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ECOSYSTEM CONSIDERATIONS IN FISHERIES MANAGEMENT:

Theory and Practice

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INTRODUCTION

The purpose of this paper is to examine recent international developments with respect to the development and application of an ecosystem approach in marine fisheries management. An enormous volume of paper and words have been generated over the past 15 years or so, discussing the need to take ecosystem considerations into account in managing marine fisheries and suggesting alternative ways of doing this. While there has been general agreement codified to some extent in international legal instruments on the need to take ecosystem considerations into account, there is no clarity or consensus on how this might best be done.

WHAT IS AN ECOSYSTEM?

Tansley (1935) defined an ecosystem "as an ecological community, together with its environment, considered as a unit." Although there are numerous variations on this definition, the basic concepts remain unchanged.

Wang (2004) summarized the key features of an ecosystem in five points:

- An ecosystem exists in a space with boundaries that may not be explicitly delineated. Ecosystems are distinguishable from each other based on their biophysical attributes and their location.
- An ecosystem includes both living organisms and their abiotic environment , including pools of organic and inorganic materials.
- The organisms interact with each other and interact with the physical environment through fluxes of energy, organic and inorganic materials among the pools. These fluxes are mediated and functionally controlled by species behavior and environmental forces.
- An ecosystem is dynamic. This structure and functions change with time.
- An ecosystem exhibits emergent properties that are characteristic of its type and are invariant within the domain of existence.

Humans are components of ecosystems. Humans and their interactions have major effects on the structure and function of ecosystems.

Figure 1 illustrates a marine ecosystem with a number of trophic levels. In this example, marine organisms interact in a variety of ways. They feed on each other, compete for key resources and provide habitat. A species' position in the food web determines its average trophic level. The first trophic level consists of primary producers, which derive energy from the sun or chemicals in seawater, e.g. phytoplankton, seaweeds. The second trophic level consists of herbivores which eat primary producers. The third trophic level is occupied by carnivores which eat herbivores. Apex predators occupy the top level, e.g. fishing, marine mammals. (Zabel et al 2003)

Fishing can affect marine ecosystems , both directly and indirectly. By targeting larger, more valuable fish, fishing can reduce the average size of fish in the population. This affects the reproductive capacity because larger fish produce more eggs. Also species with long life cycles cannot bounce back as quickly as short-lived ones. Fishing tends to alter marine communities towards short-lived species. This can affect the structure of marine communities as fisheries target lower and lower trophic levels. Daniel Pauley and his colleagues at the University of British Columbia have popularized the term "fishing down the food web "(Pauley et al. 1998)

Fishing can also have indirect effects on marine ecosystems. An example is trophic cascades, which are changes in biomass propagated across three or more trophic levels. One example is the overhunting of sea otters in the Aleutian Islands, which allowed sea urchin populations to expand and overgraze kelp populations (Zabel et al. 2003)

A recent study (April 2005) has demonstrated the dramatic effects of overfishing top predators such as sharks on coral reef ecosystems. Bascompte et al (2005) developed a model of a Caribbean marine ecosystem and its intricate predator-prey interactions. This food web covered one thousand square kilometers to a depth of 100 meters and included some 250 species of organisms. A simplified version is shown in Figure 2. Their study indicated that, in the Caribbean, overfishing of sharks triggers a domino effect of changes in abundance that carries down the ecosystem to several fish species and contributes to the overall degradation of the coral reef ecosystem. The authors concluded that ecosystems such as Caribbean coral reefs need sharks to ensure the stability of the entire system. The community-wide impacts of fishing were stronger than expected because fishing preferentially targets species whose removal can destabilize the food web.

REFERENCES TO CONSERVING/PROTECTING MARINE ECOSYSTEMS IN INTERNATIONAL CONVENTIONS AND OTHER LEGAL INSTRUMENTS

In the late 1980s -early 1990s there was a growing realization that the traditional approaches to fisheries resources were failing to conserve and protect the world's fish stocks. Overexploitation of fisheries became an increasing concern. It was recognized that fisheries resources were not inexhaustible, as Thomas Huxley had postulated. In several reports, the FAO warned that most of the world's fish stocks were fully exploited or overexploited. Most recently (FAO 2004) it estimated that in 2003 about one quarter

of the stocks monitored were under exploited or moderately exploited (3% and 21% respectively). About half of the stocks (52%) were fully exploited while approximately one quarter were overexploited, depleted or recovering from depletion and needed rebuilding. From 1974 to 2003 there was an increasing trend in the proportion of overexploited and depleted stocks, from about 10% in the mid-1970s to close to 25% in the early 2000s (Fig. 3).

A number of international instruments developed over the past two decades have included explicit references to protection of marine ecosystems. Agorau (2003) provided a review of these instruments that refer, in some fashion, to an ecosystem approach to fisheries management.

The United Nations Convention on Law of the Sea (UNCLOS 1982), which is the basic legal framework that governs the uses of the oceans and seas, outlines provisions for protection and preservation of marine ecosystems (Part XII of UNCLOS). Agorau (2003) pointed out, although the provisions do not refer specifically to fisheries, they are relevant in the sense that they urge States to prevent, reduce and control pollution of marine ecosystems through any source. In my view it is stretching things somewhat to imply that UNCLOS called for an ecosystem approach to fisheries management.

More relevant are the 1992 Convention on Biological Diversity (CBD), the 1995 UN Fish Stocks Agreement (UNFA) and the 1995 FAO Code of Conduct for Responsible Fisheries. A number of regional agreements of recent years also make explicit reference to ecosystem considerations. Foremost among these is the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) of 1982, which was the first to recognize the importance of an ecosystem approach to fisheries management. We will return to CCAMLR provisions later in this paper.

The 1992 Convention on Biological Diversity (CBD) provided a framework for the conservation and ecologically sustainable development and use of biodiversity. Although this convention does not address fisheries specifically, it applies to all terrestrial and marine biodiversity. This was made more explicit in the Jakarta Ministerial Statement on Implementation of the Convention on Biodiversity (Jakarta Mandate on Coastal and Marine Biodiversity) issued during the second meeting of the Conference of Parties (COP 2, Jakarta, 1995). This mandate specifically linked conservation, the use of biodiversity and fishing activities and identified the following as areas of critical importance:

- Integrated management of marine and coastal areas
- Marine and coastal protected areas
- Ecologically sustainable use of marine and coastal living resources
- Mariculture
- Alien species

More recently it has defined an ecosystem approach as follows:

"The Ecosystem Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The application of the Ecosystem Approach will help to reach a balance of the three

objectives of the convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" (CBD 2000).

But perhaps,from a fisheries perspective, far more relevant to our discussion is the 1995 UN Fish Stocks Agreement. UNFA provides a framework for the conservation and management of straddling stocks and highly migratory fish stocks in high seas areas regulated by regional fisheries organizations. It provides for the obligation to use the precautionary approach and an ecosystem approach when managing these fisheries. It obliges States to minimize pollution, waste and discards of fish.

The Preamble to UNFA notes that the State Parties to this agreement are:

"Conscious of the need to avoid adverse impacts on the marine environment, preserve biodiversity, maintain the integrity of marine ecosystems and minimize the risk of long-term or irreversible effects of fishing operations ."

Part II, Article 5, General Principles, stipulates that coastal States and States fishing on the high seas shall:

"5.d. Assess the impacts of fishing, other human activities and environmental factors on target stocks and species belonging to the same ecosystem or associated with or dependent upon the target stock;

"5.e. Adopt, where necessary, conservation and management measures for species belonging to the same ecosystem or associated or dependent upon the target stocks, with a view to maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened;

"5.f. Minimize pollution, waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species ….and impact on associated or dependent species…..;

"5.g. Protect biodiversity in the marine environment."

Article 6 pertains to the application of the precautionary approach, one of the major advances in UNFA. In particular, Article 6.3 (d) provides that States shall:

"develop data collection and research programmes to assess the impact of fishing on non-target and associated or dependent species and their environment, and adopt plans which are necessary to ensure the conservation of such species and to protect habitats of special concern ."

Annex II.4, dealing with Guidelines for the Application of the Precautionary Approach, stipulates that management strategies shall seek to maintain or restore populations of harvested stocks and, where necessary, associated or dependent species at levels consistent with previously agreed to precautionary reference points.

It is clear from these sections of the agreement that the UN Fish Stocks Agreement provides for an advance on the traditional single-species-based approach to fisheries

management. However, it does not provide specific definitions or reference points for an ecosystem approach to fisheries management. Agorau (2003) suggested that the implementation of UNFA will strengthen global application of ecosystem-based fisheries management. Given the current status of implementation of UNFA , whether this goal will be achieved remains unclear.

Another major document with implications for applying ecosystem considerations in fisheries management is the1995 FAO Code of Conduct for Responsible Fisheries. While the Code is not legally binding, the general principles of the Code have had an impact in shaping developments at the national and regional levels. The Code is similar to the provisions of UNFA in suggesting that fisheries management measures should ensure the protection not only of target species , but also of non-target, associated or dependent species. As Agorau (2003) notes, the provisions of the Code have the scope to provide for effective protection of marine ecosystems by protecting target and non-target species and the ecosystems associated with these species.

There are other international agreements which encourage that ecosystem considerations be taken into account in fisheries management, e.g. the Convention for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (the WCPT Convention). Space precludes me addressing these in detail.

In addition to these international agreements, there have been advances at the national and regional level in emphasizing the need to take a more holistic approach to fisheries management. Here I will briefly mention three of these: Australia, Canada and the Northeast Atlantic.

Australia

Australia released an Oceans Policy in December 1998. It had two sections. The first described broad goals and planning and management principles to guide the development of an integrated oceans management framework. The second part described specific measures sector by sector, e.g. fisheries. Here I will address only the broad-based section dealing with ecosystem-based oceans planning and management. Australia's ecosystem-based oceans planning and management approach aims to ensure the maintenance of:

- Ecological processes in all ocean areas, including, for example, water and nutrients close, community structures and food webs, and ecosystem links;
- Marine biological diversity, including the capacity for evolutionary change;
- Viable populations of all native marine species in functioning biological communities.

It also stresses, as an important element of maintaining marine ecosystems, representation within protected areas of marine ecosystem types across their natural range of variation. It identifies the fundamental objective of maintaining ecosystem integrity. It describes Australia's ocean ecosystems and their marine biological diversity as "core national assets ." The Policy identifies integrated ecosystem-based planning and management for multiple uses of the oceans as the approach to be pursued. This would

be implemented through the introduction of a Regional Marine Planning Process designed to improve linkages between different sectors and across jurisdictions.

The Policy Guidelines for Oceans Planning and Management (Australia 2000) provide the following guidelines for the maintenance of ecosystem integrity:

- Ecological links between the land and oceans, as well as within and between ocean ecosystems, must be taken into account in ocean planning and management.
- Maintenance of natural ecosystem structure and functioning should be used to develop agreed objectives and indicators for ecosystems and resource uses on the basis of the best available information on assessment of:

- natural levels of temporal and spatial variability in the sensitivity or resilience of the ecosystems likely to be affected by proposed use;
- the extent and levels of changing ecosystem components or impacts on ecosystem integrity likely to arise from proposed uses and other impacts, singly and in unison;
- level of induced changes considered acceptable;
- levels of changes in ecosystem characteristics considered incompatible with the maintenance of ecosystem health or recovery within a reasonable period ;
- gaps or uncertainties in information on resources, uses or ecosystem processes and the capacity to monitor, detect and assess change in indicators of ecosystem health.

Canada

In December 1996, the Canadian Parliament passed the Oceans Act which came into force in January 1997. This was the first comprehensive oceans management legislation in the world. The Act provides for the development and implementation of a national oceans management strategy based on the principles of sustainable development, integrated management and the precautionary approach. The Preamble to the Oceans Act guided development of Canada's Oceans Strategy. Among other things, the Preamble stated that:

- Canada promotes the understanding of oceans, ocean processes, marine resources and marine ecosystems to foster the sustainable development of the oceans and their resources;
- Canada holds that conservation, based on an ecosystem approach, is of fundamental importance to maintaining biological diversity and productivity in the marine environment;
- Canada promotes the wide application of the precautionary approach to the conservation, management and exploitation of marine resources in order to protect these resources and preserve the marine environment; and
- Canada promotes the integrated management of oceans and marine resources.

Canada's Oceans Strategy, released in 2002, emphasized the principle of integrated management, 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 oceans spaces. The Strategy

also emphasizes the promotion of an ecosystem-based approach to management. The Strategy also introduced the concept of Large Ocean Management Areas (LOMAs)

In 2004, the Canadian Department of Fisheries and Oceans defined ecosystem-based management as "the management of human activities so that ecosystems, their structure (e.g. diversity of species), function (e.g productivity) and overall environmental marine environmental quality, are maintained at appropriate temporal and spatial scales. EBM recognizes that human activities must be managed in consideration of the interrelationships between organisms, their habitats and the physical environment ." (DFO 2004)

The Government of Canada's ecosystem-based management approach involves:

- Identifying the geographical context for management areas
- Understanding the marine ecosystem
- Assessing the condition of the ecosystem
- Managing human activities
- Establishing ecosystem objectives (EOs) to maintain biodiversity, productivity, water quality and habitat quality in a given ecological region
- Selecting and monitoring ecological indicators to ensure that ecological objectives are being met (DFO 2004) .

In 2004, DFO also defined 17 (later modified to 19) marine ecoregions for the purpose of ecosystem-based integrated management.

In 2005, the Government announced funding for an Oceans Action Plan. Integrated management efforts would be focused on five Large Oceans Management Areas where there are pressing needs. The areas are: Placentia Bay/Grand Banks, Scotian Shelf, the Gulf of St. Lawrence, the Beaufort Sea and the Pacific North Coast. Early action in these areas was to include:
- establishing new oceans management arrangements;
- analyzing the state of marine ecosystems .
- seabed mapping of priority areas, and .
- identifying sensitive marine areas in need of conservation.

Actions envisaged include a national network of Marine Protected Areas in all three of Canada's oceans.

The EU/Norway/North Sea

Fisheries and Environmental Ministers from the member countries of the EU and Norway, meeting in Bergen in March 1997 (the Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues) adopted a statement of conclusions on the integration of fisheries and environmental issues (IMM 1997). The Statement explicitly recognized:

"that fisheries and environmental policies must be further integrated, and (recognized) the desirability of an ecosystem approach, with the aim of ensuring that fisheries and environmental protection, conservation and management measures are consistent with the characteristic structure and functioning, productivity and biological diversity of the ecosystems, and of a high level of protection, consistent with the needs of food production of species and their habitats" (IMM 1997).

In addition, the IMM Statement proposed, *inter alia*, the following principle (2.6):

"Further integration of fisheries, environmental protection, conservation and management measures, drawing upon the development and application of an ecosystem approach, which, as far as the best available scientific understanding and information permit, is based on, in particular:

- the identification of processes in, and influences on, the ecosystems which are critical for maintaining their characteristic structure and functioning, productivity and biological diversity ;
- taking into account the interaction among the different components in the food webs of the ecosystems (multi-species approach) and other important ecosystem interactions; and
- providing for a chemical, physical and biological environment in these ecosystems with a high level of protection of these critical ecosystem processes ."

Furthermore, the Ministers agreed that the main objectives for fisheries and environmental protection conservation and management measures are:

"3.1 to ensure sustainable sound and healthy ecosystems in the North Sea, thereby restoring and/or maintaining their characteristic structure and functioning, productivity and biological diversity;
“3.2 to achieve sustainable exploitation of the living marine resources, thereby securing a high yield of quality food; and
“3.3 to ensure economically viable fisheries."

This indicates that ecosystem issues were being identified as central to integrated fisheries and environmental management in the North Sea a decade ago.

In its 2001 Green Paper on the Future of the Common Fisheries Policy (CFP), the European Commission noted a lack or insufficiency of knowledge about the functioning of marine ecosystems and the side- effects of fishing which exacerbates the environmental shortcomings of the CFP (European Commission 2001).

In terms of the future CFP, the Green Paper proposed the implementation of multi-annual and ecosystem-oriented management. It suggested that medium-term environmental and ecosystem objectives and strategies for key species and habitats could also be established through the introduction of limits on by- catch and incidental catches. Moreover, it identified a need to further develop an ecosystem- oriented approach to all areas of fishery management, from resources to consumers, in order to contribute to the achievement of sustainable exploitation of marine ecosystems.

The Fifth International Conference on the Protection of the North Sea resulted in the Bergen Declaration of March 2002. Part I of that Declaration deals with "Establishing an Ecosystem Approach to Management." Recognizing the need to manage all human activities that affect the North Sea in a way that conserves biological diversity and ensure sustainable development, the Ministers agreed to implement an ecosystem approach by identifying and taking action on influence critical to the health of the North Sea ecosystem. The Ministers also agreed to a conceptual framework for an ecosystem approach (Fig.4). They also agreed on the need to set Ecological Quality objectives and the elements of Ecological Quality.

Currently, the EU is developing a European Marine Strategy. This is intended to include a general policy document with guidelines on how to implement it at the regional level by applying an ecosystem approach. The Regional Part will consist of the development of regional conservation and management plans, adding:

- operational, regionally based objectives
- limits, targets and indicators
- actions and delivery tools
- assessment, monitoring and scientific research
- pre-agreed risk management actions (Hagstrom 2004).

Figure 5 depicts a possible ecosystem approach at a regional scale. Note the reference to operational ecosystem objectives and indicators, targets and limits.

Ecosystem management has of course been at the forefront of discussions in many other countries/regional entities. In the USA two commissions on ocean issues reported in 2004. The Pew Commission on Oceans and the US Commission on Oceans Policy both called for implementation of ecosystem-based fisheries management. In addition, the United Nations and other international organizations have launched a number of large marine ecosystem (LME) projects in Asia, Africa, South America and Europe (Wang 2004). Space and precludes an examination here of these initiatives.

Do these diverse initiatives mean that there is a general agreement on how ecosystem considerations should be applied in fisheries management? Sadly, that is not the case. Instead, the terminological permutations constitute an “alphabet soup” of potential confusion.

WHAT IS ECOSYSTEM-BASED FISHERIES MANAGEMENT/AN ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT?

As Wang (2004) points out, there are various definitions of “ecosystem management". One definition which has gained widespread acceptance is that proposed by the Committee on the Scientific Basis for Ecosystem Management of the Ecological Society of America , which defines it as management based on "the best understanding of the ecological interactions and processes necessary to sustain ecosystem structure and function (Christensen et al. 1996). The Ecological Society outlined the major elements of ecosystem management thus:

- Long-term sustainability as fundamental value;
- Clear operational goals;
- Sound, more ecological models and understanding;
- Understanding complexity and interconnectedness;
- Recognition of the dynamic character of ecosystems;
- Attention to context and scale;
- Acknowledgment of humans as ecosystem components; and .
- Commitment to adaptability and accountability.

This is similar to that adopted by the Fifth Meeting of the Conference of Parties to the Convention on Biological Diversity (COP 5). For an elaboration of the principles and guidelines proposed by COP 5 for application of the ecosystem approach, see Wang (2004). COP 5 interpreted an "ecosystem approach" as a strategy for the integrated management of natural resources that equitably promotes both conservation and utilization. An ecosystem approach focuses on "levels of biological organization, which encompass the essential processes, functions and interactions among organisms and their environment" but it also recognizes that humans are an integral part of ecosystems .

At this juncture, it is perhaps worth taking a step back to emphasize an important point that should be self-evident. In reality, whatever the terminology, we are not talking about managing ecosystems. Rather, we are talking about managing the human activities which are part of, and impact on, marine ecosystems.

As Larkin (1996) observed, ecosystem management means different things to different people. He viewed the term "ecosystem management" as shorthand for more holistic approaches to resource management. From a fisheries management perspective, he described it as centered on multi-species interactions in the context of a variable physical and chemical environment. He viewed terms such as “ecosystem health” and “ecosystem integrity” as rhetorical devices, none of which can be readily translated into operational language for resource management. Larkin saw the essential components of ecosystem management as being sustainable yield maintenance, maintenance of biodiversity and protection from the effects of pollution and habitat degradation.

Larkin concluded:

"Management of marine ecosystems, or more properly management of marine fisheries with awareness of ecosystem properties, is essentially a question of distinguishing the impacts of fishing from those of fluctuations in the ocean environment, understanding the dynamics of species interactions and appreciating the way in which fishing fleets will respond to changes in the abundance of various stocks of fishes, all with the objective of achieving sustainable yields. One of the morals is to the ease up on fishing when environmental conditions are unfavorable. A common feature of many collapses in fish stocks is the combination of top-down and bottom-up effects that ensues from continued heavy fishing after a series of recruitment failures caused by adverse environmental conditions."

In 1998 , the US Department of Commerce established an Ecosystem Principles Advisory Panel which in April 1999 submitted a report to Congress entitled "Ecosystem-based Fishery Management " (NOAA 1999). The Panel concluded that ecosystem-based management can be an important complement to existing fisheries management approaches. The Panel suggested that, when fishery managers understand the complex ecological and socioeconomic environments in which fisheries exist, they may be able to anticipate the effects fisheries management will have on the ecosystem and the effects that ecosystem change will have on fisheries. However, they noted that ecosystem-based management cannot resolve all of the underlying problems of the existing fisheries management régimes. Absent the political will to stop overfishing, protect habitat and support expanded research and monitoring programs, an ecosystem-based approach cannot be effective.

The Panel concluded:

"A comprehensive ecosystem-based fisheries management approach would require managers to consider all interactions that a target fish stock has with predators, competitors and prey species; the effects of weather and climate on fisheries biology and ecology; the complex interactions between fish and their habitat; and the effect of fishing on fish stocks and their habitat. However, the approach need not be endlessly complicated. An initial step may require only that managers consider how the harvesting of one species might impact other species in the ecosystem."

The Panel developed a set of eight operating principles (Principles) with societal goals and a set of six management policies.

Principles

- The ability to predict ecosystem behavior is limited.
- Ecosystems have real threshold limits, which, when exceeded, can effect major system restructuring.
- Once threshold limits have been exceeded, changes can be irreversible.
- Diversity is important to ecosystem functioning.
- Multiple scales interact within and among the ecosystems.
- Components of ecosystems are linked.
- Ecosystem boundaries are open.
- Ecosystems change with time.

Goal

- Maintain ecosystem health and sustainability

Policies

- Change the burden of proof
- Apply the precautionary approach
- Purchase “insurance” against unforeseen adverse ecosystem impacts
- Learn from management experiences

- Make local initiatives compatible with global goals
- Promote participation, fairness and equity in policy and management.

They suggested an incremental strategy for moving towards ecosystem-based fisheries research and management. In particular, they proposed that the US Fishery Management Councils should continue to use existing Fishery Management Plans for single species or species complexes but these should be amended to incorporate ecosystem approaches consistent with an overall Fisheries Ecosystem Plan (FEPs).

Link (2002) tackled the question "What does ecosystem-based fisheries management mean?" Does it mean ecosystem management in a fisheries context or fisheries management in an ecosystem context? He argued that it is the latter because we cannot manage an ecosystem. Link posed the question, "What is the objective of ecosystem-based fisheries management?" He argued that the terms "ecosystem health" and "ecosystem integrity" are misnomers and should be replaced by terms such as "ecosystem status" and ecosystem state sustainability". Link described an apparent duality when considering ecosystem approaches to fisheries management polarized at two extremes: either one can approach management from the perspective of the entire ecosystem, or from a single species approach that is aware of broader ecological considerations. These represent two extremes along a gradient. Finally, Link pointed out that invoking ecosystem considerations should not be a crutch for failing to implement clear cut single species fisheries management advice.

Alverson (2004) noted that, while the concept of management using ecosystem principles is broadly endorsed by many scientists, opinions still differ about many terms associated with the state of ecosystems, the attributes that will retain ecosystem productivity, and the principles that should guide management. He observed that many of the terms lack quantifiable dimensions and, when used, frequently lack operational definitions although they may imply a concept or process. He concluded that we should not view managing marine living ocean resources with ecosystem principles as a panacea for the global overfishing problems or view failures to use them as explaining the failure of single species management.

Pikitch et al (2004) argued that ecosystem-based fishery management (EBFM) is a new direction for fisheries management, essentially reversing the order of management priorities to start with the ecosystem rather than the target species. They saw the overall objective of EBFM as one of sustaining healthy marine ecosystems and the fisheries they support. In particular, EBFM should (i) avoid degradation of ecosystems, as measured by indicators of environmental quality and system status; (ii) minimize the risk of irreversible change to natural assemblages of species and ecosystem processes; (iii) obtain and maintain long-term socioeconomic benefits without compromising the ecosystem; and (iv) generate knowledge of ecosystem processes sufficient to understand the likely consequences of human actions. They argued that, where knowledge is insufficient, robust and precautionary fishery management measures that favor the ecosystem should be adopted.

Mace (2001) discusses the pros and cons of moving beyond single species assessment and management. She identified the obvious limitation of single species fisheries management is that is not holistic. In general, it does not explicitly consider species interactions, changes in ecosystem structure or function, biodiversity, non-harvest ecosystem services, the needs of rare or endangered species, other non-target species, the ecosystem effects of discarding large quantities of unwanted by-catch or gear impacts on habitat. With respect to ecosystem approaches, she pointed out that, due to the complexity of most marine ecosystems, approaches that attempt to model the system as a whole generally do not consider major size- based variation in demographic parameters: density- dependent effects; stock- recruitment relationships; effects of fishing on genetic diversity; uncertainties in the form of measurement errors, estimation errors, process errors and implementation errors; standards and reference points; or interactions and feedback between the harvested species, the stock assessments and the management system. She identified another major difficulty with an ecosystem approach is the difficulty of defining operational objectives and performance measures. Mace argued that ecosystem models have not yet proved themselves as management tools, particularly in terms of making realistic predictions about the future. Hall (1999) pointed out that, given current levels of understanding about marine ecosystems, it is difficult to identify key interactions between species, let alone manage for them.

Mace (2001) posed the question: what do we gain from an ecosystem approach that we do not already get from single species approaches? She suggested two potential answers:

- A better appreciation of the effects of fishing on ecosystem structure and function; and
- A better appreciation of the need to consider the value of marine ecosystems for functions other than harvesting fish and invertebrates for fish and livelihoods.

Impediments to ecosystem-based management include: greater information requirements, greater complexity, numerous alternative hypotheses about ecosystem structure and function, lack of operational objectives, lack of widely applicable performance measures and possibly reduced predictability about future stock sizes of key species.

From this analysis, Mace concluded that integrating the two approaches might give us the best of both worlds. There is a need to integrate comprehensive models of key species of interest with comprehensive models of the biological, physical and chemical environment in which they live, while, at the same time, reducing the dimensions of complexity to manageable levels. As an example, a single species quota might be set relatively more conservatively for forage species than for a predator. Another alternative is to restrict fishing further in certain areas or seasons to avoid local depletion of fish species consumed by protected or endangered species, or to reduce by-catch of non-target species, or to minimize impacts on fragile bottom types. In conclusion, Mace (2001) suggested that the best way forward may be to build on existing successful single species approaches and expand them into the ecosystem arena.

In a paper presented at the 2001 Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem, Sissenwine and Mace (2003) discussed various aspects of an ecosystem approach to responsible fisheries management. They defined an ecosystem approach as "fisheries management that recognizes fisheries are set within ecosystems, uses knowledge about the relationship between fisheries and ecosystems and, where

knowledge is lacking, makes robust decisions in the face of uncertainty (such that the outcome is likely to be ecologically benign and unlikely to be irreversible)." They challenged the widespread view that we need an ecosystem approach because single species fisheries management has failed to prevent undesirable outcomes, such as depleted fish stocks. They argued that these undesirable outcomes usually result from the failure to apply the scientific advice being given on single species approaches.

Sissenwine and Mace (2003) suggested that an ecosystem approach to a responsible fisheries management system should include:

- Goals and Constraints that characterize the desired state of the fishery, and undesirable changes in ecosystems (including the human dimension) that fisheries should not be allowed to cause;
- Conservation of fishery resources that is precautionary, takes account of species interactions and is adaptive;
- Allocation of fishing rights in a manner that provides incentives for conservation and efficient use of living resources;
- Decision-making that is participatory and transparent;
- Ecosystem protection for habitat and for species vulnerable to extinction or deemed by society to warrant special protection.

They also concluded that more rigorous (usually more cautious) application of single species methods is an important step toward an ecosystem approach, and realistically we can only move to an ecosystem approach incrementally.

The 2001 Reykjavik Conference convened by the FAO and Iceland resulted in the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem. This Declaration:

- recognized that sustainable fisheries management incorporating ecosystem considerations entails taking into account the impacts of fisheries on the marine ecosystem and the impacts of the marine ecosystem on fisheries;
- confirmed that the objective of including ecosystem considerations in fisheries management is to contribute to long-term food security and to human development and to assure the effective conservation and sustainable use of the ecosystem and its resources;
- recognized the complex interrelationship between fisheries and other components of the marine ecosystems;
- affirmed that incorporation of ecosystem considerations implies more effective conservation of the ecosystem and sustainable use and increased attention to interactions such as predator - prey relationships among different stocks and species of living marine resources; furthermore, that it entails an understanding of the impact of human activities on the ecosystem, including the possible structural distortions they can cause in the ecosystem.

The Declaration emphasized the need to work on incorporating ecosystem considerations to reinforce responsible and sustainable fisheries in the marine ecosystem. To this end, it concluded:

- There is a clear need to introduce immediately effective management plans with incentives to encourage responsible and sustainable use of marine ecosystems, including mechanisms for reducing excessive fishing effort to sustainable levels.
- It is important to strengthen, improve and, where appropriate, establish regional and international fisheries management organizations and incorporate in their work ecosystem considerations…
- It is important to advance the scientific basis for incorporating ecosystem considerations, building on existing and future available scientific knowledge.

The Reykjavik Conference called on FAO to develop technical guidelines for best practices with regard to introducing ecosystem considerations into fisheries management.

The World Summit on Sustainable Development (WSSD 2002) adopted a plan of implementation, in which Parties agreed to:

- encourage the application by 2010 of the ecosystem approach, noting the Reykjavik Declaration on Responsible Fisheries in the Marine Environment (article 30d);
- maintain productivity and biodiversity of important and vulnerable marine and coastal areas, including areas within and beyond national jurisdiction (article 30a);
- develop and facilitate the use of divergent approaches and tools, including the ecosystem approach, the elimination of destructive practices, the establishment of marine protected areas……. and the integration of marine and coastal areas into key sectors (article 30c) .

FAO subsequently produced guidelines on the ecosystem approach to fisheries (EAF) to supplement the FAO Code of Conduct for Responsible Fisheries (FAO 2003).

FAO GUIDELINES ON THE ECOSYSTEM APPROACH TO FISHERIES (EAF)

These Guidelines state that the purpose of an ecosystem approach to fisheries " is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems ."

The Guidelines define an EAF as follows:

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

These definitions merged two related paradigms. The first is ecosystem management that focuses on protecting and conserving ecosystem structure and functions by managing the biophysical components of ecosystems (e.g. introducing marine protected areas), and the

second is fisheries management that focuses on providing food and income/livelihoods for humans by managing fishing activities. An EAF recognizes the broader uses and users of the marine environment (including fishing) and the need to accommodate and reconcile the many objectives of these users so that future generations can also derive the full range of goods and services provided by the ecosystem. An EAF is a holistic approach (FAO 2003). This sounds like sustainable development for fisheries, does it not?

The Guidelines stress that EAF is neither inconsistent with, nor a replacement for, current fisheries management approaches and is likely to be adopted as an incremental extension of current fisheries management approaches (as advocated by Sissenwine and Mace, 2003).

The FAO guidelines proposed that fisheries management under an EAF should respect the following principles:

- Fisheries should be managed to limit their impact on the ecosystem to the extent possible;
- Ecological relationships between harvested, dependent and associated species should be maintained;
- Management should be compatible across the entire distribution of the resource (across jurisdictions and management plans);
- The precautionary approach should be applied because the knowledge on ecosystems is incomplete; and
- Governance should ensure both human and ecosystem well-being and equity.

The real issue of course is how to translate this into action. The first step is to translate the principles into high-level policy goals. Then it is necessary to:

- identify broad objectives relevant to the fishery (or area) in question;
- further subdivide these objectives into smaller priority issues and sub-issues that can be addressed by management measures;
- set operational objectives;
- develop indicators and reference points;
- develop decision rules on how the management measures are to be applied; and
- monitor and evaluate performance (FAO 2003) .

ECOSYSTEM- BASED OPERATIONAL OBJECTIVES/INDICATORS/REFERENCE POINTS

There is a vast literature on the question of setting operational objectives, indicators and reference points for incorporating ecosystem considerations into fisheries management. I will now briefly consider the differing perspectives on this aspect.

Two good overviews of this challenge can be found in Murawski (2000) and Hall and Mainprize (2004).

Murawski (2000) suggested that ecosystem considerations could be incorporated into fisheries management by modifying existing overfishing paradigms or by developing new approaches to account for ecosystem structure and function in relation to harvesting. Murawski pointed out that, although existing concepts of overfishing have a strong theoretical basis for evaluating policy choices and much practical use, they do not provide direct guidance on issues such as biodiversity, serial depletion, habitat degradation and changes in the food web caused by fishing. He identified a series of ecosystem attributes that impact on the development of optimal fishing strategies for species assemblages of resources including: technical (by- catch) interactions, biological interactions (including predation and density dependence), the impact of abiotic (climatological) factors on species and fisheries, spatial processes (the geographic range of stocks in fisheries and patterns of density and catchability) and temporal (seasonal, annual, decadal) scales.

As observed by Pauly and Christensen (1995), one characteristic of overfished ecosystems is sequential depletion of stocks of economic value. Some stocks may in effect become economically extinct. Symptoms of ecosystem overfishing include: reductions in biodiversity; reductions in aggregate production of exploitable resources; decline in mean trophic level; increased by-catch; greater variability in the abundance of species , and sometimes régime shifts (Murawski 2000) .

Attempts have been made to use diversity indices to interpret changes in ecosystems but no consensus has developed on the usefulness of diversity indices as a measure of overfishing (Rice 2000).

Murawski (2000) suggested that management actions need to be linked to measurable attributes such as:

- biomass and production of important system components
- diversity
- variability
- social and economic benefits.

He concluded that it is inconceivable that any single metric could result in the simultaneous achievement of optima related to these ecosystem attributes. In other words, there is no value of a single metric, which, if attained, would result in the avoidance of ecosystem overfishing. Nonetheless, he suggested that the development of explicit ecosystem overfishing criteria might be appropriate to judge the cumulative effects of various management programs.

As one alternative, he suggested that ecosystems can be considered overfished when the cumulative impact of catches, non-harvest mortality, and habitat degradation result in one or more of the following conditions:

- Biomasses of one or more important species assemblages or components fall below minimum biologically acceptable limits, such that (1)recruitment prospects are significantly diminished, (2) rebuilding times to levels allowing catches near MSY are extended, (3) prospects for recovery are jeopardized because of species interactions or (4) any species is threatened with local or biological extinction;

- Diversity of communities or populations declines significantly as a result of sequential fishing down of stocks, selective harvesting of ecosystem components, or other factors associated with harvest rates or species selection;
- The pattern of species selection and harvest rates leads to greater year-to-year variation in population or catches than would result from lower cumulative harvest rates;
- Changes in species composition or population demographics as a result of fishing significantly decrease the resilience or resistance of the ecosystem to perturbations arising from non-biological factors;
- The pattern of harvest rates among interacting species results in lower cumulative net economic or social benefits than would result from a less intensive overall fishing pattern or alternative species selection;
- Harvest of prey species or direct mortalities resulting from fishing operations impair the long-term viability of ecologically important , non-resource species (e.g. marine mammals, turtles, seabirds).

Applying these criteria to three case histories, Murawski 's(2000) analysis indicated that the effect is likely to result in more conservative management of fishing capacity, and greater attention to habitat and species interaction effects of possible measures. He concluded:

"Rather than supplanting current management approaches, ecosystem considerations may increasingly be used to modify regulations intended primarily to conserve these high-value species, to address ecosystem concerns such as by-catches, predator-prey demands, and the side effects of fishing effort. In all likelihood, advice resulting from the explicit incorporation of ecosystem effects will further emphasize the need for conservative management of fishing capacity."

Hall and Mainprize (2004) examined the prospects for expanding current single species approaches for target species to consider non-target species in the context of an ecosystem-based fisheries management framework. They also examined the development of performance measures and reference points for emergent ecosystem-level properties. They concluded the expansion of single species reference points to take account of non-target species of the fishery is tractable and desirable. In contrast, they argued that the use of performance measures for a single or a small selection of ecosystem metrics is not possible at present, owing to the absence of a clear understanding of ecosystem dynamics and a lack of underlying theory to explain the behavior of these ecosystem metrics.

They observed: "Unfortunately, despite the legislative imperative and clearly articulated principles, arriving at an operational framework for an ecosystem-based approach is fraught with difficulty. This difficulty is due to not only to the inherent challenge in establishing, and quantifying, the effects of fishing at the ecosystem level…. but also to the social and political dimensions associated with harvesting fisheries at an environmentally sustainable level ."

Hall and Mainprize (2004) noted that the traditional fisheries management process almost always focuses on biological reference points -- the few economic reference points that

are available in theory, e.g. MEY, have rarely been used. While it is well known that social objectives such as maximizing employment or maintaining the status quo have often taken precedence over biological and economic considerations in management decision-making, they were unable to find any such objectives codified as formal performance measures.

With respect to performance measures in general, they argued that performance measures and reference points should be Quantifiable, Simple, Logical (relevant), Tractable, Faithful, Comparable and Cost-effective. They give a number of examples where such reference points have been developed for non-target species:

- Incidental take limits for the short tailed albatross in Alaskan fisheries;
- Potential biological removal limits for many marine mammals in the United States;
- By-catch limits for groundfish off Alaska;
- Kittiwake offspring limits in the North Sea; and
- By-catch limits on small cetaceans in Europe.

The ICES Working Group on Ecosystem Effects of Fishing Activities (ICES 2001) examined many ecosystem performance measures and reference points that could potentially be used as single measures in an ecosystem framework. The Working Group concluded that, while there were numerous metrics available, it is currently impossible to develop useful ecosystem-level measures because of a deficiency in practical knowledge of their dynamics. It concluded that reference points beyond those for single species were actually unnecessary. If the individual components of the ecosystem were sufficiently well protected, there would likely be minimal effects at the community and ecosystem scale.

There are of course alternative views. For example, Sainsbury and Sumaila (2003), in a paper presented at the Reykjavik Conference, argued that there is a need to go beyond single species reference points and develop system-level indicators to take into account the emergent properties in ecosystems as well as component species and habitat. They advanced four points to support this view:

- Several conceptual objectives of sustainable fisheries relate to emergent properties, and so performance measures should address them directly.
- Not all species and habitats and ecosystem can be monitored and managed individually.
- Even for species and habitats that can be individually addressed, the appropriate species and habitat specific reference points to achieve emergent properties are not understood.
- Understanding of ecosystem dynamics is poor; therefore, arguing that emergent properties will be protected by protecting certain components is suspect.

Despite this line of reasoning, Rice (2000) concluded that there appears to be no metric or class of metrics that can be recommended or applied without reservation. Changes in size structure may prove to be useful in the long run in incorporating a wider ecosystem perspective but not yet. Hall and Mainprize (2004) noted that, while ecosystem-based

fisheries management is currently the buzzword, almost all the reference points currently suggested as realistic candidates for forming part of an ecosystem approach are in reality single species reference points, both for target and non-target species. In April 2004 a Symposium held in Paris focused exclusively on Quantitative Indicators for Fisheries Management. The papers from that symposium,which will shortly be available in the ICES Journal of Marine Science, were not yet available when this paper was being prepared.

Hall and Mainprize (2004) observed, in conclusion, that perhaps the most important discussion of all must be about what constitutes a desirable or an undesirable state for an ecosystem and how one weighs the importance of the various attributes. This implies a consultative process where all the views are heard.

This links back to the FAO Guidelines for making an ecosystem approach to fisheries operational, which concluded that one of the implications of implementing the EAF is an expansion of stakeholder groups and sectoral linkages. The Guidelines encourage the participation of all relevant stakeholders, translating high-level policy goals into day-to-day management activities. Competing goals and aspirations should be debated to promote consensus.

EXAMPLES WHERE ECOSYSTEM CONSIDERATIONS HAVE BEEN TAKEN INTO ACCOUNT IN FISHERIES MANAGEMENT

Realizing that the ecosystem approach to fisheries as described in the FAO Guidelines has not yet been fully implemented in any jurisdiction, I have selected a few examples which illustrate the range of ways in which ecosystem considerations are currently being taken into account in fisheries management.

CCAMLR

CCAMLR is best known as the only international commission currently applying an ecosystem approach to managing fisheries. CCAMLR manages the harvesting of living resources in the Southern Ocean. The Convention establishing CCAMLR came into force in 1982, well before the recent focus on ecosystem-based fisheries management. It was the first international organization to take an ecosystem approach to managing fisheries and to develop a precautionary approach to setting catch limits (Constable 2004).

Article II of the Convention defined CCAMLR's approach to the conservation of Antarctic marine living resources. In particular, it specifies that any harvesting and associated activities in the area to which the Convention applies shall be conducted in accordance with the following conservation principles:

(a) prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose , the size should not be allowed to fall below a level close to that which ensure the greatest net annual increment;

(b) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined above;
(c) prevention of change(s) or minimization of the risk of change(s) in the marine ecosystem which are not potentially reversible over two or three decades.

CCAMLR pursues an ecosystem approach to management, attempting to take into account all the delicate and complex relationships between organisms (of all sizes) and physical processes that constitute the Antarctic marine ecosystem (Fig. 6). CCAMLR's ecosystem approach not only focuses on regulating fishing for certain species; it also aims to ensure that fishing does not adversely affect other species that are related to, or dependent on, the target species. Krill harvesting is regulated and monitored directly. CCAMLR endeavors to monitor the potential effect which krill harvesting may exert on species that that either eat krill or which in turn are eaten by krill predators. CCAMLR seeks to preserve the "health" of the ecosystem by setting conservative krill catch limits to take account of the needs of associated species in a manner which preserves the ecological sustainability of all the species concerned (CCAMLR 2005).

Constable et al (2000) reviewed the steps in the evolution of the ecosystem approach to management under CCAMLR. They described the reasons why a precautionary approach to setting catch limits evolved, how the precautionary approach takes account of ecosystem objectives , and provides for the orderly development of new fisheries and how the use of ecosystem indicators in the setting of catch limits for monitoring the effects of fishing is being evaluated.

The first precautionary catch limit for krill was set in 1991, following agreement by the Commission in 1990 on the following general concepts for setting catch limits for krill:

- To keep krill biomass at a level higher than would be the case for single species harvesting considerations , and, in so doing , to ensure sufficient escapement of krill to meet the reasonable requirements of predators;
- Given that krill dynamics have a stochastic component, to focus on the lowest biomass that might occur over a future period, rather than the average biomass at the end of the period, as might be the case in the single species context; and
- To ensure that any reduction of food to predators which might arise out of krill harvesting is not such that land-based breeding predators , which have restricted foraging ranges ,are disproportionately affected compared with predators in pelagic habitats (Constable et al 2000).

The 75% level was chosen as the midpoint between taking no account of predators (i.e. treating krill as a single species fishery and thereby choosing an escapement level of 50%) and providing complete protection for predators (i.e., no krill fishery).

For each species consideration is given to its recruitment pattern and its role in the ecosystem. For example, Patagonian toothfish, as a large predator, is unlikely to constitute much of the diet of seals and birds. Thus the species is considered in a single

species context. Mackerel ice- fish, which is a prey species, has high recruitment variability. So modified decision rules are applied to take account of this.

As Constable et al (2000) note, despite the apparent simplicity of the system, the effects of a krill fishery on krill predators may be difficult to detect because of spatial and temporal variability in the dynamics of the Antarctic marine ecosystem. In 1986, CCAMLR agreed to introduce an Ecosystem Monitoring Program to monitor the effects of fishing on the ecosystem. Since monitoring the entire ecosystem would be impractical, the CEMP was restricted to monitoring a few selected predators in a few areas.

Constable et al (2000) concluded that it remains to be determined whether the current methods used to assess catch controls on single species, to predict the effects of fishing and to monitor ecosystem are sufficient to avoid changes that are irreversible over 20-30 years. They also concluded that the CCAMLR provides two important lessons. First, conservation objectives can only be achieved by implementing management measures even when little is known. Second, methods have been found for achieving scientific consensus despite uncertainties. They note, however, that CCAMLR had yet to face the real test of its ecosystem approach. The krill catch was still low compared with estimates of a long-term precautionary yield. Also, CCAMLR apparently suffers from the inherent weakness of any international organization. Achievement of objectives is based on the cooperation of many members and recognition of measures by non-members. As an example, Constable et al (2000) concluded that the toothfish fishery is unsustainable because it was driven to overfishing by forces beyond the scientific approaches to management.

Gulf of Alaska

Witherell et al (2000) described the implementation of an ecosystem-based approach for Alaskan groundfish fisheries. The approach involves public participation, reliance on scientific research and advice, conservative catch quotas, comprehensive monitoring and enforcement, by-catch controls, gear restrictions, temporal and spatial distribution of fisheries, habitat conservation areas, and other biological and socioeconomic considerations. The basic ecosystem consideration is a precautionary approach to the harvesting of fish resources. Management measures are also taken to minimize potential impacts of fishing on seafloor habitat and other ecosystem components such as marine mammals and seabirds.

Fluharty (2004) summarized the approach as "using what you know about the ecosystem to manage fisheries." A key element of the approach is that harvest rates for groundfish are set at very low conservative levels. A second tier TAC, which is considerably less than the sum of all the ABCs (acceptable biological catches), applies to all Bering Sea/Aleutian Islands groundfish (Fig.7).

To reduce discards, the North Pacific Fishery Management Council has adopted an improved retention and utilization program for all groundfish target fisheries. Beginning in 1998, 100 percent retention of pollock and Pacific cod was required, regardless of how or where it was caught. Only fish not fit for human consumption can be discarded. This was extended to demersal shelf rockfish species in 1999 and other species subsequently.

Marine Protected Areas have been established to protect habitats for fish, crabs and marine mammals. In the Bering Sea three large areas have been closed to groundfish trawlers and scallop dredging to reduce potential adverse impacts on king crab and crab habitat. These MPAs constitute a relatively large portion of the Continental shelf and in some respects act as marine reserves. Fluharty (2004) estimated that approximately 25% of the Continental shelf in the Bering Sea was closed to trawling, an area of approximately 60,000 square nautical miles.

In 2005, the North Pacific Fishery Management Council proposed a larger ban on trawling for more than a half-million square miles of ocean near the Aleutian Islands to protect deepwater corals and sponges. The region of the extended ban accounted for only a fraction of the commercial fish caught in Alaska, about 5%. Thus the immediate impact was not a dramatic change from the status quo, but conceptually the approach was quite different (Seattle Times, February 11, 2005). Measures have also been implemented to reduce potential impacts of localized depletion of prey for higher trophic levels(Witherell et al 2000).

Pollock is a primary prey species for endangered Stellar sea lions. The TACs for pollock and Atka mackerel are spatially and seasonally apportioned into smaller sub TACs to prevent prey removals from occurring all at once and in localized areas. In the Aleutian Islands region all pollock fishing has been prohibited to eliminate any potential competition with sea lions. Directed fishing for forage species such as capelin and krill is prohibited. Incidental catch levels have been established for Stellar sea lions and the endangered short- tailed albatross .

The approach being pursued in the Gulf of Alaska has been described as conscious underexploitation of fish resources to protect overall ecosystem processes, ecosystem integrity and biodiversity to some degree. According to Livingston (2005), a scientific framework for providing ecosystem-based advice that puts the ecosystem first has been evolving over the last few years. This framework provides a way of assessing ecosystem factors influencing target species, the impact the target fishery may have on associated species and ecosystem-level impacts of fishing. This approach is now being expanded to utilize a variety of models to predict possible future trends in various ecosystem indicators. Livingston (2005) notes that identification of sensitive and meaningful ecosystem indicators that are linked to specific management objectives is also required before a more formalized decision-making processes that includes ecosystem considerations can occur.

The Northeast Atlantic

Earlier in this paper I referred to initiatives by the EU and Norway to take ecosystem considerations into account more generally in fisheries management. Both the EU and Norway receive advice on fisheries management and ecosystem issues from ICES, the International Council for the Exploration of the Sea. ICES in 2001 established the Advisory Committee on Ecosystems (ACE), in addition to its traditional Advisory Committee on Fishery Management and its Advisory Committee on the Marine Environment. Since then, ICES has been working on the development of an ecosystem approach to fisheries management through incremental additions to fisheries advice in the

Advisory Committee on Fishery Management and, in relation to ecosystem health and specific issues, through the Advisory Committee on Ecosystems .

At the 13th ICES Dialogue Meeting in April 2004 ICES discussed with its clients how it plans to introduce an ecosystem approach in the advisory process. The implementation will include interaction with stakeholders and will be incremental. Beginning in 2004 ICES introduced mechanisms on an experimental basis allowing stakeholders to provide input to the assessment process.

The first step in this process has been to present the ICES advice in an ecosystem context, i.e., to advise on an area basis and integrate information on the ecosystem and the fisheries, including ecosystem impacts of fisheries.

ICES is pursuing two separate routes towards advice based on an ecosystem approach. The first is a pragmatic route, taken in the practical day-to-day provision of advice to the ICES client commissions such as the European Commission, International Baltic Sea Fisheries Commission, the Northeast Atlantic Fisheries Commission and the North Atlantic Salmon Conservation Organization, and to national governments such as Iceland, Norway and Russia. The other is a general approach attempting to provide a status report of the State of the Ecosystem. These are complementary approaches.

With respect to fisheries management, ICES has been working on the development of an ecosystem approach through incremental additions to fisheries advice in ACFM and in relation to ecosystem health and specific issues through ACE. In 2004 ICES took an approach of integrating ACFM and ACE advice by restructuring it on an ecosystem basis, by including relevant known ecosystem aspects in the fisheries advice and by integrating responses to requests regarding ecosystems and fisheries. In 2005 it is expected that environmental advice will be integrated in the same way.

ICES is also pursuing a holistic approach recently centered on the development of Ecological Quality Indicators (EcoQOs). This work is carried out jointly with the Oslo -- Paris commission (OSPAR) and has been based on OSPAR's 2003-2005 work programme for the North Sea Pilot Project on Ecological Quality Objectives. ICES has proposed the use of ten Ecological Quality Objectives that are part of the North Sea Pilot Project, see Table 1 (Lassen and Griffith 2005).

ICES is working on this with the Regional Environmental Commissions (OSPAR and HELCOM). The OSPAR Ministerial Conference in Bremen in 2003 also agreed on further measures to expand existing OSPAR policy. Of particular note is the agreement to pursue the protection of marine biodiversity in ecosystems by establishing a network of Marine Protected Areas Working in collaboration with HELCOM and the EC. The first set of such areas is to be identified by 2006, with the aim of establishing an ecologically coherent network by 2010. OSPAR Ministers also expressed particular concern about cold-water coral reefs and resolved to take immediate action to protect vulnerable coral reefs from further damage due to the use of active fishing gear on the reefs.

Development of ecosystem-based management is a key objective of the European Marine Environment Strategy (EMS) which the European Commission has been developing

since 2002 in cooperation with OSPAR, HELCOM, and ICES. During 2003-2004 a core group set up jointly by ICES and the European Commission prepared a document entitled ”Guidance on the Application of the Ecosystem Approach to Management of Human Activities in the European Marine Environment” as an input to the development of the EMS (European Commission 2004). A stakeholder conference convened in Rotterdam in November 2004 concluded that the document covers all issues relevant to starting work at the regional level. The conference also endorsed the approach (objectives supported by indicators, limits, reference points and targets) as the appropriate way forward.

This document contains a good section on defining objectives, indicators limits and targets. It makes the point that unambiguous ecological and operational objectives are needed to underpin the implementation of an ecosystem approach. At all scales ecological and operational objectives should be SMART:

(1) Specific. Objectives should clearly specify the state to be achieved , and be interpreted unambiguously by all stakeholders.
(2) Measurable. Good objectives should relate to measurable properties in ecosystems and human societies so that indicators and reference points can be developed to measure progress toward the objectives.
(3) Achievable. Good objectives should not be in conflict.
(4) Realistic. Good objectives will be implemented using the resources available to managers and stakeholders.
(5) Time bound. There should be a clearly defined time scale for meeting objectives (EC 2005).

Although this document is focused on broader environmental/ecosystem issues rather than specifically on fisheries, I recommend it as background reading for those attempting to apply an ecosystem approach in fisheries. I have extracted one diagram dealing with the Strategic Goal of Ecological Health which illustrates nicely the hierarchical concepts of Strategic Goals, Ecological Objectives , Ecological Sub-objectives , Indicators and Targets (Fig.8).

INCORPORATING ECOSYSTEM CONSIDERATIONS INTO MANAGEMENT DECISIONS BY REGIONAL FISHERIES MANAGEMENT ORGANIZATIONS (RFMOs)

As we have seen, incorporating ecosystem considerations into fisheries management is not a simple task, even for marine ecosystems whose management falls entirely under one jurisdiction. The challenge is even greater when managing fisheries in marine ecosystems which cross the boundaries of national fisheries jurisdiction (straddling stocks) or lie entirely beyond national jurisdiction on the high seas.

UNFA clearly envisages that Regional Fisheries Management Organizations responsible for the management of straddling and highly migratory fish stocks will take ecosystem considerations into account when making fisheries management decisions. Straddling fish stocks do not carry passports. Similarly, the marine ecosystems upon which fish species depend for survival know not the boundaries drawn by humans. Hence, a holistic

approach to the management of human activities on such species and ecosystems is necessary.

As the first international commission which has explicitly incorporated ecosystem considerations into its mandate and *modus operandi*, CCAMLR provides a useful reference point for other RFMOs moving forward to embrace the challenge of a more holistic ecosystem approach to fisheries management. The particulars of how this is done will, of course, vary from one RFMO to another.

The FAO Guidelines on an Ecosystem Approach to Fisheries could serve as a starting point for discussions on how a particular RFMO might start taking ecosystem considerations into account in its decision-making process. To take one example close to the heart of the Conference in St. John's, it is obvious that the Grand Banks ecosystem has undergone profound changes over the past couple of decades. It is possible that some of these changes are irreversible. Many groundfish stocks are at extremely low levels of abundance. In contrast, invertebrate species such as shrimp and crab have surged in abundance. How can an RFMO like the Northwest Atlantic Fisheries Organization (NAFO), which has been focused on single species management, act to take ecosystem considerations into account in managing these and associated and dependent stocks?

First of all, an organization like NAFO needs to decide explicitly that it will take ecosystem considerations into account in its decision making. Then it will have to agree to a process as to how this will be done and on the principles that will be applied. Having decided on a set of principles and objectives, it would then have to decide on how these can be translated into specific, tractable and effective management actions.
As Jennings (2004) observed, the most effective progress towards an ecosystem approach is likely to be achieved by integrating the useful aspects of existing approaches into new ones. The most significant and cost-effective progress towards the ecosystem approach is likely to be achieved by reorientation of existing science and management tools. In this context, effective change is more likely to be evolutionary than revolutionary.

CONCLUSIONS

In recent years the concepts of ecosystem-based fisheries management (EBFM) or an ecosystem approach to fisheries (EAF) have been hailed by many as a panacea for the problems confronting world fisheries. This is a simplistic and mistaken view of what EBFM/EAF can contribute to the management of global fisheries**.**

Over the past 10-15 years there has been a growing move to incorporate the need to take ecosystem considerations into account in fisheries management into international legal instruments and national legislation and policies. As an example, UNFA make several references to ecosystem considerations and issues. However, the concept of ecosystem-based fisheries management is not codified in UNFA to the same extent as the Precautionary Approach, which is clearly articulated there with definitions of standards, limits and reference points. Of course, a Precautionary Approach is an essential element of an ecosystem approach to fisheries management even though views of what the latter means, and how it might be applied, can differ widely.

Indeed, while there has been general agreement on the need to take ecosystem considerations into account in fisheries management, there is no clarity or consensus on how this might best be done. There are a wide variety of definitions of an ecosystem approach to fisheries management. An ecosystem approach means different things to different people.

One of the most widely accepted definitions is that proposed by the Ecological Society of America, which outlined the major elements of ecosystem management as follows:

- Long-term sustainability as a fundamental value;
- Clear operational goals;
- Sound, more ecological models and understanding;
- Understanding complexity and interconnectedness;
- Recognition of the dynamic character of ecosystems;
- Attention to context and scale;
- Acknowledgment of humans as ecosystem components; and .
- Commitment to adaptability and accountability.

The US Ecosystem Principles Advisory Panel (NOAA 1999) developed the following set of operating principles for an ecosystem-based fisheries management approach:

- The ability to predict ecosystem behavior is limited.
- Ecosystem have real thresholds which, when exceeded, can effect major system restructuring.
- Diversity is important to ecosystem functioning.
- Multiple scales interact within and among the ecosystems.
- Components of ecosystems are linked.
- Ecosystem boundaries are open.
- Ecosystems change with time.

There are two extremes. One can approach management from the perspective of the entire ecosystem, or from a single species approach that takes into account broader ecosystem considerations.

The FAO (2003) has defined an ecosystem approach to fisheries as follows:

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

It stressed that an EAF is a holistic approach. In effect, it defined an EAF as sustainable development for fisheries.

It also proposed a set of principles that should be taken into account in implementing an EAF:

- Fisheries should be managed to limit their impact on the ecosystem to the extent possible;
- Ecological relationships between harvested, dependent and associated species should be maintained;
- Management should be compatible across the entire distribution of the resource (across jurisdictions and plans) ;
- The precautionary approach should be applied because the knowledge on ecosystems is incomplete; and
- Governance should ensure both human and ecosystem well-being and equity.

These principles provide more guidance than the FAO definition of an EAF, which is somewhat fuzzy.

While there are differing views and terminology on what ecosystem-based fisheries management means, one thing is clear. We are not talking about managing ecosystems. Rather, we are talking about managing the human activities that are part of, and impact on, marine ecosystems.

One key issue is how to translate high-level principles and objectives into action. There is a need to subdivide objectives into manageable "chunks" and to set operational objectives, develop indicators and reference points, develop decision rules on how the management measures are to be applied, and then to monitor and evaluate performance. (FAO 2003)

Unfortunately, this is easier said than done. There is a vast and growing literature on the question of setting operational objectives, indicators and reference points for incorporating ecosystem considerations into fisheries management. A number of authors/groups have concluded that, while there are numerous potential metrics (measures) available, the use of performance measures for a single or a small selection of ecosystem metrics is not possible at present. This is due to the absence of a clear understanding of ecosystem dynamics and a lack of underlying theory to explain the behavior of these ecosystem metrics. There are dissenting voices (e.g. Sainsbury and Sumaila,2003; Babcock and Pikitch 2004) which argue that fisheries science is approaching a state of knowledge in which EBFM based on ecosystem metrics is technically feasible , and that it seems possible to derive a single metric, incorporating both economic goals and ecosystem health that could replace single-species control rules. While that may indeed be possible someday, we seem to be a long way at the moment from EBFM that includes ecosystem-based metrics and predictive models. Indeed, Hall's (1999) conclusion that, given current levels of understanding about marine ecosystems, it is difficult to identify key interactions between species, let alone manage for them, still seems valid.

Given this, what is the best way forward? The best way forward may be to build on existing successful single species approaches and expand them into an ecosystem approach to fisheries management. Realistically, we can only move to an ecosystem approach incrementally, starting with more rigorous (usually more cautious) application and extension of single species methods. This is recognized in the FAO Guidelines for an EAF which stress that EAF is neither inconsistent with, nor a replacement for, current

fisheries management approaches and is likely to be adopted as an incremental extension of current fisheries management approaches. Others have also argued that expansion of single species reference points to take account of non-target species is a reasonable approach to pursue.

This, in effect, is the approach that is being pursued in the three examples mentioned earlier-CCAMLR, Gulf of Alaska, and ICES advice for the North Sea. For example, in the Gulf of Alaska example, they have acted, without waiting for perfect models of the interactions among all components of the ecosystem, by:

- Setting a cap on total groundfish yields less than the sum of the potential individual Allowable Biological Catches;
- Imposing restrictions on the incidental take of short-tailed albatross and introducing seabird by-catch mitigation devices;
- Prohibiting fishing in Stellar sea lion foraging areas and establishing a minimum biomass threshold for sea lion prey; and
- Prohibiting bottom trawling on large areas of the Continental shelf, e.g. to protect deep-water corals.

Meanwhile, they are developing and monitoring various ecosystem status indicators, such as seabird population trends, measures of environmental fluctuations, measures of the fish community size spectrum, the status of structural habitat biota, and population trends of non-target fish species.

Similarly, in the Northeast Atlantic, ICES advice on fisheries management is a three-step process where:

- Single stock exploitation boundaries are identified first.
- Then mixed fisheries issues are addressed. Stocks that are in the most critical state may determine the advice for those stocks that are taken together with critical stocks.
- The final consideration regards ecosystem concerns, which are related to mixed fisheries or groups of stocks. Such concerns may include habitat and biota impacts of bottom trawling, incidental by-catches of non-target species, and food chain effects when such impacts are known to occur. These may impose further constraints on single species yields. (ICES 2004)

As Sissenwine and Mace (2003) observed, there is an erroneous widespread view that we need an ecosystem approach because single species fisheries management has failed to prevent undesirable outcomes such as overexploitation and depletion of many stocks. In reality, these undesirable outcomes usually result from failure to apply the scientific advice being given on single species approaches. Invoking ecosystem considerations should not become a crutch for failing to implement clear- cut single species fisheries management advice (Link 2002).

In conclusion, while moving forward incrementally to incorporate ecosystem considerations into fisheries management is a desirable and necessary step toward improved fisheries management, this does not negate the need to move forward aggressively to address the worldwide problem of excessive fishing capacity and fishing

effort, the root cause of overfishing. Various analyses suggest that advice resulting from the explicit incorporation of ecosystem effects will further emphasize the need for conservative management of fishing capacity, e.g. Murawski (2000). A key element of any ecosystem approach will likely be to set harvest rates for target species at even lower conservative levels than might be suggested by single species analysis. This is exemplified by the description of the approach being pursued in the Gulf of Alaska as "conscious under-exploitation of fish resources" to protect overall ecosystem processes, ecosystem integrity and biodiversity.

Reducing the killing power/overcapacity of the world's fishing fleets is an essential first step towards ecosystem-based fisheries management.

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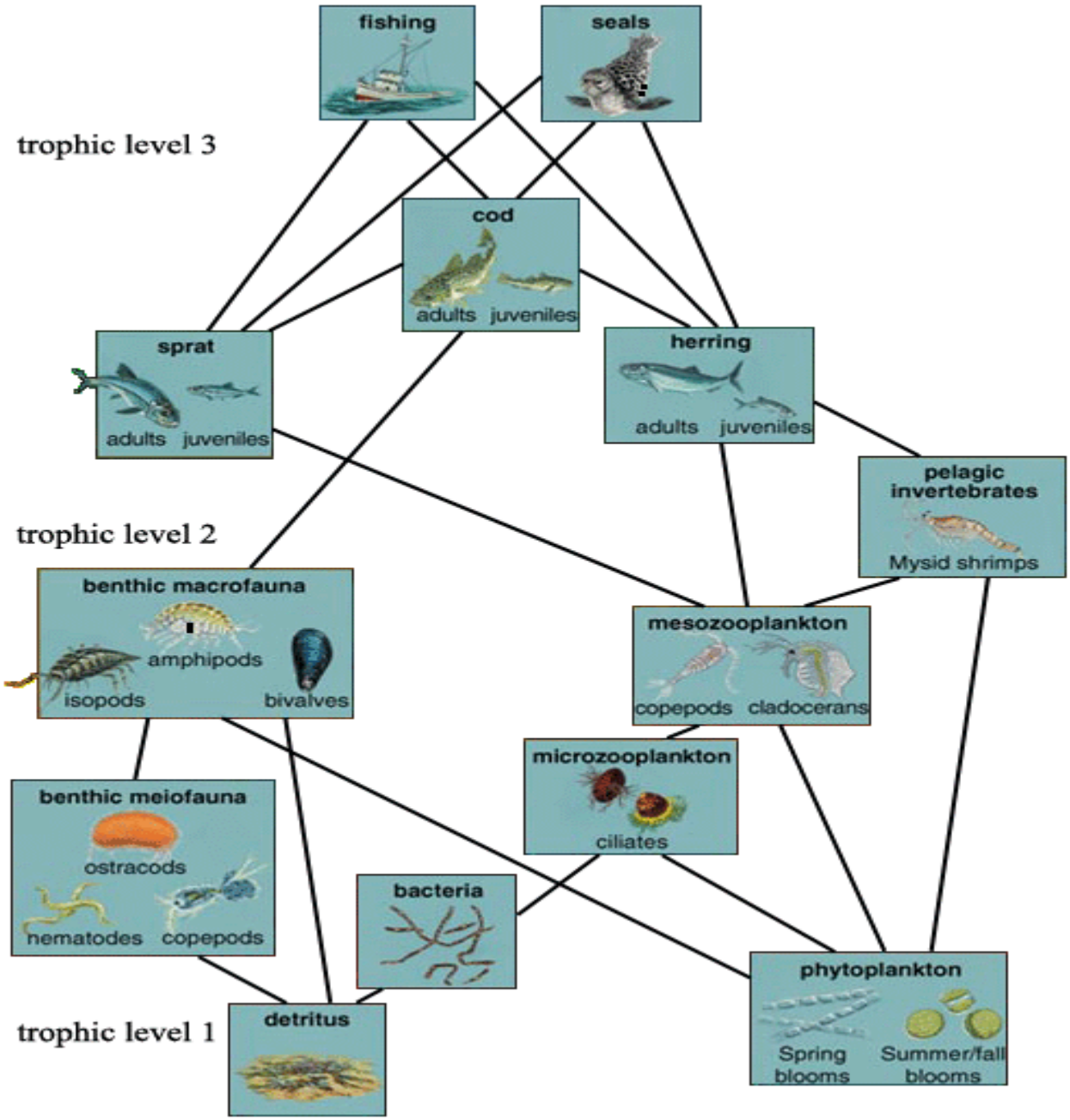


Fig. 1. Illustration of a typical marine ecosystem (adapted from Zabel et al 2003)

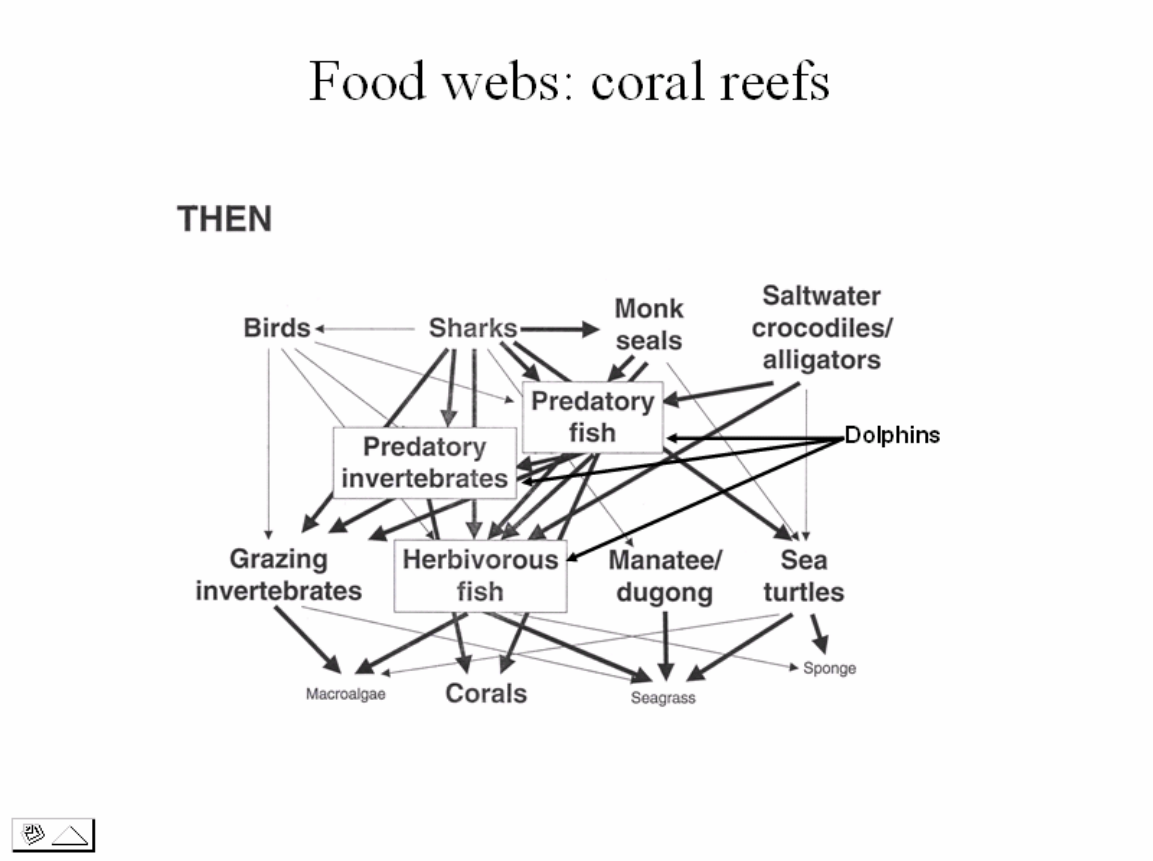


Fig. 2. Simplified illustration of a Caribbean coral reef marine ecosystem (adapted from Bascompte et al 2005).

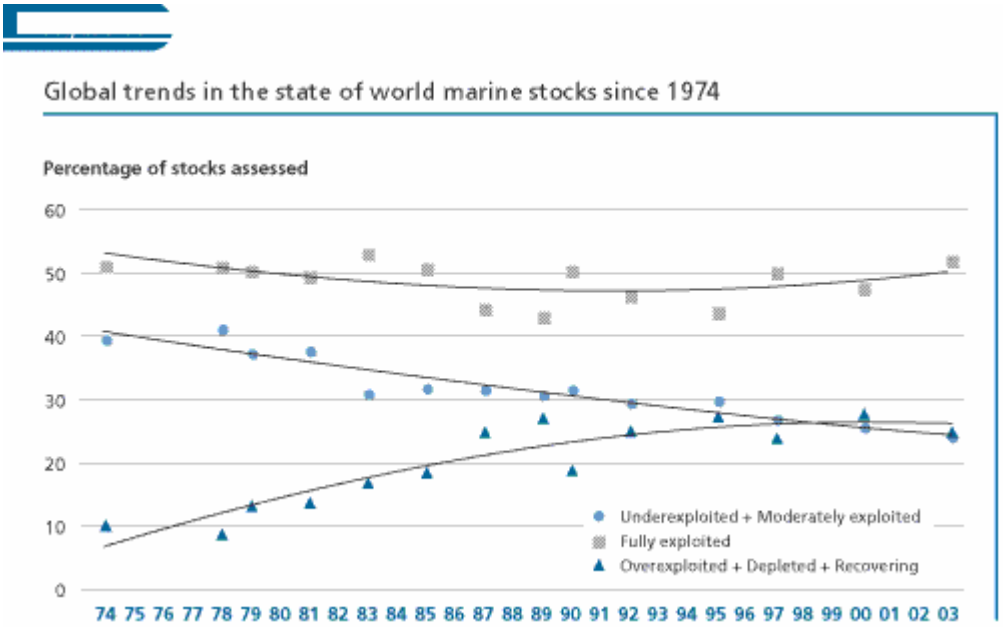
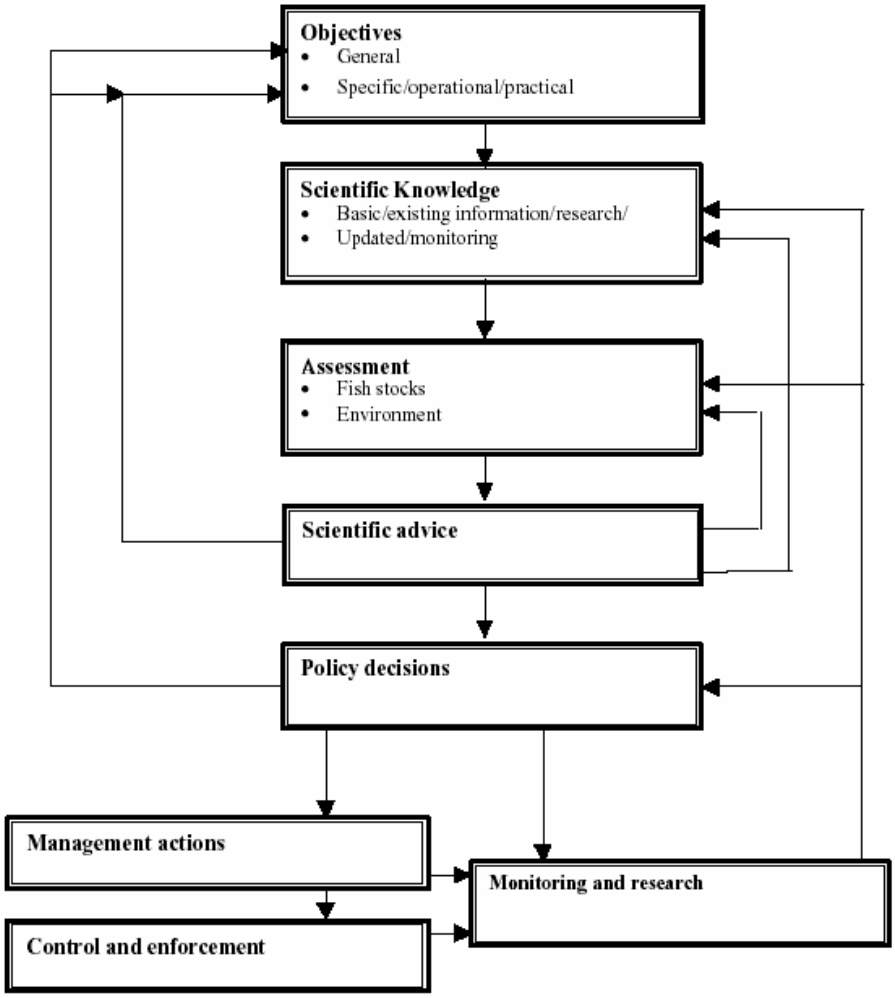


Fig. 3. Trends in the proportion of overexploited and depleted stocks (FAO 2004)

ANNEX 2

A conceptual framework for an Ecosystem Approach[7] to the management, protection and restoration of the North Sea. Stakeholders, along with scientists, managers and politicians, should be involved at different stages of the decision process to promote openness, transparency and responsibility



[7] ICES working definition of Ecosystem Approach: Integrated management of human activities based on knowledge of ecosystem dynamics to achieve sustainable use of ecosystem goods and services, and maintenance of ecosystem integrity'.

Fig. 4. A conceptual framework for an ecosystem approach to the management, protection and restoration of the North Sea (Bergen Declaration 2002, Annex 2).

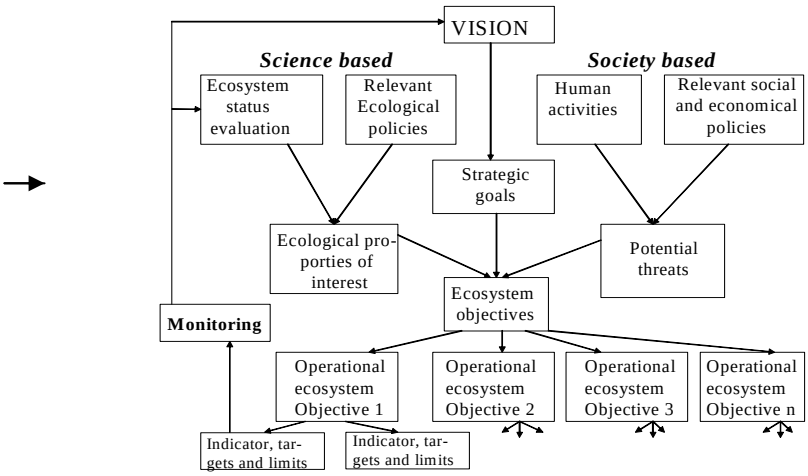


Fig. 5. A possible ecosystem approach at the regional scale (adapted from Hagstrom 2004)

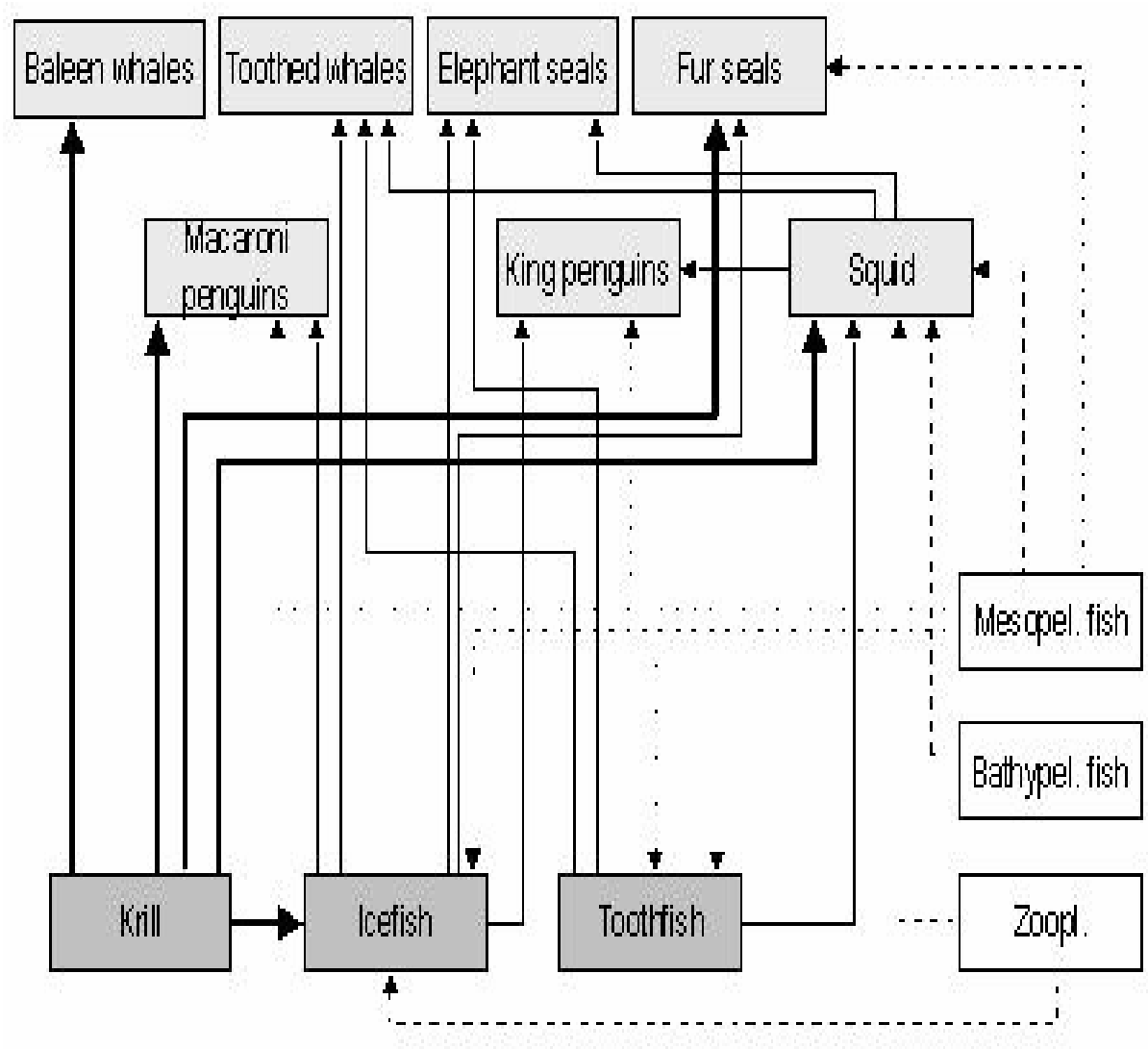


Fig. 6. Illustrative structure of the food web in the marine Antarctic, including the fisheries for krill, Patagonian toothfish, and mackerel icefish. Dark grey boxes represent fished species, the light grey boxes predators of fished species and the white boxes other types of prey. (Adapted from Constable 2004)

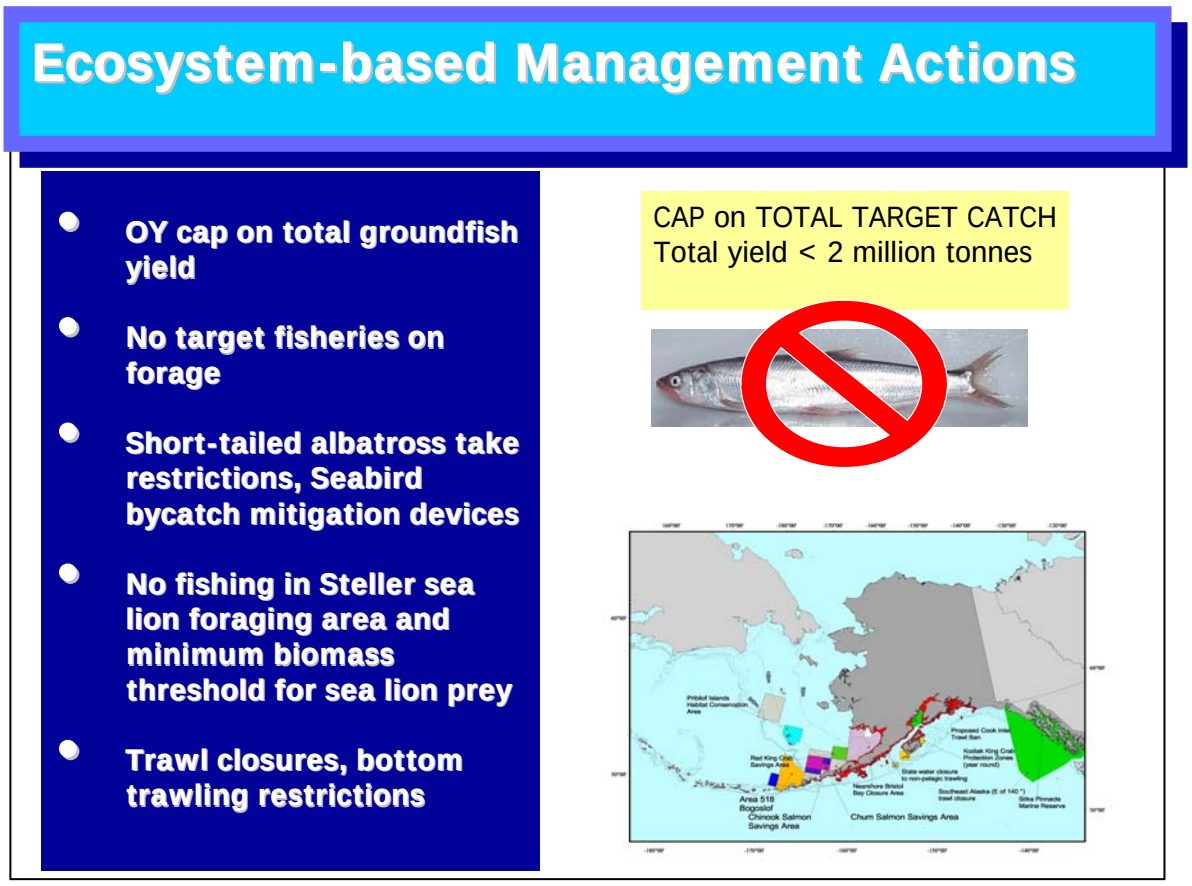


Fig. 7. Ecosystem-based management actions in the Gulf of Alaska (adapted from Livingston 2005)

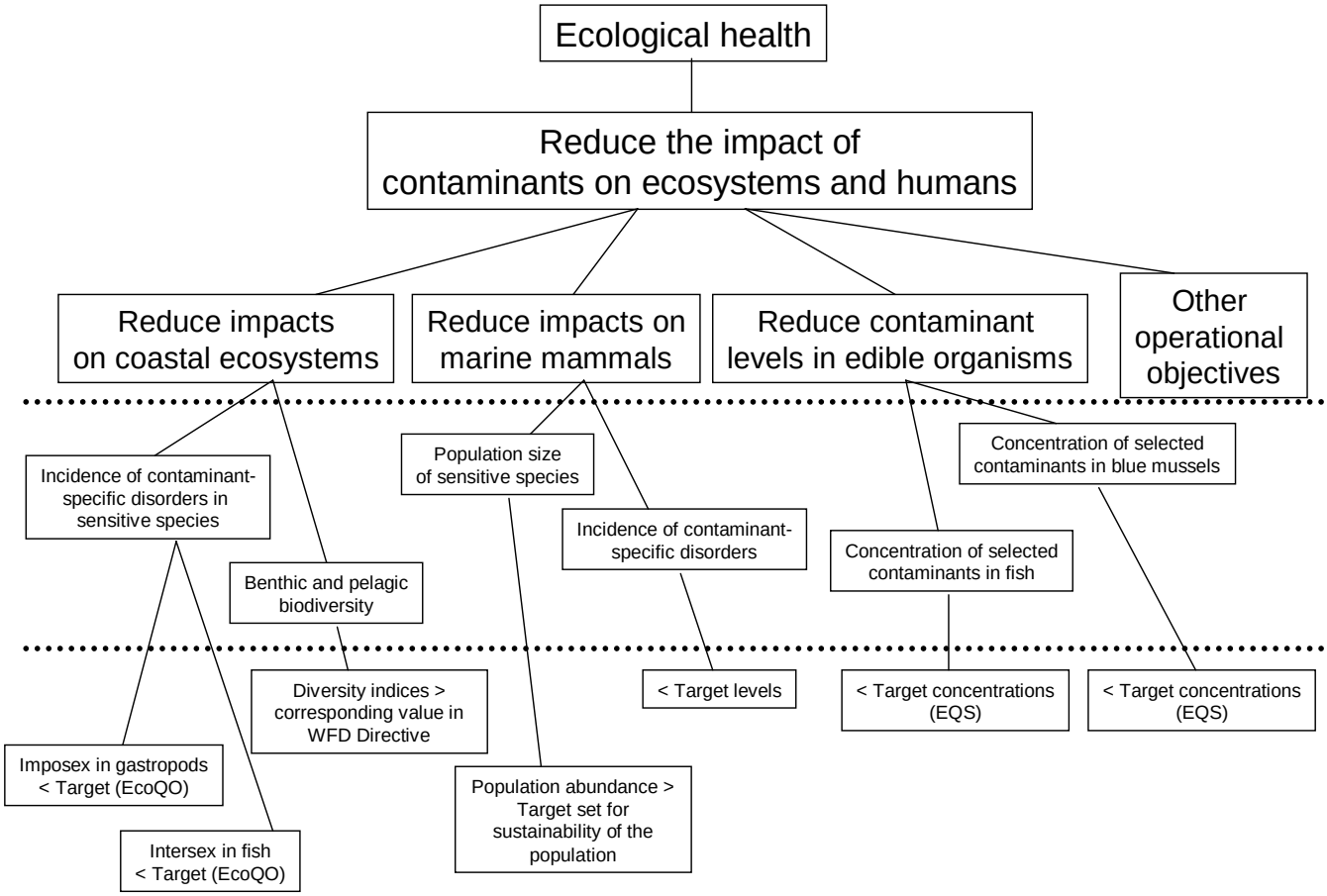


Fig. 8. Illustration of the hierarchical concepts of Strategic Goals, Ecological Objectives, Ecological sub-objectives, Indicators and targets (From European Commission Discussion Document on European Marine Strategy 2004)

The 5 vertical levels in the diagrams reflects (top –down) 1. Strategic Goals; 2. Ecological Objectives; 3 Ecological Sub-Objectives; 4. Indicators; 5. Targets

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Issue	Ecological quality element
1. Commercial fish species	**(a) Spawning stock biomass of commercial fish species in the North Sea**
2. Threatened and declining species	(b) Presence and extent of threatened and declining species in the North Sea
3. Sea mammals	**(c) Seal population trends in the North Sea** (d) Utilisation of seal breeding sites in the North Sea **(e) By-catch of harbour porpoises**
4. Seabirds	**(f) Proportion of oiled Common Guillemots among those found dead or dying on beaches** (g) Mercury concentrations in seabird eggs and feathers (h) Organochlorine concentrations in seabird eggs (i) Plastic particles in stomachs of seabirds (j) Local sand-eel availability to black-legged Kittiwakes (k) Seabird population trends as an index of seabird community health
5. Fish communities	(l) Changes in the proportion of large fish and hence the average weight and average maximum length of the fish community
6. Benthic communities	**(m) Changes/kills in zoobenthos in relation to eutrophication** **(n) Imposex in dogwhelks (*Nucella lapillus*)** (o) Density of sensitive (e.g., fragile) species (p) Density of opportunistic species
7. Plankton communities	**(q) Phytoplankton chlorophyll *a*** **(r) Phytoplankton indicator species for eutrophication**
8. Habitats	(s) Restore and/or maintain habitat quality
9. Nutrient budgets and production	**(t) Winter nutrient (DIN and DIP) concentrations**
10. Oxygen consumption	**(u) Oxygen**

Table 1. Elements of ecological quality (Bergen Declaration 2002).