be national efforts to develop predictive models that incorporate human and climate effects and important ecosystem processes (such as predator-prey dynamics). The Working Group could then comment on key gaps in the ecosystem monitoring system of the North Pacific and recommend development of additional models for decision-making.

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 "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES.

The FAO Technical Guidelines for Responsible Fisheries recognise that for ecosystems to be a functional management unit, they need to be geographically-based with ecologically meaningful boundaries. Eco-regions are defined by jurisdictions differently, but are used here with Canada's definition*: "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."* Such ecosystem features often cross national boundaries. The product envisaged here is the listing of criteria for identifying ecological boundaries. Ecologically relevant boundaries are needed to allow scientific evaluation of how EBM objective achievement can be assessed, and to determine what potential components in an ecosystem monitoring and prediction program are most appropriate for the ecosystem being considered. It is important to have a standardised set of terms and vocabulary for defining spatial scales of interest.

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 following scientists are suggested as members of the Working Group based on their experience, qualifications, and active participation to date (key participants are italicised; recommended Co-Chairman is marked by *):

<u>Canada</u>:
*Glen Jamieson**, Robert O'Boyle, Ian Perry,

<u>Japan</u>:
Tokio Wada

<u>People's Republic of China</u>:
Xian-Shi Jin, Wei Hao

<u>Republic of Korea</u>:
Jae-Bong Lee, Inja Yeon, *Chang-Ik Zhang**

<u>Russia</u>:
Vladimir Radchenko

<u>U.S.A</u>:
*Patricia Livingston**, Christopher Harvey

2. The convening of a joint FIS/MEQ Topic Session at the PICES Fourteenth Annual Meeting (October 2005, Vladivostok, Russia) on "Ecosystem indicators and models".

Draft description of proposed Topic Session:
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 will bring 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.

Suggested co-convenors:
Glen Jamieson (Canada), Tokio Wada (Japan), Xian-Shi Jin (People's Republic of China), Chang-Ik Zhang (Republic of Korea), Vladimir Radchenko (Russia), Patricia Livingston (U.S.A.).

10. Appendices

Appendix 10.1 Study group membership and participants

A. Membership of the Study Group on *Ecosystem-based management and its application to the North Pacific*

Canada

Glen Jamieson (Co-Chairman)
Pacific Biological Station
Fisheries & Oceans Canada
3190 Hammond Bay Road
Nanaimo, British Columbia
Canada. V9T 6N7
Phone: (1-250) 756-7223
Fax: (1-250) 756-7138
E-mail: JamiesonG@pac.dfo-mpo.gc.ca

Robert O'Boyle
Bedford Institute of Oceanography
Fisheries & Oceans Canada
1 Challenger Drive
Dartmouth, Nova Scotia
Canada. B2Y 4A2
Phone: (1-902) 426.3526
Fax: (1-902) 426.5435
E-mail: oboyler@mar.dfo-mpo.gc.ca

Japan

Hideaki Nakata
Faculty of Fisheries
Nagasaki University
1-14 Bunkyo-cho
Nagasaki
Japan. 852-8521
Phone: (81-95) 819-2816
Fax: (81-95) 819-2799
E-mail: nakata@net.nagasaki-u.ac.jp

Tokio Wada
National Res. Inst. Far Seas Fisheries
Fisheries Research Agency
Shimizu-Orido 5-7-1
Shizuoka
Japan. 424-8633
Phone: (81) 543-36-6011
Fax: (81) 543-35-9642
E-mail: wadat@affrc.go.jp

People's Republic of China

Xian-Shi Jin
Yellow Sea Fisheries Research Institute
106 Nanjing Road
Qingdao, Shandong
People's Republic of China. 266071
Phone: (86-532) 584-9430
Fax: (86-532) 581-1514
E-mail: jin@ysfri.ac.cn

Ling Tong
Yellow Sea Fisheries Research Institute
106 Nanjing Road
Qingdao, Shandong
People's Republic of China. 266071
Phone: (86-532) 584-8631
Fax: (86-532) 581-1514
E-mail: tongling@ysfri.ac.cn

Quan Wen
National Mar. Environmental Monitoring Center
42 Linhe Street, Shahekou District
Dalian, Liaoning
People's Republic of China. 116023
Phone: (86-411) 478-2522
Fax: (86-411) 478-3277
E-mail: qwen@nmemc.gov.cn

Xian-Yong Zhao
Yellow Sea Fisheries Research Institute
106 Nanjing Road
Qingdao, Shandong
People's Republic of China. 266071
Phone: (86-532) 583-6344
Fax: (86-532) 581-1514
E-mail: zhaoxy@ysfri.ac.cn

Republic of Korea

Jae-Bong Lee
Fisheries Research & Management Division
National Fisheries Res. & Development Institute
408-1, Shirang-ri, Gijang-up, Gijang-gun Jung-Gu
Busan
Republic of Korea. 619-902
Phone: (82-51) 720-2296
Fax: (82-51) 720-2277
E-mail: leejb@nfrdi.re.kr

In-Ja Yeon
Fisheries Research & Management Division
National Fisheries Res. & Development Institute
408-1, Shirang-ri, Gijang-up, Gijang-gun Jung-Gu
Busan
Republic of Korea. 619-902
Phone: (82-51) 720-2290
Fax: (82-51) 720-2277
E-mail: ijyeon@nfrdi.re.kr

Chang-Ik Zhang (Co-Chairman)
Marine Production Management Department
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan
Republic of Korea. 608-737
Phone: (82-51) 620-6124
Fax: (82-51) 622-3306
E-mail: cizhang@pknu.ac.kr

Russia

Alexei Yu. Merzlyakov
Pacific Fisheries Research Center
4 Shevchenko Alley
Vladivostok
Russia. 690950
Phone: (7-4232) 401-504
Fax: (7-4232) 300 752
E-mail: interdept@tinro.ru

United States of America

David L. Fluharty
School of Marine Affairs
University of Washington
3707 Brooklyn Ave. N.E.
Seattle, WA
U.S.A. 98105
Phone: (1-206) 685-2518
Fax: (1-206) 543-1417
E-mail: fluharty@u.washington.edu

Christopher James Harvey
Northwest Fisheries Science Center
National Marine Fisheries Service
2725 Montlake Blvd. E.
Seattle, WA
U.S.A. 98112
Phone: (1-206) 860-3228
E-mail: Chris.Harvey@noaa.gov

Selina Heppell
Department of Fisheries and Wildlife
Oregon State University
104 Nash Hall
Corvallis, OR
U.S.A. 97331
Phone: (1-541) 754-4853
E-mail: Selina.Heppell@orst.edu

Patricia Livingston
Alaska Fisheries Science Center
National Marine Fisheries Service
7600 Sand Point Way N.E.
Seattle, WA
U.S.A. 98115-6349
Phone: (1-206) 526-4242
Fax: (1-206) 526-6723
E-mail: Pat.Livingston@noaa.gov

B. Participants of the Study Group meeting at PICES XIII (October 14, 2004, Honolulu)

Participant	Country	Study Group membership
Glen Jamieson*	Canada	Yes
Wei Hao	People's Republic of China	No
Ik Kyo Chung	Republic of Korea	No
Suam Kim	Republic of Korea	No
Jae Bong Lee*	Republic of Korea	Yes
Inja Yeon	Republic of Korea	Yes
Chang Ik Zhang	Republic of Korea	Yes
Elena Dulepova	Russia	No
Oleg Katugin*	Russia	No
Olga Lukyakova	Russia	No
Oleg Zolotov	Russia	No
Christopher Harvey*	U.S.A.	Yes
Patricia Livingston*	U.S.A.	Yes
John Stein	U.S.A.	No

*Presenters of national reports

Appendix 10.2 Terminology definitions

The ecosystem literature is rich with definitions and terms. The Canadian National Workshop on "Objectives and indicators for ecosystem-based management" (Feb. 27 – Mar. 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 3.4). 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)
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).

Appendix 10.3 Present state of implementing ecosystem-based fishery management in Alaska: Alaska groundfish fisheries

10.3.1 Regulatory legislation, documents, and actions

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 (FMPs): the Bering Sea/Aleutian Islands Groundfish FMP (http://www.fakr.noaa.gov/npfmc/fmp/bsai/bsai.htm) and the GOA Groundfish FMP (http://www.fakr.noaa.gov/npfmc/fmp/goa/goa.htm).

Acceptable biological catch (ABC) and total allowable catch (TAC) levels are prescribed for a number of species in the BSAI and GOA management regions, although some may not necessarily be a target species of groundfish fisheries. The final specifications for the 2003 fisheries on these species, which include 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/npfmc/CouncilBSAIFinal03.pdf and http://www.fakr.noaa.gov/npfmc/GOAABC03CouncilFinal.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 (includes sculpins, skates, sharks, and octopus).

Catch limits are prescribed for the following species/groups in the GOA: walleye pollock, Pacific cod, deep-water flatfish (Dover sole, Greenland turbot, and deep-sea sole), rex sole, shallow-water flatfish (northern rock sole, southern rock sole, yellowfin sole, starry flounder, butter sole, English sole, Alaska plaice, and sand sole), flathead sole, arrowtooth flounder, sablefish, other slope rockfish (sharpchin, redstripe, harlequin, silvergrey, yellowmouth, and redbanded rockfish are the dominant species), northern rockfish, Pacific ocean perch, shortraker/rougheye rockfish, pelagic shelf rockfish (predominantly light dusky rockfish), demersal shelf rockfish (predominantly yelloweye rockfish), Atka mackerel, thornyhead rockfish, and an "other species" group (includes sculpins, skates, sharks, squid, and octopus).

The North Pacific Fishery Management Council has developed several programs to address over-capacity in the Alaskan fisheries. For most groundfish, management programs limit the number of harvesting vessels that may be deployed off Alaska. The License Limitation Program for groundfish and crab vessels was implemented on January 1, 2000, and replaced the moratorium placed on new vessel entry into federal groundfish fisheries in Alaska implemented in 1996. Halibut and fixed gear sablefish fisheries are managed under an Individual Fishing Quota (IFQ) program, which, rather than limiting harvesting vessels, grants Quota Share holders the privilege of harvesting a specified percentage of the Total Allowable Catch (TAC) each year. There also exists a Community Development Quota (CDQ) program that allocates a percentage of all BSAI groundfish quotas to eligible communities. The purpose of the program is to provide the means for starting or supporting commercial fisheries business activities that will result in an ongoing, regionally-based, fisheries-related economic activity in coastal Native communities of western Alaska.

Congress, too, has provided statutory tools to help relieve over-capitalization. The *American Fisheries Act* (AFA) retires and limits harvesting vessels, authorizes harvesting cooperatives to which a portion of the total allowable catch of BSAI pollock is granted, prevents pollock fishery participants from expanding historical activities to other fisheries, and stabilizes deliveries to shoreside processors.

The other groundfish fisheries not managed by IFQ or cooperative, are managed primarily through TACs and a variety of vessel/gear restrictions specific to each fishery. For example, Pacific cod TACs are allocated to fixed proportions of certain gear types (pot, longline, trawl). Bottom trawls are banned for the BSAI walleye pollock fishery.

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

10.3.2 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 North Pacific Fishery Management Council and are less than or equal to the ABCs set by stock assessment scientists, which are in turn less than defined overfishing levels (OFL). The following document summarizes the tier system for setting groundfish ABCs and also includes life history parameters for the managed stocks in the BSAI region: http://www.fakr.noaa.gov/npfmc/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 that are on the Groundfish Plan Teams of the North Pacific Fishery Management Council. 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 North Pacific Fishery Management Council.

In general, pollock and cod are dominant target species in the BSAI and are fairly productive on the r-K spectrum. Pollock is a mid-trophic level species that is also a key prey of many groundfish, birds, and marine mammals in the region. Atka mackerel, the dominant target in the Aleutian Islands, is also a relatively productive, primarily planktivorous species that is also preyed upon by groundfish and marine mammals in that region. Cod have a very diverse diet, consisting of a broad mixture of benthic invertebrates including commercially important crab, and also fish such as walleye pollock and flatfish. Other species such as rockfish are very long-lived, viviparous, primarily planktivorous species. Flatfish species are somewhat intermediate in the r-K spectrum, tending to be longer-lived than pollock and cod. Some flatfish such as yellowfin sole and rock sole feed on benthic infauna while other flatfish such as Greenland turbot and arrowtooth flounder are very piscivorous.

Recruitment variability of some of these species is summarized by Hollowed *et al.* (2001). Flatfish species such as Greenland turbot, arrowtooth flounder, rock sole, and yellowfin sole, tend to have recruitment time series that have high autocorrelation with strong decadal-scale patterns while the gadids (pollock and cod) tend to have large inter-annual variability in recruitment.

Control rules, recovery rules and targets are contained in a more detailed description on pages 2.7-71 through 2.7-93 of the January 2001 Draft Programmatic Supplemental Environmental Impact Statement on Alaska Groundfish Fisheries (http://www.fakr.noaa.gov/sustainablefisheries/seis/intro.htm). In general, OFL is a limit reference point and ABC is used as a target reference point. A minimum stock size threshold (MSST) is also defined. If a stock falls below this level it is considered overfished (although a stock could fall below the threshold without being fished) and a rebuilding plan is developed. ABCs are derived for various stocks using a tier system that establishes maximum allowable fishing rates depending on the amount of information available for the stock. The tier system is configured such that max ABC is always less than OFL except at very low stock sizes (where both maxABC and OFL are zero). The FMPs require that ABC be set between zero and maxABC. One of the central features of Tiers 1-3 is that Fofl and MaxFabc decreases linearly with biomass whenever biomass falls below a tier-specific reference level. Most individual stocks are currently managed under Tier 3, where max Fabc equals F40% if biomass is above B40%. In Tier 1 (but not in any other tier), greater statistical uncertainty automatically results in a lower max ABC. This adjustment implies a fixed level of risk aversion and is computed using the statistical uncertainty surrounding both the estimate of the projected stock size and the estimate of Fmsy. In the 2002 harvest season for the BSAI, only one stock (walleye pollock) was in Tier 1, ten were in Tier 3, eight were Tier 5, and two were in Tier 6 of our tier system. Our Tier 6 appears to correspond to Tier 5 in Appendix 2 of the Australian Best Practice Reference Points. At present, there are no Alaskan groundfish stocks that are considered overfished although we are unable to determine this for stocks that are below our Tier 3. In Alaska, there is a detailed in-season management program that tracks catch amounts of all groundfish species that have TACs (including bycatches in groundfish fisheries that are not targeting that species and which may discard those) and closes fisheries to ensure that TACs are not exceeded. The Observer Program is an important part of TAC monitoring. Some target groundfish fisheries may not achieve their TAC allocations because the TAC of another species that is bycatch in their fishery has been reached. Bycatch (discards) of target groundfish species amounted to about 6% of the total groundfish catch in 2001, a rate that is not exceptional compared to other major fisheries in the world.

This tier system places a buffer between the overfishing levels and the annual ABC. Stocks in Tiers 1-3 include an additional precaution by decreasing fishing mortality rates for stocks that fall below the MSY level. Tier 1 stocks include further precaution by reducing the target fishing mortality rate in direct relation to the level of uncertainty regarding the stock's productive capacity. However, very few stocks have sufficient information to be in Tier 1. Some stocks are still managed as a complex of species, which may not ensure the most optimum management of the lesser abundant stocks in the complex. The lack of sufficient information to estimate MSST for some stocks is also problematic. Harvest rates used to establish ABCs are reduced at low stock size levels, thereby allowing depleted stocks to rebuild rapidly. If the biomass of any stock falls below Bmsy or B40% (the long term average biomass that would be expected under average recruitment and F=F40%), the fishing mortality is reduced relative to stock status. This serves as an implicit rebuilding plan should a stock fall below a reasonable abundance level. Specific consideration of genetic biodiversity in the retained species has not been made in the management measures although the present system of temporal/spatial allocations of TAC may provide protection in this regard. Evaluation of the effects of fishing on genetic diversity of the target species has been made in the draft *Programmatic Environmental Impact Statement for Alaskan Groundfish Fisheries*, which used MSST as a threshold to evaluate these impacts. Further detailed review of single species harvest strategies (from a single species and ecosystem point of view) can be found in an independent panel analysis provided to the North Pacific Fishery Management Council (http://www.fakr.noaa.gov/npfmc/Reports/f40review1102.pdf).

10.3.3 Bycatch species

There are several facets of bycatch management in Alaska groundfish fisheries depending on the type of bycatch. There is 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 are under development that include target and non-target species.

For bycatch of non-target species, there is a special category called prohibited species that is managed. In the eastern Bering Sea, 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/Reports/bycpaper.htm. There are many time/area closures, gear restrictions, seasonal TAC apportionments designed to reduce bycatch of prohibited species. One benefit of IFQ fisheries (sablefish) is reduced catch of prohibited species. There is a detailed reporting and accounting system, that includes at-sea observers, that provides estimates of total catch and discard mortality for prohibited species in 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 MSSTs). Some western Alaska salmon stocks are depressed and 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.

Bycatch 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 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 broken out 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. A TAC for other species in the GOA is set at 5% of the sum of target species TACs each year. It is possible under current “other species” management that a species, or even a species group, could be disproportionately exploited while the overall aggregate other species TAC is not reached. This potential is a concern because the “other species” category includes groups with extremely diverse habitats and life history strategies. In addition, data limitations plague different groups within this category. The lack of biomass estimates for cephalopods has been a source of difficulty for determining stock status relative to bycatch and the lack of adequate species identification in the catch data hampers the analysis of catch trends for skate and sculpin species. In the current FMP tier system for setting acceptable biological catch, these species groups are in the lowest tiers, which set allowable catch equal to average bycatch or biomass times 75% of the natural mortality rates. It is difficult to determine how much protection is afforded by a TAC set with the use of these data-poor criteria, although it is likely to be better than unrestricted catch. Discussions are underway for improving the management of these groups through improved detail in the catch reporting, *etc*. In the meantime, a directed fishery for skate species in the GOA has started, which may spur additional management action. Survey estimates for most of these species do not indicate worrisome trends, however, sharks and cephalopods are not well-estimated in surveys, so their population trends are not well-known. Because of the vulnerable nature of some of the species in this group, the present system of TAC setting for the aggregate may not provide sufficient protection.

A group of invertebrate species called HAPC (habitat areas of special concern) biota has been defined. This group of species 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. Various proposals for management of this species group have been made, including prohibition of commercial sale and harvesting of corals and sponges. However, action is pending. Bottom trawl surveys, which provide an index of abundance of sea pens/whips and anemones, do not indicate problems with those groups. Though, corals and sponges are not well-sampled by trawls and their distribution and status is not well-known. An environmental impact statement (EIS) is being prepared to provide alternatives for protection of essential fish habitat, and protection may be provided for these HAPC biota, depending on the alternative chose. Monitoring of catch amounts and biomass amounts of these species is occurring, and development of an EIS is nearly complete.

Finally, there is a group of non-specified species that are bycatch in groundfish fisheries. These include a huge diversity of fish and invertebrate species. There is currently no management and some catch monitoring of species in this category, although retention of any non-specified species is permitted. The complete lack of reporting requirements may be problematic. For example, bycatch of grenadiers, a non-specified species group, is higher in the GOA than the catch of all species in the "other species" category combined. Grenadiers are long-lived species that may be vulnerable to fishing; however, they are afforded no protection within the existing non-specified species category. An *ad hoc* committee, consisting of federal and council scientists and regional fishery managers, is discussing a framework system for identifying and protecting vulnerable species in the bycatch (including target, other, and non-specified). However, meetings are ongoing and a final plan has not yet been completed. Research is continuing to identify population trends in non-commercial species relative to fishing and climate but the effects of fishing on these species are not well-known. Species identification is very detailed for fish species in research surveys of the area but not very detailed for non-commercial invertebrates. Design of effective management measures to reduce bycatch will require additional economical and socio-cultural information.

10.3.4 Threatened or protected species

A number of threatened or endangered species or habitats for these species occur in Alaskan waters and these species are afforded protection under the *Endangered Species Act*. The species include some marine mammals, seabirds, and fish. The full list is available at http://www.fakr.noaa.gov/protectedresources/esaakspecies.pdf. Other marine mammal species are also afforded protection under the *Marine Mammal Protection Act*. 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 protection Steller sea lion and short-tailed albatross. Measures are in place to protect Steller sea lions in near-shore 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 biomass reaches B20%, 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 (4 takes within 2 years) that will trigger consultation. In addition, seabird avoidance measures for fishing vessels have been mandated.

Level of information and uncertainty is approximately Tier 5: 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 decline.

Status of Steller sea lion 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 status of the stock of concern, relate to the stocks' productivity, and provide a sufficient trigger for management intervention. The qualitative nature of determining the degree of species protection provided, due to area closures, and prey species harvest control rules, when indirect interactions are the concern, is problematic and uncertain. Considerable work needs to be done to determine more quantitative standards for reference points dealing with fishery potential to jeopardize continued existence or adversely modify 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 EIS and a Biological Opinion. The EIS recently won a national award because of the open public process that was employed, including the use of a unique stakeholder constituent committee to develop the alternatives.

No consideration has been given to community biodiversity, except through protection of the individual species (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.

10.3.5 Habitats

Habitat management for Alaska groundfish fisheries includes the consultation process mentioned above and the development of an 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 of these measures in http://www.fakr.noaa.gov/npfmc/Reports/efhjdc.pdf). An unusually productive and fragile area called the Sitka Pinnacles Marine Reserve has been designated. This habitat is known to contain higher diversity of species than surrounding areas. Habitat assessment reports were developed for

EFH of all managed species in Alaska (http://www.fakr.noaa.gov/habitat/efh_har).

The BSAI and GOA groundfish management regions encompass a variety of habitat types. The Bering Sea shelf consists primarily of sand, mixed sand and mud, and mud substrates and an outer continental shelf. The Gulf of Alaska has shallow, deep and slope areas which 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 seapens/whips and anemones; not much is known of recovery rates of these organisms. Of the infauna in the regions, larger, longer-lived organisms include clams. Smaller, higher turnover rate organisms such as polychaetes also occur throughout the region but little effort has been expended in mapping these distributions after U.S. surveys 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 NMFS if that agency's actions may adversely effect EFH and for NMFS to provide conservation recommendations if deemed necessary. For details on the consultation process see http://www.nmfs.noaa.gov/habitat/efh/Consultation/1_0.htm1#nmfs.

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 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 which 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.

10.3.6 Food webs

The *Magnuson-Stevens Fishery Conservation and Management Act* allows the modification of a target species biological yield estimates to be modified to an optimum yield (OY) that takes into account the protection of marine ecosystems; 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 Bering Sea, the maximum OY is capped at 2 million metric tons 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 Bering Sea 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 SAFE document of Alaska groundfish fisheries includes an Ecosystem Considerations Chapter 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 multi-species 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 previously, the NPFMC has also designated a "forage fish" category that consists of relative fast turnover rate forage species such as gunnels, bathylagids, gonostomatidae, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. A maximum retainable bycatch rate (MRB) 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. Measures are in place to protect Steller sea lion foraging in near-shore 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 biomass reaches B20%, 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 pollock in the EBS and GOA have been developed that include predation by other species, including target groundfish. A multi-species VPA model has also been developed for the EBS. The MSVPA showed that most predation mortality on target species tends to occur on juveniles. 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 Chapter of the SAFE at http://www.afsc.noaa.gov/refm/docs/2002/ecochap.pdf).

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

Aside from the Steller sea lion prey protection rules mentioned above (B20% lower threshold for pollock, cod, and Atka mackerel biomass and closed areas in sea lion foraging areas), the forage species maximum retainable bycatch rules, and stock assessment scientist consideration 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.

Level of information available to parameterize models of groundfish predator/prey dynamics is relatively good – MSVPA has been developed for EBS and statistical catch-at-age models that include predators have 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.

Multi-species reference points have not been defined for this system and for cannibalistic species such as walleye pollock and Pacific cod, such reference point may result in Fmsy estimates that are higher than in the single species case. Pollock, cod, and Atka mackerel are above the B20% value established for Steller sea lions and MRBs of forage species have not been exceeded. The 2 million 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 t, which is 1.3 million t 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 Chapter of the SAFE (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, birds, and marine mammals.

There are no planned management responses that consider the food web except the inclusion of ecosystem information in the Ecosystem Considerations Chapter of the SAFE 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 the *National Environmental Protection Act* (NEPA) to evaluate ecological effects of human activities (Table 10.3.1). Environmental impact statements are being prepared that evaluate fishing effects on these ecosystems. 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

Table 10.3.1 Significance thresholds for fishery induced effects on ecosystem attributes.

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 trends of 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 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 non-native species	Fishery vessel ballast water and hull fouling organism exchange levels high enough to cause viable introduction of one or more non-native 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)

Issue	Effect	Significance Threshold	Indicators
	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, nontarget) 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

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 particular organisms, groups, or ecosystem attributes are changing in an undesirable direction (Table 10.3.1).

Level of information presently being used in this evaluation is mainly Tier 5 – understanding and data is 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.

Strengths/limits of general food web reference points: 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.

10.3.7 Physical environment

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 and State of Alaska have responsibility primarily 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 and have “total maximum daily load” (TMDL) plans required 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 the following web link for more details on environmental protection in Alaska: http://yosemite.epa.gov/R10/Homepage.NSF/webpage/Alaska's+Environment?opendocument.

Also, fishery managers are not directly involved in managing activities that might be root causes of global warming, although there is potential for this warming to have significant impacts on fish production in Alaska. Environmental impact analyses of the effects of fishing on the environment also consider the effects of fishing on the physical environment through water pollution.

10.3.8 References

Aydin, K.Y., Lapko, V.V., Radchenko, V.I. and Livingston, P.A. 2002. A comparison of the eastern Bering and western Bering Sea shelf and slope ecosystems through the use of mass-balance food web models. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-AFSC-130. 78 pp.

Hollowed, A.B., Hare, S.R. and Wooster, W.S. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. Prog. Oceanogr. 49: 257-282.

Appendix 10.4 Present state of implementing ecosystem-based fishery management off the West Coast of the United States: Pacific Coast groundfish fisheries

10.4.1 Regulatory legislation, documents, and actions

The federally-managed groundfish fishery off the states of California, Oregon and Washington occurs on the shelf and slope areas in the U.S. EEZ. The fishery is managed by the Pacific Fishery Management Council (PFMC; http://www.pcouncil.org) under the *Pacific Coast Groundfish Fishery Management Plan* (http://www.pcouncil.org/groundfish/gffmp/fmpthru17.pdf), with catch levels proposed in the *Groundfish Environmental Impact Statement* (Groundfish EIS; http://www.pcouncil.org/groundfish/gfspex/gfspex03.html). In-season adjustments are often recommended by the PFMC (http://www.pcouncil.org/groundfish/gfins.html) and must then be approved by NMFS (see http://www.nwr.noaa.gov/1press/sfdpress.htm, or in greater detail at http://www.nwr.noaa.gov/1sustfsh/groundfish/gfmgmt.htm). Management measures are generally adopted biennially; that is, every two years, the PFMC and NMFS convene to update and adjust policies that are currently in place.

The Pacific Coast groundfish fishery has limited entry, open access, recreational, and tribal components. Most harvest is allocated to the limited entry permit fishery, comprised of separately regulated trawl and fixed-gear fleets, with the majority of landings coming from trawlers. The open access commercial fishery may not use trawl gear directed at groundfish harvest. Harvests are currently managed by 2-month cumulative trip limits and seasonal or annual quotas, although there is ongoing debate about transitioning to an individual fishing quota (IFQ) system.

Several management tools have been used by the PFMC, NMFS, and Congress in order to regulate groundfish harvest, lower bycatch, and reduce the probability of overfishing along the Pacific Coast. The first notable example is the regular use of time/space closures. Such closures can be enacted when certain species reach defined quotas in a season or year. Recently there have also been several large-scale closures throughout the EEZ, often referred to as Groundfish Conservation Areas (GCAs). These areas are large and complexly shaped polygons defined by many waypoints in order to cover the appropriate depth strata. Examples include the large Rockfish Conservation Area (RCA) designed to protect bocaccio, canary rockfish, darkblotched rockfish, and Pacific ocean perch off the Pacific Coast; the Cowcod Conservation Area (CCA) 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 (VMS) to track the movement of fishing vessels through closed areas.

A second management tool is restricted size of footropes on shelf trawls. Rollers on footropes may be no greater than 8 inches in diameter, which essentially prevents fishing in rocky habitats. 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 also to increase financial stability among the fishing community. It ultimately funded the buyout of 92 vessels and 92 groundfish permits.

The Observer Program for the Pacific Coast groundfish fishery (http://www.nwfsc.noaa.gov/research/divisions/fram/Observer/) provides data critical in the conservation and management of groundfish, non-target species, and habitat. Concerning bycatch issues, observer data are used to study patterns of co-occurrence among target and bycatch species, to identify gear-specific bycatch and discard activity, and to note changes in fishing behavior as vessels approach 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 (*i.e.*, vessels that fish hake and deliver their catch to at-sea processing vessels). These boats receive 100% observer coverage. Some further observation effort is implemented into fixed gear fisheries and for special projects.

10.4.2 Retained species

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 overfishing (OFL) levels. Alternative ABCs, optimum yields (OY) and TACs for the fishery are prescribed in Chapter 2 of the *Groundfish Environmental Impact Statement* (Groundfish EIS; http://www.pcouncil.org/groundfish/gfspex/gfspex03.html). The alternatives are offered because there are multiple goals of fishery management that may be at odds; chief among these potentially conflicting goals are the desire to maximize the economic value of the fishery and the need to rebuild depleted stocks that often co-occur with healthy target species. Federal fishery scientists are, in general, responsible for deriving ABC and OFL estimates that are then reviewed by a panel of federal, state, and tribal scientists that are on the Groundfish Management Team of the PFMC. These ABCs and OFLs are then presented to the Council's Science and Statistical Committee for review. The Committee then makes the ABC and OFL recommendations to the PFMC.

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. Routine restrictions are in place for all groundfish caught by open access or recreational fisheries. The PFMC can recommend, and NMFS can implement, management actions beyond the scope of the routine actions in order to address arising conservation or socio-economic concerns.

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); 6 roundfish (lingcod, cabezon, kelp greenling, Pacific cod, Pacific whiting (hake) and sablefish); 1 morid (finescale codling); 1 grenadier (Pacific rattail); and 7 elasmobranchs (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 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. Flatfish vary broadly in terms of life span and size-specific fecundity. Sablefish have longer generation times than hake and episodic year class strength that appears strongly related to climate conditions. Rockfish are potentially subject to depletion due to fishing, with varying degrees of generation times often measured in decades; for example, overfished rockfishes have generation times ranging from 14 years (bocaccio) to 44 years (yelloweye). In general, rockfish (particularly large-bodied species) are slow to mature. They are generally live-bearing fish with very high fecundities, but survival of larvae is very poor and episodic.

Rockfishes occupy a broad range of trophic roles, owing to their species diversity, size diversity, and habitat diversity. Their diets range from gelatinous zooplankton to piscivory, with euphausiids being almost universally important. Larval, juvenile, and smaller adult rockfish provide food for other groundfish, albacore, marine mammals, sharks, and birds. 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. Sablefish diets include fishes, cephalopods and benthic invertebrates. Young sablefish provide food for seabirds, fishes (including lingcod), and marine mammals. Juvenile and adult flatfishes 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. These surveys provide data on spatial distributions, habitat-specific abundances, and age structure of groundfish populations in trawlable habitats. NMFS 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 mid-water trawl sets are done to monitor hake, which inhabit mid-water regions. Data from these surveys and from the fishery are incorporated into formal stock assessment analyses (described in http://www.pcouncil.org/groundfish/gfspex/gfspex03.html, Section 3.4.2). A compilation of Stock Assessment and Fishery Evaluation (SAFE) documents for Pacific Coast groundfish from 2001 to present is available at http://www.pcouncil.org/groundfish/gfsafe.html. 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, the current plan for stock assessments through the 2007-2008 biennium will include 23 species, prioritized according to population status and importance to the fishery.

For the purposes of management, a species in this FMP is designated at "precautionary status" if its spawning stock biomass (SSB; the biomass of mature females) falls below 40% of the estimated unfished biomass. Species in this category currently include Dover sole, sablefish, and shortspine thornyhead (these three species are collectively referred to as the DTS complex). More drastically, a species is considered "overfished" if its SSB is below 25% of the estimated unfished biomass. Under that criterion, the following species are considered overfished: bocaccio, canary rockfish, cowcod, darkblotched rockfish, lingcod, Pacific ocean perch, widow rockfish, and yelloweye rockfish (Pacific hake were declared overfished in 2002, but the 2004 stock assessment indicates that they are above the 40% threshold). 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 five of the overfished species (bocaccio, canary rockfish, cowcod, lingcod, and yelloweye rockfish); owing to the long generation times and low productivity of rockfish species, target biomasses for the four rockfish listed here are not expected to be achieved before 2021 (bocaccio) to 2095 (cowcod). Other species listed in FMP are considered either at target level, above target level, or have insufficient information to assess their populations.

10.4.3 Bycatch species

A draft of the NMFS bycatch mitigation EIS for the Pacific Coast groundfish fishery is available at http://www.nwr.noaa.gov/1sustfsh/groundfish/eis_efh/pseis/DPEIS/. This document goes into considerable detail about many of the species listed in both this section and the subsequent "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 total fleet size, fishing times, or trip 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 EIS.

Non-target species are often incidentally caught in groundfish gear in the Pacific Coast fishery. 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, particularly Pacific hake. Although this bycatch is recognized as unavoidable, the PFMC and NMFS attempt to restrict it by setting low quotas for these species and monitoring those catches in season through the Observer Program. Meeting or exceeding these 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 FMP, unless as affected by effort reallocation because of the vessel buyback or general decreases in groundfishing opportunities.

CPS (*e.g.*, squid, sardine, anchovy, mackerel) are often caught in the Pacific hake fishery, which is a mid-water trawl fishery, but in much lower numbers in gears associated with the bottom. Bycatch in the hake fishery can be large; for example, over 80 metric tons of squid were caught in the 2001 at-sea hake fishery. The Groundfish FMP and the Groundfish EIS require that these species' status be considered in terms of impact. For that reason, take of these species is monitored, although any decisions would 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 may be strongly driven by interactions with climate regimes (Chavez *et al*., 2003) as well as by fishing.

There is a special category of non-targeted 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 immediately be 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 most 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 probably 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.

Many species receive additional protection under the ESA and MMPA, namely marine mammals, sea birds, and sea turtles, although information on interactions between groundfish fisheries and these species is limited by relatively scant observer coverage in all but the hake fishery. ESA-listed species that may be affected by groundfish harvest include certain stocks of Pacific salmon (covered above in the prohibited species section) and four species of sea turtles, namely the loggerhead, leatherback, green, and olive ridley. Turtles may occasionally by injured or killed by interactions with groundfishing boats (direct harvest mortality, collisions with boats, or pollution), but such incidents are very rare, especially compared to the mortality inflicted on turtles by other fisheries, such as longline fisheries. Incidental take of marine mammals and sea birds is rare, according to observer data, but these animals certainly interact with groundfish boats by scavenging discard.

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. This concern is especially acute because trawling effort in the deeper waters has increased following the establishment of the large-scale RCAs on the continental shelf. Although the overall decrease in trawling effort brought on by the vessel/permit buyback will mitigate the effort shift to some extent, 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 pending development of an *Essential Fish Habitat Environmental Impact Statement* (EFH EIS), however, these issues will be addressed. Additionally, in the standard fishery-independent trawl surveys of groundfish abundance conducted annually by NMFS, biologists are now recording data on benthic invertebrates, although these data are essentially limited to presence/absence of species.

Many other species are bycatch in groundfish fisheries. These include a huge diversity of fish and invertebrate species, including some of commercial value, that are managed at state or federal levels in other FMPs (*e.g.*, California halibut, shrimp, crab, sea cucumber). There is currently no management and some catch monitoring of species in this category, although retention of any non-specified species is permitted. The impacts of different management alternatives on species such as shrimp, elasmobranchs, bony fishes, and other species not directly covered by the FMP are discussed in the groundfish draft Programmatic EIS (available at http://www.nwr.noaa.gov/1sustfsh/groundfish/eis_efh/pseis/DPEIS/). Development of effective management measures to reduce bycatch will require additional economical and socio-cultural information.

10.4.4 Threatened or protected species

In addition to the prohibited species noted in the previous section, there are several threatened and protected species in the EEZ off of 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 *Migratory Bird Treaty Act* (MBTA), and Executive Order 13186). Further protection for some of these species is outlined in the *Magnuson-Stevens Act*.

A number of threatened or endangered species or habitats for these species occur in Pacific Coast EEZ waters, and these species are afforded protection under the Endangered Species Act. The species, and their ESA designations, include Pacific salmon (numerous threatened and endangered stocks in California, Oregon, and Washington), 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). Marine mammal species not listed are either not threatened or endangered or, they have not been recorded in Pacific Coast EEZ waters. The 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 harvest.

Take of Pacific salmon was discussed above in the Bycatch section; 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).

No directed harvest may occur on any marine mammal, regardless of their threatened or endangered status, because of protections afforded by the *Marine Mammal Protection Act*. The MMPA further establishes management for cetaceans and pinnipeds (by NMFS) and sea otters (by the 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 on. However, the Pacific Coast groundfish fishery is considered a relatively low-risk fishery in this context.

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 porpoise/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. The judgment of the PFMC is that groundfish harvest in this region has little overall impact on marine mammals compared to other human activities.

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 the United States Canada, Russia, Japan and Mexico that forbids the killing, taking, or possessing of a migratory bird. Executive Order 13186 mandates agencies to work with the Fish and Wildlife Service to establish Terms of Understanding about the impact of human activities upon migratory birds; NMFS and the FWS are currently developing such Terms for migratory birds. Finally, the *Magnuson-Stevens Act* requires compliance among NMFS-enforced fisheries management actions and all legislation designed to protect seabirds.

As with marine mammals, direct impacts of groundfishing on birds appear to be minimal, whereas indirect 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 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.

10.4.5 Habitats

EFH for Pacific Coast groundfish is defined generally as the aquatic habitat necessary to allow for groundfish production to support long-term sustainable fisheries for groundfish, and for groundfish contributions to a healthy ecosystem. To satisfy this description, EFH must be described for all life history stages of managed species. EFH descriptions have been incorporated into the groundfish FMP in both Section 11.10 and in a detailed appendix (http://www.nwr.noaa.gov/1sustfsh/efhappendix/page1.html). West Coast groundfish species managed by the groundfish FMP occur throughout the EEZ and occupy diverse habitat types at all stages in their life histories, as listed in the appendix. EFH for any one species may be large (*e.g.*, if a species' pelagic eggs and larvae are widely dispersed) or comparatively small (*e.g.*, nearshore rockfishes which show strong affinities to a particular location or type of substrate).

Most commercial groundfish harvest occurs through mid-water or bottom trawling, with lesser amounts conducted via fixed gears (traps and pots) and longlines. Bottom trawling is effectively limited to areas with soft sediments because of restrictions on the diameter of trawl footropes. The small rollers allowed on bottom trawls means that fisheries are unlikely to fish around rocky bottoms to avoid gear damage. This means that rocky reef habitat, which is believed to be critical habitat for groundfish and essential to rebuilding depleted stocks, is "untrawlable." It is, however, subject to recreational angling. Recreational fishing for groundfish occurs over a variety of bottom types and around artificial structures, such as oil rigs, that attract groundfish.

Habitat management for Pacific Coast groundfish fisheries includes the standard federal consultation process, and also the development of a new EFH Environmental Impact Statement (EIS), which is documented at http://www.nwr.noaa.gov/1sustfsh/groundfish/eis_efh/efh/. The EFH EIS is intended to be an improvement over the current use of EFH as a classification and management tool, which is somewhat unwieldy. The unwieldiness stems from the extent to which habitat in the EEZ is considered "essential": there are some 400 categories of habitat that the Pacific Coast Groundfish FMP defines as essential, and these habitats collectively comprise all of the waters from terrestrial boundaries (including coastal high water levels, estuaries, and upper limits of riverine saltwater intrusion) to the 200-mile extent of the U.S. EEZ. The EFH EIS will implement several models in determining priority EFH. In these models, physical and biological data on habitats and species are combined with fishery impact models to produce multi-scale, process-based estimates of habitat responses to fishery-related perturbations. Output from these models can then be used to guide management as to which habitats and dependent groundfish resources are most impacted by fishing activities. It will also provide guidance on how to best manage sensitive habitat types, such as the deep-sea coral communities described in the Bycatch section. The draft EFH EIS is scheduled to be available for public comment in February 2005, and finalized in December 2005.

The standard consultation processes involved in identifying EFH, the modeling involved in the EFH EIS, and a general assessment of groundfish fishing impacts on all 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 multi-beam sonar equipment, echosounders, 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, NMFS biologists have begun efforts to assess the populations of groundfish in untrawlable habitats through use of ROVs, hook-and-line surveys, and mark-recapture studies. Such information will increase the accuracy of coast-wide stock assessments.

10.4.6 Food webs

Studies of food webs involving Pacific Coast groundfish have been relatively limited to date. "Limited" in this context means that studies featuring quantitative, seasonal diet information for multiple life history stages of key species are rare. General trophic characteristics of many species have been surmised based on stomach analyses or stable isotope analysis, and some species' diets (*e.g.*, hake) are quite well documented. Also, some relatively ubiquitous prey can certainly be identified as key to groundfish production, such as squid, euphausiids, and some myctophid fishes. Additionally, community-level food web modeling (using ECOPATH with ECOSIM) is being done (Field *et al*., 2001, with more papers forthcoming). Further modeling at the community level (*e.g.*, incorporating groundfish into models focused primarily on salmon and associated pelagic and vertically migrating species) and ecosystem level (*i.e.*, incorporating food webs, fisheries, oceanography, climate, and biogeochemistry) is also under way. However, this remains an area where there is much to be learned.

There is increasing emphasis on food web studies as a complement or alternative to traditional fisheries management based on single-species, stock assessment-based approaches because many scientists believe that species interactions have strong influence on population dynamics. Hence, in order to successfully manage marine fisheries, targeted stocks must be viewed within the proper ecological context, particularly the context of predator-prey interactions or competition with similar species. Several examples follow.

Worldwide, a growing number of studies suggest that fishing influences marine food web structure and population dynamics. Removal of top predators by fisheries can produce cascading trophic interactions throughout the food web that profoundly affect its functioning. Other studies have found that trawl damage to the sea floor and its infauna can affect the base of food webs driven by benthic production. Studies of this type are generally lacking for food webs involving Pacific Coast groundfish.

Some studies have linked food availability with reproductive fitness of female rockfish. Thus, production regimes affected by climate are propagated through the food web to groundfish; this may be true through many other pathways, *e.g*., climate-driven production that supplies food to larval groundfish, or factors that affect production of euphausiids, which are key prey to different stages of most groundfish. Many researchers have concluded that the declines in some rockfish stocks over the past 20 years have been a result not just of overfishing, but also of poor oceanic productivity that led to poor recruitment.

Single-species population models, such as basic stock assessments, may benefit from incorporation of multi-species interactions, as is done in multi-species virtual population analysis (MSVPA) or related modeling. In MSVPA, age-specific predator-prey interactions involving targeted species are explicitly incorporated, which may be of benefit in the Pacific Coast groundfish fishery because so many groundfish consume one another or cannibalize their own juveniles. In 2001, a panel of NMFS 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 climate effects and food web interactions into population dynamics. A specific need cited in that document for Pacific Coast groundfish was to account for the role of climate shifts (and the associated changes in productivity) and the increase in pinniped abundance, which could signal an increase in predation mortality on groundfish.

A food web approach may also be important for rehabilitating depleted species of rockfish off the Pacific Coast. The overfished rockfish are typically large-bodied and long-lived, and NMFS scientists are currently studying the interactions between these species and the highly abundant small-bodied rockfish that co-occur with them and may constrain their rebuilding through competition for food. In addition, the growing interest in establishing marine reserves as a means of rockfish rehabilitation requires a food web perspective because cessation of fishing will affect rockfish predators as well as rockfish themselves.

For example, lingcod co-occur with many depleted rockfish. Lingcod have greater growth rates and shorter generation times than rockfish, and thus may be expected to respond more rapidly to a fishing moratorium than rockfish. Lingcod are also top predators that feed on rockfish. Therefore, a marine reserve may actually benefit lingcod at the expense of rockfish (Mangel and Levin, in press).

In a similar vein, a food web modeling approach would be a useful tool in evaluating possible responses of key species to fisheries management decisions. For example, the small quotas established for overfished species may lead to large-scale time-area closures as those quotas are reached. A food web modeling approach could be used to ask whether closing the fishery leads to unforeseen species interactions. If, for instance, incidental catch of overfished rockfish leads to a closure of the hake fishery, a food web model could be used to evaluate whether rockfish benefit from lower fishing mortality, or suffer greater predation mortality inflicted by a relatively large (and now unfished) hake population.

In summary, quantitative food web information, though recognized as necessary, is lacking for Pacific Coast groundfish. There are relatively few specifics concerning food web dynamics in the FMP or the Groundfish EIS, which may not imply lack of concern so much as acknowledge the difficulty in acquiring this information and integrating it into an already complex system of population assessment and management.

10.4.7 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, water temperatures, and climate. All of these factors can influence the distribution of groundfish species.

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.

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 that leads to increased primary production that can be propagated throughout the food web. Upwelling is often associated with areas that have submarine canyons. 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 1-2 years (*i.e.*, El Niño Southern Oscillations (ENSOs) and La Niñas) to decadal-scale shifts in climate regime (*e.g.*, the Pacific Decadal Oscillation (PDO)). ENSOs have probably received the most attention, and their effects appear to 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 produced incidents of 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 appears to be strong in years after ENSOs (Hollowed *et al*., 2001). Different PDO regimes promote differences in air pressure, oceanic circulation, and other key oceanic properties that affect primary production and virtually all consumers. These changes are widely held to benefit different subsets of marine organisms, such that shifts from one regime to another can result in dramatic changes in productivity and species dominance (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 West Coast appears more related to factors such as seasonal Ekman transport and sea level than to adult abundance in a traditional stock-recruit relationship (Schirripa, unpublished data).

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.

10.4.8 References

Brodeur, R.D. and Pearcy, W.G. 1992. Effects of environmental variability on trophic interactions and food web structure in a pelagic upwelling ecosystem. Mar. Ecol. Prog. Ser. 84: 101-112.

Chavez, F.P., Ryan, J., Lluch-Cota, S.E. and Niquen, C.M. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299: 217-221.

Field, J.C., Francis, R.C. and Strom, A. 2001. Toward a fisheries ecosystem plan for the northern California current. Rep. Cal. Coop. Oceanic Fish. Invest. 42: 74-87.

Francis, R.C., Hare, S.R., Hollowed, A.B. and Wooster, W.S. 1998. Effects of interdecadal climate variability on oceanic ecosystems of the NE Pacific. Fish. Oceanogr. 7: 1-21.

Hollowed, A.B. and Wooster, W.S. 1992. Variability of winter ocean conditions and strong year classes of Northeast Pacific groundfish. ICES Mar. Sci. Symp. 195: 433-444.

Hollowed, A.B. and Wooster, W.S. 1995. Decadal scale variations in the Eastern Subarctic Pacific: 2. Response of Northeast Pacific fish stocks. Can. Spec. Pub. Fish. Aquat. Sci. 121: 373-385.

Hollowed, A.B., Hare, S.R. and Wooster, W.S. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. Prog. Oceanogr. 49: 257-282.

Love, M., Yoklavich, M. and Thorsteinson, L. 2002. The Rockfishes of the Northeast Pacific. Univ. California Press, Berkley, CA, 405 pp.

Mangel, M. and Levin, P.S. 2004. Regime shifts, phase shifts and paradigm shifts: Making community ecology the basic science for fisheries. Phil. Trans. Royal Soc. London. In press.

Moser, H.G., Charter, R.L., Watson, W., Ambrose, D.A., Butler, J.L., Charter, S.R., Sandknop, E.M. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the southern California Bight in relation to environmental conditions and fishery exploitation. Rep. Cal. Coop. Oceanic Fish. Invest. 41:132-147.

NRC (National Research Council). 2002. Effects of trawling and dredging on seafloor habitat. National Academy Press, Washington DC.
Williams, E.H. and Ralston, S. 2002. Distribution and co-occurrence of rockfishes (family: Sebastidae) over trawlable shelf and slope habitats of California and southern Oregon. Fish. Bull. 100: 836-855.

Appendix 10.5 Descriptions of multi-species and ecosystem models developed or under development in the U.S. North Pacific region that might be used to predict effects of fishing on ecosystems

10.5.1 North Pacific multi-species and ecosystem models of the Alaska Fisheries Science Center

Model hypotheses and descriptions are compiled by Kerim Aydin (Alaska Fisheries Science Center; Kerim.Aydin@noaa.gov). This list does not include the extensive statistical analyses being performed to develop indicators of climate- or fishing-related changes in fish production or ecosystem characteristics. Examples of these types of indicators and analyses can be found in the Ecosystem Considerations section of the Alaska Groundfish Stock Assessment and Fishery Evaluation (SAFE) document (http://www.afsc.noaa.gov/refm/reem/Assess/Default.htm).

<u>Single-species stock assessment models with predation</u>

So far we have developed two of these models: one for eastern Bering Sea pollock (Livingston and Methot, 1998) and one for GOA pollock (Hollowed *et al*., 2000). We might develop one for Aleutian Islands Atka mackerel in the future. The purpose of these models is to better understand the sources and time trends of natural mortality for pollock by explicitly incorporating predation mortality induced by their major predators into an age-structured fish stock assessment model. We have learned that not only is natural mortality at younger ages much higher than for adults but that it varies across time, depending on time trends in predator stocks. This has given us better ideas of what influences predation has on fish recruitment over time and helps us to separate predation and climate-related effects on recruitment. We can better show the demands of other predators such as marine mammals for a commercially fished stock and how it might influence the dynamics of that stock (although we still need to make progress in understanding the effects on marine mammals).

<u>Bering Sea multi-species virtual population analysis</u>

We presently have a multi-species virtual population analysis model (MSVPA) for the Bering Sea (Livingston and Jurado-Molina, 2000). This model includes predation interactions among several commercially important groundfish stocks and also predation by arrowtooth flounder and northern fur seal on these stocks. This model can give us a better idea of the predation interactions among several stocks. We can use output from this type of model to understand what the possible multi-species implications are of our single species-oriented fishing strategies. Results from these forecasting exercises show that a particular fishing strategy may have the opposite effect of what is intended if multi-species interactions are taken into consideration. We have also done multi-species forecasting with this model using different hypotheses about regime shifts and associated fish recruitment patterns.

<u>Boreal migration and consumption model for the eastern Bering Sea</u>

We have an initial version of a spatially explicit model of pollock movement and cannibalism in the eastern Bering Sea. We hope to better understand the differences in spatial overlap of predators and prey, and how that affects the population dynamics of each. The model we have modified for the Bering Sea is one being used in other boreal ecosystems, BORMICON (Boreal Migration and Consumption model). Migrations are prescribed at present with the hope that we can prescribe movement based on physical factors in the future. The influence of spatial overlap of cannibalistic adult pollock with juveniles on the population dynamics of pollock is investigated. Hypotheses about larval drift positions and the resulting overlap and cannibalism are also being explored. This model could be linked in the future to an individual-based larval pollock model and to NPZ model that could prescribe zooplankton abundance by area as alternate food for adults and as primary food for juveniles.

Analytical approach to evaluating alternative fishing strategies with multiple gear types

The analytical approach for simulating current groundfish management in the North Pacific U.S. EEZ involves considering interactions among a large number of species (including target, non-target, and prohibited), areas, and gear types. To evaluate the consequences of alternative management regimes, modeling was used to predict the likely outcome of management decisions using statistics on historical catch of different species by gear types and areas. Management of the Alaska groundfish fisheries is complex given the large numbers of species, areas, and gear types. The managers schedule fisheries openings and closures to maximize catch subject to catch limits and other constraints. These management actions are based on expectations about the array of species likely to be captured by different gear types and the cumulative effect that each fishery has on the allowable catch of each individual target species and other species groups. Management decisions were simulated by an in-season management model that predicts capture of target and non-target species by different fisheries based on historical catch data by area and gear type. The groundfish population abundance for each alternative regime was forecast for a five-year period beginning from the present. This approach provides a reasonable representation of the current fisheries management practice for dealing with the multi-species nature of catch in target fisheries. In addition to the model and its projected results, agency analysts also used the scientific literature, ongoing research, and the professional opinion of fishery experts in their respective fields to perform qualitative assessments.

Influence of advection on larval pollock and flatfish recruitment

This model investigates the environmental relationship between surface advection during the post-spawning period (pollock egg and larval stages) and pollock survival. Wespestad *et al*. (1997) found that during years when the surface currents tended north-northwestward along the shelf that year class strength was improved compared to years when currents were more easterly. They used the OSCURS surface advection model to simulate drift. Subsequently (Ianelli *et al*., 1998), their analysis was extended to apply within a stock assessment model. The model uses surface advection over a 90-day period to determine the "goodness" of the advective field for juvenile pollock. Similar analyses were performed by Wilderbuer *et al*. (2002) for winter spawning flatfish in the eastern Bering Sea.

Shelikof pollock individual-based model

This individual-based model (IBM) was designed to run in conjunction with the 3-D physical model (SPEM), and the Shelikof NPZ model. Its purpose is to examine, at a mechanistic level, hypotheses regarding recruitment of pollock in Shelikof Strait, especially as these refer to transport, growth and (somewhat) mortality of pollock from spawning through the fall of the 0-age year.

GLOBEC nutrient-phytoplankton-zooplankton (NPZ) 1-D and 3-D models

This modeling effort (the NPZ model coupled with a 3-D physical model of the circulation of the region) is designed to test hypotheses regarding the effect of climate change/regime shifts on production in the coastal region of the Gulf of Alaska, including effects on cross-shelf transport, upstream effects, local production, and effect on suitability of the region as habitat for juvenile salmon.

Steller sea lion individual-based model

This individual-based model will be designed to examine how sea lion energy reserves change, through foraging and bioenergetics, depending on the distribution, density, patchiness and species composition of a dynamic prey field (as influenced by factors such as potential local depletion by fishing). It should be applicable to any domain surrounding a specific sea lion rookery or haul-out in the Bering Sea, Aleutian Islands or GOA. Lion characteristics such as age, location, life-stage, birthdate, *etc*. are recorded. Caloric balance is the main variable followed for each individual.

Shelikof nutrient-phytoplankton-zooplankton (NPZ) 1-D and 3-D models

This NPZ model was developed to produce a temporally and spatially explicit food source (Pseudocalanus stages) for larval pollock, designed to be input to the pollock IBM. This set of coupled (biological and physical) models was developed to examine hypotheses about pollock recruitment in the Shelikof Strait region.

Gulf of Alaska walleye pollock stochastic switch model

This model was designed as a mathematical representation of a conceptual model described in Megrey *et al*., 1996. It is a numerical simulation model of the recruitment process. A generalized description of stochastic mortality is formulated as a function of three specific mortality components considered important in controlling survival (random, due to wind mixing events, and due to prevalence of oceanic eddies). The sum total of these, under some conditional dependencies, determines the overall survival experienced by the recruits.

North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO)

This model was designed to represent the minimum state variables needed to characterize a generic NPZ marine ecosystem model for the North Pacific. Ecosystem fluxes are tracked in both units of nitrogen and silicon. Carbon flux process equations have been recently added. Its purpose is to examine the effect of climate variability on the marine ecosystem through regional comparisons by using the same ecosystem model structure and process equations.

Mass-balance ecosystem models for North Pacific regions of interest (multiple models)

Mass-balance food web models (ECOPATH models) provide a way for evaluating the importance of predator/prey relationships, the roles of top-down and bottom-up forcing in modeled ecosystems, and the changes in ecosystem structure resulting from environmental perturbations (natural or anthropogenic). Additionally, the models may provide a way to compare natural predation mortality with respect to predator biomass and fishing levels, and determine the quality of data available for a given system.

Eastern Bering Sea shelf model 1

Although many of ECOPATH models were done in the past for the Alaska region, the most up-to-date published model is the effort by Trites *et al.* (1999) for the eastern Bering Sea. These models are highly aggregated over age groups and species groups and best highlight gaps in our understanding of how ecosystems function, and our lack of data on certain ecosystem components. Walleye pollock is broken into two biomass groups: pollock ages 0-1 and pollock age 2 and older. This model is useful for testing ecosystem hypotheses about bottom-up and top-down forcing and to examine system level properties and energy flow among trophic levels. The eastern Bering Sea model extent includes the main shelf and slope areas north to about 61ºN and excludes near-shore processes and ecosystem groups.

Eastern Bering Sea shelf model 2 and western Bering Sea shelf model

The second eastern Bering Sea shelf ECOPATH model breaks down the earlier model into more detailed species groupings to tease apart the dynamics of individual species, especially in the commercially important groundfish. Spatial extensions to the model include sub-dividing into inner, middle, and outer biophysical domains for parameter estimation. The model will be calibrated with respect to top-down and bottom-up forcing using "check-point" food webs for several years in the 1990s and using 1979-1998 time series of trawl data and MSVPA/other assessment analyses. The primary purpose of this model is to investigate the relative role of natural and anthropogenic disturbances on the food web as a whole. A western Bering Sea shelf ECOPATH model, built as a joint U.S./Russian project, has also been completed (Aydin *et al*., 2002).

Gulf of Alaska, continental shelf and slope (excluding fjord, estuarine and intertidal) model

Throughout the 1990s, there have been extensive commercial fisheries in the GOA for groundfish, as well as crab, herring, halibut, and salmon. Removals of both target species and bycatch by these (and historical) fisheries have been suggested as a possible cause for the decline of the western stock of Steller sea lions, which are now listed as endangered species. An ECOPATH/ECOSIM model for the GOA could test the hypothesis that fishery removals of groundfish and bycatch during the 1990s has contributed to the continued decline of Steller sea lions.

In addition, a community restructuring, in which shrimp populations declined dramatically and commercial fish populations increased between the 1960s and the 1990s, may have taken place, according to small mesh trawl surveys conducted by NMFS and ADF&G. An additional hypothesis which could be tested with this model is that this trophic re-organization has had a negative impact on marine mammal and bird populations in the GOA. Finally, the effects on an apparent increase in shark populations on their prey and the relative importance of these effects in the whole system could be evaluated with an ECOPATH model.

Aleutian Islands and Pribilof Islands models

While the eastern Bering Sea and Gulf of Alaska ECOPATH models may capture broad-scale dynamics of widespread fish stocks, their scale is too large to address local depletion. This may be an important issue for island-based fish such as Atka mackerel, and may be critical for determining the effect that changes in the food web may have on the endangered Steller sea lion in the Aleutians or on northern fur seals around the Pribilof Islands (Ciannelli *et al.*, 2004). These smaller-scale ECOPATH models will be used in conjunction with larger-scale models to examine the possibility of linking the models across scales.

Prince William Sound model

An ECOPATH model of Prince William Sound (PWS) was constructed by a collaboration of experts from the region during 1998-1999 (Okey and Pauly, 1999). The Exxon Valdez Oil Spill Trustee Council (EVOS) funded this effort for the purpose of “ecosystem synthesis.” Project was coordinated by the UBC Fisheries Centre and overseen by the NMFS Office of Oil Spill Damage Assessment and Restoration. Prince William Sound (Alaska) is well defined geographically; spatial definition of the system consisted of drawing lines across Hinchenbrook Entrance, Montague Strait, and smaller entrances. The time period represented by the model is 1994-1996, as this is the post-spill period with the broadest and most complete set of ecosystem information. This food web model consists of 48 functional groups ranging from single ontogenetic stages of special-interest species to highly aggregated groupings. A variety of hypotheses are being addressed with the PWS model — most relate to the 1989 Exxon Valdez oil spill and the fisheries in the area.

Alaska effects of fishing gear and habitat recovery model

This model was developed to derive measures of the effects of fishing on particular habitats and biota. It uses estimates of fishing intensity, sensitivity of habitat features, and recovery rates of features to derive indices of effects, termed Long-term Effect Indices (LEI). The model contains a number of assumptions about effect rates, habitat recovery rates, habitat distribution, and habitat utility. Fishing intensity is derived from observer data for 5 × 5 km blocks for the years 1998 to 2002. Reported effort (duration for trawls, hooks for longlines, and pot drops for pots) was converted into swept areas. LEI values were derived for benthic organism groups such as infauna, epifauna, living structure (sponges, soft and stony corals, anemones, and stalked tunicates), and hard corals.

Loop analysis of community inter-action models for Steller sea lions

Because of the large data requirements for mass balance models, uncertainty may hinder our ability to quantify the effects of fishing and environmental change on food webs. Qualitative interaction models, originally proposed by Levins, can predict changes in biomass and turnover rates of community components following a "press" perturbation through an analysis of positive and negative feedback loops. Community models can include within trophic level interactions (interference competition, mutualism) and non-organism components, such as nutrients or space. Models for Aleutian and Gulf of Alaska communities show a range of potential effects of fishing and top predators on Steller sea lions that are dependent on community structure. The analyses will indicate whether community structure, diet, or fish stock depletions are most relevant to Steller sea lion population responses, and the potential interactive effects of fisheries and bottom-up forcing due to climate shifts.

10.5.2 Multi-species and ecosystem models that concern groundfish in the U.S. Pacific Coast EEZ

Model hypotheses and descriptions are compiled by Christopher Harvey (Northwest Fisheries Science Center; Chris.Harvey@noaa.gov). This list is likely incomplete, because West Coast groundfish are studied by two regional offices of NOAA Fisheries as well as multiple academic, state government, and non-government institutions.

<u>Sablefish recruitment as influenced by oceanographic variables</u>

Northwest Fisheries Science Center (NWFSC) Oregon State University scientists are incorporating changes in oceanic conditions into stock assessment modeling of West Coast sablefish. Juvenile sablefish recruitment has been highly variable over the past three decades. Estimates of spawning stock biomass over this same period point to external factors having significant effects on population level recruitment. Variation in ocean conditions off the West Coast showed a strong relationship to fluctuations in sablefish recruitment. A General Additive Model (GAM) revealed significant relationships between juvenile recruitment and northward Ekman transport, eastward Ekman transport, and sea level. The overall model explained nearly 70 percent of the variability in sablefish recruitment between the years 1974 and 2000. Stability testing produced little change in the dynamics or predictability of the model when using less and predicting more recruitment years. Bootstrapping techniques were applied to the parameter estimates and the resulting distributions were found to support the modeling assumptions. Given the above model, it is possible to draw some very preliminary conclusions concerning year-class strength of cohorts not yet available to the survey gear as well as historic year-class strengths. Using the oceanographic variables, estimates of recruitment for a given year may be possible by August, providing useful early predictions that could influence catch quotas. Historical analysis (hindcasting) will provide additional information for assessment of virgin stock levels. Fitting the recruitment relationship internal to the stock assessment model will allow for fitting, hindcasting, and forecasting to be done simultaneously.

<u>Effects of climate variability on bocaccio population dynamics</u>

Bocaccio are one of the most imperiled rockfish stocks on the West Coast, and their rebuilding will be constrained greatly by the continued exploitation and the climate-mediated infrequency of successful recruitment, as demonstrated in recent modeling work by NWFSC scientists. Scientists from the NWFSC and the University of Washington are developing bocaccio population models that incorporate the effects of density dependence and climate on bocaccio extinction risk. Given the associations elucidated between climate and bocaccio recruitment, these researchers are running stochastic population models that use a variety of possible climate change scenarios that may realistically occur in the coming decades.

<u>Interactions between rockfish and predators in marine reserves</u>

This model was designed to estimate the effectiveness of a marine reserve in a community context, *i.e.*, with predation on the species presumed to benefit from the reserve. The model depicts population dynamics of a bocaccio population under three marine reserve regimes: a cessation in targeted offshore fishing on bocaccio (although bocaccio bycatch in other fisheries continues); an offshore marine reserve (no targeted or bycatch removal of bocaccio); and an inshore marine reserve (no targeted removal of in near-shore habitats, where juveniles are most abundant). In a single-species modeling scenario, the near-shore reserve model predicted the greatest increase in bocaccio biomass. However, when the population dynamics of a bocaccio predator, lingcod, was included in the model, the near-shore reserve performed poorly in terms of bocaccio rebuilding, due to intense lingcod predation on juvenile bocaccio, whereas the offshore reserve was most successful.

Habitat-specific demographics of groundfish

This study involves using Leslie matrix models of groundfish populations to determine what life history stages represent critical windows of high mortality, and hence represent areas in which proper management may reap tremendous benefits for maintaining or rebuilding stocks. The key is to identify not just the critical life history stages, but the associated habitat. This may make distinction of truly essential fish habitat easier, and also provide managers and conservation biologists with specific habitat areas upon which to focus their energy.

Fishery-driven changes in groundfish community composition, size spectra, and population trends

NWFSC and SWFSC fishery biologists are modeling changes in groundfish abundance and individual body size, based on data collected in assessment surveys over the last several decades. These data and basic demographic data are being used to estimate population growth rates (expressed as lambda, the population growth rate metric commonly used in the conservation biology community) of different groups of groundfish (rockfish, flatfish, elasmobranchs) to estimate the general trends in community composition that are occurring in the groundfish community.

Bioenergetics modeling of climate and fishing impacts on rockfish

A generic bioenergetics model for *Sebastes*, based on several laboratory studies of rockfish feeding and physiology, is currently being used on two fronts. First is a model of how long-term exposure of rockfish to climate anomalies (in particular, El Niño events) influences the growth, maturation, and reproductive output of rockfish at an individual and a population level. A second modeling effort is an extension of the work described above that demonstrated the change in rockfish size and abundance on the West Coast. In this case, the bioenergetics model is used to estimate the change in energy flow through different components of the rockfish assemblage. These changes may indicate a limit, imposed by multi-species interactions and changes in food web structure, on rebuilding of some depleted rockfish species.

Marine bird prey consumption in California

Researchers at the Point Reyes Bird Observatory (PRBO) are developing bioenergetics models of common murre to estimate prey consumption, including hake, shortbelly rockfish and yellowtail rockfish. This modeling work will make use of 30 years of diet data collected around the Farallon Islands. The goal is to determine how much food, in aggregate, is required to sustain murre populations. Murres feed on krill as well as squid, juvenile groundfish and juvenile salmon.

Juvenile rockfish recruitment responses to climate variability, as evidenced by bird diets

PRBO researchers have modeled the relationships between the occurrence of different species of juvenile rockfish in the diets of common murre and anomalies in climate, including El Niño, La Niña, and PDO events. Using 30 years of data and linear and quadratic models, they compared the timing of climate anomalies and the proportion of juvenile rockfish in murre diets as a proxy for rockfish recruitment. Their work suggested that recruitment of rockfish was strongly, negatively affected by El Niño, and that rockfish recruitment also responded, although more subtly and with long time lags, to regime shifts associated with PDOs.

ECOPATH with ECOSIM model of the California Current food web

This model was developed by scientists at the University of Washington. Its main purpose has been to quantify food web interactions among key species and trophic groups in the Northern California Current Ecosystem, and to provide a framework within which to ask basic questions about the effects of fishing on community structure and processes. Work published to date includes an ECOPATH model that compares the state of the food web (34 different trophic groups) in the 1960s, a relatively cool period with low fishing pressure; and the 1990s, a warmer period with high fishing pressure. Simulation work with ECOSIM, to evaluate the potential system responses to fisheries management as part of a broader Fisheries Ecosystem Plan (FEP) is ongoing.

ECOPATH/ECOSIM/ECOSPACE model of bird foraging patterns in the San Juan Islands

This model was originally developed as an ECOPATH with ECOSIM model describing the general food web structure of waters around the San Juan Islands. It is now being expanded to incorporate spatial dynamics (hence the use of the spatial module ECOSPACE) and to more explicitly model the role of sea birds, which had previously been pooled together as one monolithic trophic group. This research, conducted at the NWFSC, will explore the role of different species of sea birds as predators on marine forage species, and will also examine the potential influence of marine protected areas on bird-fish predator-prey dynamics.

Pelagic food web models of Astoria Canyon region

NWFSC scientists, in conjunction with the Global Ocean Ecosystem Dynamics program (GLOBEC), are using modeling approaches to look at the role of top-down and bottom-up processes in controlling fish production in the California Current upper pelagic zone, largely focusing on waters off the coast of Oregon. Their models consider primarily bottom-up approaches (physics linked to plankton production linked to fish feeding) and integrated food web approaches that include food supply, predation, and competition in controlling fish populations. For examining plankton production, they are using a variety of plankton models, from simple nitrogen-phytoplankton-zooplankton (NPZ) models to a simplified version of the PICES NEMURO model. These models can be used to estimate the effects of oceanographic events on production that supports upper trophic levels. They are taking two approaches to modeling integrated trophic effects throughout the pelagic food web. The first is an ecosystem simulation approach (similar to ECOSIM). Because the trophic web off the coast is quite complex, they are using guild analysis to reduce the food web to a number of functional groups, based on diet data collected during GLOBEC studies off Oregon and northern California. The fish components of the food web focus on pelagic species but include a "bottom fish" group, comprised of juvenile flatfish and rockfish, that are preyed upon by pelagic omnivores. The second approach uses a structural model that describes growth and survival of juvenile salmon as they are influenced by a number of factors. Population abundance is influenced by various mortality terms, which in tern are determined by predator abundances and other environmental factors. Individual weight is influenced by the balance of trophic demands (food requirement) and food availability. Food availability in turn is determined by prey abundances and competition, again with indirect effects of environmental conditions. Groundfish comprise portions of the prey and predator groups, and also compete for prey groups.

ATLANTIS model of the California Current ecosystem

This work is recently underway and will be developed over the course of the next several years. It is a joint effort between scientists at the NWFSC, the University of Washington, and CSIRO (Australia). The Australian scientists have developed a modeling package called ATLANTIS that is a spatially explicit ecosystem model, with components for flux of water and dissolved or suspended materials in three-dimensional space; biogeochemical fluxes; climate; food web interactions at the level of "trophospecies," *i.e.*, groups of species with similar trophic roles; and fisheries. Model parameterization is scheduled to begin in 2004 and will likely require at least a year to complete. Once completed, this model can be used to address many questions examined with models such as ECOPATH with ECOSIM. However, this will be a more spatially explicit model with a greater emphasis on ecosystem dynamics and not just community dynamics. In other words, the model will allow users to examine spatially explicit questions concerning the response of key functional groups to fisheries management alternatives (*e.g.*, optimal yield alternatives; time-space closures; marine protected areas), juxtaposed against variability in productivity, climate, and oceanography.

10.5.3 References

Aydin, K.Y., Lapko, V.V., Radchenko, V.I. and Livingston, P.A. 2002. A comparison of the eastern Bering and western Bering Sea shelf and slope ecosystems through the use of mass-balance food web models. U.D. Dept. Commerce, NOAA Tech. Memo. NMFS-AFSC-130. 78 pp.

Ciannelli, L., Robson, B.W., Francis, R.C., Aydin, K. and R.D. Brodeur. 2004. Boundaries of open marine ecosystems: an application to the Pribilof Archipelago, southeast Bering Sea. Ecol. Appl. 14: 942-953.

Hollowed, A., Ianelli, J.N. and Livingston, P. 2000. Including predation mortality in stock assessments: A case study for Gulf of Alaska pollock. ICES J. Mar. Sci. 57: 279-293.

Ianelli, J.N., Fritz, L., Honkalehto, T., Williamson, N. and Walters, G. 1998. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 1999. *I*n: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1: 1-79.

Livingston, P.A. and Jurado-Molina, J-J. 2000. A multispecies virtual population analysis of the eastern Bering Sea. ICES J. Mar. Sci. 57: 294-299.

Livingston, P.A. and Methot, R.D. 1998. Incorporation of predation into a population assessment model of eastern Bering Sea walleye pollock. pp. 663-678. *In* Fishery Stock Assessment Models. Alaska Sea Grant College Program Publication AK-SG-98-01. 1037 pp.

Megrey, B.A., Hollowed, A.B., Hare, S.R., Macklin, S.A. and Stabeno, P.A. 1996. Contributions of FOCI research to forecasts of year-class strength of walleye pollock in Shelikof Strait, Alaska. Fish Ocean. 5: 189-203.

Okey, T. A. and Pauly, D. 1999. A mass-balanced model of trophic flows in Prince William Sound: de-compartmentalizing ecosystem knowledge. pp. 621-635 *In* Keller, S. (Ed.) Ecosystem approaches for fisheries management. University of Alaska Sea Grant, Fairbanks.

Trites, A.W., Livingston, P., Mackinson, S., Vasconcellos, M.C., Springer, A.M. and Pauly, D. 1999. Ecosystem change and the decline of marine mammals in the eastern Bering Sea: Testing the ecosystem shift and commercial whaling hypotheses. Univ. British Columbia, Fisheries Centre Research Reports 1999, Vol. 7.

Wespestad, V.G., Fritz, L.W., Ingraham, W.J. and Megrey, B.A. 1997. On relationships between cannibalism, climate variability, physical transport and recruitment success of Bering Sea walleye pollock, *Theragra chalcogramma*. ICES International Symposium, Recruitment Dynamics of Exploited Marine Populations: Physical-Biological Interactions. Baltimore, MD, Sept. 22-24.

Wilderbuer, T.K., Hollowed, A.B., Ingraham, Jr., W.J., Spencer, P.D., Conners, M.E., Bond, N.A. and Walters, G.E. 2002. Flatfish recruitment response to decadal climatic variability and ocean conditions in the eastern Bering Sea. Prog. Oceanogr. 55: 235-247.

Table 10.5.1 Model areas, time period, contact person, and model status.

Model Name/Region	Time Period	Contact	Status
Single-species stock assessment models that include predation	EBS: 1964-95 GOA: 1964-97 (Annual)	Patricia Livingston	Working (not updated)
Bering Sea MSVPA	1979-present 3 months (quarterly)	Patricia Livingston and Jesus Jurado-Molina	Working
BORMICON for the eastern Bering Sea	1979-97 1 month	Patricia Livingston	Planning/construction
Evaluating alternative fishing strategies	Current	Jim Ianelli	Working
Advection on larval pollock and flatfish recruitment	90 Days of larval drift 1970s-present	Jim Ianelli and Tom Wilderbuer	Working
Shelikof pollock IBM	YD 60-270 Daily	Sarah Hinckley	Working
GLOBEC NPZ 1-D and 3-D models	YD 60-270 (eventually year-round). Daily	Sarah Hinckley	In progress
Steller sea lion IBM	Summer or Winter, Minutes to Days	Sarah Hinckley	Planning/construction
Shelikof NPZ 1-D and 3-D models	YD 60-270 (eventually year-round). Daily	Sarah Hinckley	In progress
GOA pollock stochastic switch model	32 years (replicates) Daily	Bernard Megrey	Working
NEMURO	1 Full Year, Daily	Bernard Megrey	Completed
Eastern Bering Sea shelf ECOPATH model 1	1950s & early 1980s Annual	Patricia Livingston	Completed
Eastern Bering Sea shelf ECOPATH model 2	1979-1998 Annual	Kerim Aydin	Working
Western Bering Sea shelf ECOPATH model	Early 1980s Annual	Kerim Aydin and Victor Lapko	Completed
Gulf of Alaska shelf ECOPATH model	1990-99 Annual	Sarah Gaichas	Completed
Aleutian Islands & Pribilof Islands ECOPATH models	1990s-2000s Annual	Ivonne Ortiz, Lorenzo Ciannelli	In progress Completed
Prince William Sound, ECOPATH model	Pre- and Post 1989 oil spill Annual	Thomas Okey	Completed
Alaska effects of fishing gear and habitat recovery model	1998-2002	Jeff Fujioka and Craig Rose	Completed

Model Name/Region	Time Period	Contact	Status
Loop analysis for Steller sea lions	Theoretical model system	Selina Heppell and Gabriela Montano-Moctezuma	In progress
West Coast sablefish recruitment	1974-2000 Annual	Michael Schirripa and J.J. Colbert	In progress
Climate variability and bocaccio dynamics	1970s-2000s Annual	Nick Tolimieri and Rich Zabel	In progress
Rockfish and predators in marine reserves	Theoretical model system (Annual)	Phil Levin and Mark Mangel	Completed
Habitat-specific demographics of groundfish	1970s-2000s Annual	Phil Levin	In progress
Changes in groundfish communities, size	1980-2000 Triennial	Phil Levin and Eli Holmes	In progress
Rockfish bioenergetics	1980-2000 Annual	Christopher Harvey	In progress
Marine bird prey consumption	1973-2002 Annual	William Sydeman and Nadav Nur	In progress
Juvenile rockfish in bird diets	1973-2002 Annual	William Sydeman	Completed
ECOPATH/ECOSIM model of California Current	1960s-present Annual	John Field, Jodie Little, Robert Francis	In progress
ECOPATH/ECOSIM/ ECOSPACE model of San Juan Islands birds	1990s-present Annual	Thomas Good	In progress
Pelagic food web models of Astoria Canyon	2000s Annual	Ric Brodeur and Thomas Wainwright	In progress
ATLANTIS model of California Current Ecosystem	1990s-present Annual	Christopher Harvey and Beth Fulton	Planning/construction

Table 10.5.2 Model spatial domains, currencies, inputs and outputs

Model Name/Region	Model Spatial Domain	Input	Output/Currency
Single-species stock assessment models that include predation	Across EBS and GOA Pollock distributions	Fisheries data and predator biomass	Pollock population and mortality trends—number at age (and biomass at age)
Bering Sea MSVPA	The modeled region is the eastern Bering Sea shelf and slope north to about 61ºN	Fisheries, predator biomass, and food habits data. This model requires estimates of other food abundance supplied by species outside the model	Age-structured population dynamics for key species—numbers at age
BORMICON for the eastern Bering Sea	The model is spatially explicit with 7 defined geographic regions that have pollock abundance and size distribution information	Temperature is included and influences growth and consumption	Spatial size distribution of polloc.
Evaluating Alternative Fishing Strategies	U.S. EEZ	Gear-specific fishing effort including bycatch	Biomass of managed fish species
Advection on larval pollock and flatfish recruitment	Southeast Bering Sea Shelf	OSCURS surface currents (wind-driven)	Index of pollock and winter-spawning flatfish recruitment
Shelikof Pollock IBM	Western GOA from just southwest of Kodiak Island to the Shumagin Islands, shelf, water column to 100 m	From physical model: Water velocities, wind field, mixed-layer depth, water temperature and salinity, From NPZ model: Pseudocalanus field	Individual larval characteristics such as age, size, weight, location, lifestage, hatchdate, consump-tion, respiration.
GLOBEC NPZ 1-D and 3-D Models	Water column (0-100 m) Coastal GOA from Dixon Entrance to Unimak Pass, 100 m of water column over depths < 2000m 5 m depth bins × 20 km horizontal grid.	Irradiance, MLD Temperature, diffusivity, bottom depths, water velocities (u,v,w)	Diffusivity,ammonium, nitrate, detritus, small and large phytoplankton, dinoflagellates, tintinnids, small coastal copepods, neocalanus and euphausiids (nitrate and ammonium): mmol/m^3 (all else): mg Carbon/m^3
Steller Sea Lion IBM	Should be applicable to any domain surrounding a specific sea lion rookery or haul-out in the Bering Sea, Aleutian Islands or GOA	The main input to the SSL-IBM will be a 3D field of prey (fish) distribution, derived either from hypothetical scenarios or (later) modeled based on acoustic data	Individual sea lion characteristics such as age, location, lifestage, birthdate, etc are recorded. Caloric balance is the main variable followed for each individual.

Model Name/Region	Model Spatial Domain	Input	Output/Currency
Shelikof NPZ Model, 1-D and 3-D Versions	water column (0-100m), GOA from southwest of Kodiak Island to Shumagin Islands. 1 m depth bins for 1-D version, 1 m depth × 20 km for 3-D version	Irradiance, MLD, Temperature, Bottom depths, water velocities (u,v,w)	Nitrogen, phytoplankton, Neocalanus densities, Pseudocalanus numbers/m^3 for each of the 13 stages (egg, 6 naupliar, 6 copepodite)s
GoA Pollock Stochastic Switch Model	Shelikof Strait, Gulf of Alaska	Number of eggs to seed the model. Base mortality, additive and multiplicative mort. adjustment parameters for each mort. Factor	number of 90 day old pollock larvae through time
NEMURO	Ocean Station P (50ºN 145ºW), Bering Sea (57.5ºN 175ºW), and station A7 off the east of Hokkaido island, Japan (41.3ºN 145.3ºW)	Fifteen state variables and parameters including 2 phytoplankton, 3 zooplankton, and multiple nutrient groups	Ecosystem fluxes are tracked in units of nitrogen and silicon.
Eastern Bering Sea Shelf Model 1 Ecopath	500,000 km^2 in eastern Bering Sea south of 61°N	Biomass, Production, Consumption, and diet composition for all major species in each ecosystem	Balance between produced and consumed per-area biomass (t/km^2). Future work will explore energy ($kcal/km^2$) and nutrient dynamics.
Eastern Bering Sea Shelf Model 2 Ecopath	500,000 km^2 in eastern Bering Sea south of 61°N		
Western Bering Sea Shelf Ecopath	300,000 km^2 on western Bering Sea shelf		
Gulf of Alaska Shelf Ecopath	NPFMC management areas 610, 620, 630, and part of 640		
Aleutian Islands, Pribilof Islands Ecopath	Not determined		
Prince William Sound, Ecopath	Whole Prince William Sound		
Alaska Effects of Fishing Gear and Habitat Recovery Model	Eastern Bering Sea, Gulf of Alaska, and AI shelf and slope regions 1998-2002	Fishing effort, sensitivity of habitat features, recovery rates of habitat, geographic distribution of fishing effort by gear type	Long term effect index (LEI) for given habitat features: percent reduction of a habitat feature at equilibrium
West Coast sablefish recruitment	West Coast of U.S.	Northward Ekman transport, Eastward Ekman transport, sea level	Sablefish recruitment
Climate variability and bocaccio dynamics	West Coast of U.S.	Stochastic population model with year-class strength a function of climate, density	Extinction risk of bocaccio under different climate and fishing regimes

Model Name/Region	Model Spatial Domain	Input	Output/Currency
		dependent growth parameters, long-term climate data with inter-annual and -decadal anomaly indexes	
Rockfish and predators in marine reserves	Theoretical model system (Annual)	Stage-based population growth parameters for bocaccio (prey) and lingcod (predator), Beverton-Holt recruitment parameters for bocaccio, spatially discrete stage-based fishing mortality	Population dynamics of bocaccio under different marine reserve designs
Habitat-specific demographics of groundfish	1970s-2000s Annual	Standard life table data for stage-based Leslie matrices, stage-specific habitats	Elasticity analysis indicates the most critical life stage and associated habitat for improved conservation planning
Changes in groundfish communities, size	1980-2000 Triennial	Triennial survey data for the U.S. West Coast, including total abundance and weight of major species in each haul	Population trend estimates, relationships between mean size and population trends, relationships between harvest rate and population trends
Rockfish bioenergetics	West Coast of U.S.	Population estimates, Sex-specific VBGF, length-weight conversions, temperatures, mean sizes from assessment surveys	Rockfish prey consumption and egg production
Marine bird prey consumption	1973-2002 Annual	Consumption, respiration, waste, reproduction, growth, and diet parameters for common murre	Energy requirements for common murre; historical predation rate estimates on juvenile groundfish
Juvenile rockfish in bird diets	1973-2002 Annual	Diet data from common murres in Farralon Islands; indexes of inter-annual and interdecadal climate variability	Proxy estimates of strength of juvenile rockfish recruitment relative to climate conditions
Ecopath, Ecosim model of California Current	1960s-present Annual	Biomass, Production, Consumption, harvest and diet composition for	Estimated trophic structures of each food web; biomass dynamics

Model Name/Region	Model Spatial Domain	Input	Output/Currency
Ecopath, Ecosim, Ecospace model of San Juan Islands birds	1990s-present Annual	diet composition for major species in each ecosystem	web; biomass dynamics in response to different fisheries management scenarios
Pelagic food web models of Astoria Canyon	2000s Annual		
ATLANTIS model of California Current Ecosystem	1990s-present Annual	Spatially explicit biomass, production, consumption, and diet composition for major functional groups of consumers; spatial harvest rates by gear type; production rates of primary producers as a function of light, nutrients, and temperature; large-scale water fluxes at seasonal and annual time scales; seasonal biogeochemical data on material fluxes and nutrient loading; long-term climate anomaly data	Spatially explicit biomass dynamics in response to different fisheries management scenarios, climate variability, oceanographic variability; indicator species for monitoring responses to perturbations

Appendix 10.6 A potential standard reporting format (developed by Australia, and currently being used by the U.S.A in their contribution to this report)

10.6.1 Introduction

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, the following format is focused on fisheries. Alternate formats will be assessed or be developed that capture the ecosystem effects resulting from other human activities, and that describe how these ecosystem effects are being monitored. In some cases, 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.

10.6.2 What we hope to achieve

We intend that this national reporting framework will be progressively applied to all fisheries in PICES member countries and become an integral part of fisheries management. Although the primary goal is to assist and improve fisheries management, the reporting framework is also intended to address an increasing number of environmental and other requirements imposed by legislation, certification schemes, and consumer and community demands.

With a comprehensive, national approach, individual fisheries should be well placed to show how they are performing against identified national EBM objectives. Further details can be found on the Australian ESD reporting framework project web site, where the set of generic component trees are listed, along with the latest version of the case study guidelines and a listing of associated events.

10.6.3 The implications of ecosystem-based management and its implementation

Within fisheries management, social and economic factors have always been included as part of the decision-making process. What is needed is a more formal, transparent and structured way of considering these issues - which Ecologically Sustainable Development (ESD) provides. The ESD process will therefore have implications for the level of community input and understanding, because it will reveal the machinery of management. Previously, many aspects of fisheries and their management have often been assessed in an implicit fashion, but now they will be looked at explicitly.

In addition to understanding the major environmental issues for each fishery - including those associated with the target species and the wider ecosystem that the fishery operates within - fisheries managers need sensible assessments of the economic and the social costs, contributions and benefits which flow from the fishing activities associated with each fishery. These assessments will not necessarily drive the fisheries management decisions that have to be made, but at least by understanding their implications, fisheries managers can determine the best way of managing an issue. If catch or effort levels have to be reduced within a fishery, there are often a number of different ways of achieving this - one way may produce good social benefits, whilst another may produce better economic benefits. For the same biological outcome, fisheries managers should be trying to find the approach that provides the most benefits whilst increasing the transparency as to how decisions are being made. Not all stakeholders may agree with the final decision, but at least they can see on what basis it was made.

10.6.4 Format for summary of reference points in local situations to address the identified issues under various circumstances

From the fisheries that you are directly involved with, please choose a fishery or fisheries that illustrate what you regard as best practice for management of the various issues being addressed in this project (*i.e.*, retained species, bycatch species, threatened or protected species, *etc*.). It may be that different fisheries illustrate best practice for different issues, and so several fisheries may be reported on here. It would help greatly if all of the issues in this format were commented on for each fishery that is reported on. It is likely that many of the issues are not relevant to some fisheries, and in this case please just make that comment in the relevant part of the format (*i.e.*, say "not relevant" rather than leaving the entry ambiguously blank).

<u>Fishery</u>

- Name and location
- Relevant fishery management plan, policy, legislation (please provide copies of these or a source, such as a www site or a contact point, so that we can obtain copies)
- Main target species
- Main retained species
- General form of management (*e.g*., open access, input control (what vessel/gear restrictions, limited entry), output control (competitive quota, individual quota)) or any other general comments on the management regime.

<u>Retained species</u>

- General approach to retained species management
- For all or a representative selection of species:
  - 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 inter-annual recruitment variability: highly variable recruitment; 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)
  - Status of species in relation to reference point (*e.g.*, under, acceptably near target, over)
  - Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries). Please comment on whether any specific consideration has been given to genetic biodiversity in the retained species, and if so what approach to its management was taken.

<u>Bycatch species</u>

- General approach to bycatch management
- 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 and recovery rules and targets)
  - Level of information/uncertainty (elaborate as necessary)
  - Reference points (target, limit and trigger if used)
  - Status of species/groups in relation to reference point (*e.g.*, under, acceptably near target, over)
  - Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries). Please comment on whether any specific consideration has been given to species biodiversity among the bycatch species, and if so what approach to its management was taken.

<u>Threatened or protected species and communities</u>

- 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 and recovery rules and targets)
  - Level of information/uncertainty (elaborate as necessary)

- Reference points (target, limit and trigger if used)
- Status of species/ communities in relation to reference point (*e.g.*, under, acceptably near target, over)
- Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries). Please comment on whether any specific consideration has been given to community biodiversity, and if so what approach to its management was taken.

<u>Habitats</u>

- 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 and recovery rules and targets)
  - Level of information/uncertainty (elaborate as necessary)
  - Reference points (target, limit and trigger if used)
  - Status of habitats in relation to reference point (*e.g.*, under, acceptably near target, over)
  - Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries). Please comment on whether any specific consideration has been given to the effects of habitats on biodiversity, and if so what approach to its management was taken.

<u>Food webs</u>

- 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 and recovery rules and targets)
  - Level of information/uncertainty (elaborate as necessary)
  - Reference points (target, limit and trigger if used)
  - Status of species/ communities in relation to reference point (*e.g.*, under, acceptably near target, over)
  - Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries)
- For food webs in general:
  - Ecological properties involved
  - Level of natural variability
  - 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)
  - Status of species/ communities in relation to reference point (*e.g.*, under, acceptably near target, over)
  - Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries).

<u>Physical environment</u>

- 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 and recovery rules and targets)
  - Level of information/uncertainty (elaborate as necessary)
  - Reference points (target, limit and trigger if used)
  - Status of species/ communities in relation to reference point (*e.g.*, under, acceptably near target, over)
  - Comment on strengths/weakness of reference points and score out of 10 (1 for poor and 10 for best practice in your fisheries).