FRM 599 – CREDIT SEMINAR (1+0)

CREDIT SEMINAR ON
ECOSYSTEM BASED FISHERIES MANAGEMENT

SUBMITTED
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2016

INTRODUCTION

Ecosystems play an important role in human societies by providing services that directlyor indirectly benefits humans. However, there is growing evidence that ecosystems are being negatively affected by humanpressures such as overfishing, eutrophication, toxic pollution, and habitat degradationOverfishing is a typical exampleof humanity’s impacts on marine ecosystems. Many marine fisheries are sufferingfrom a combination of recruitment overfishing and growth overfishing of fish stocks1 andthe overcapacity of fishing fleets. In 2010, the Food and Agriculture Organizationestimated that 85% of the world’s marine fish stocks were either fully exploited, overfished, or had collapsed (Food and Agriculture Organization 2010). The global marinefishing fleet was estimated to be more than two and a half times the size that the oceanscan sustainably support. The rent loss due to overfishing was globally estimatedto be about $50 billion annually (World Bank 2009). In addition, the ocean’s productivityhas also been declining because of marine environment degradation and interference with ecosystems through pollution.87% of the world's wild-caught fisheries are fully exploited, overexploited or depleted.

According to NOAA’s Strategic Plan, the definition of an **ecosystem** is “a geographicallyspecified system of organisms (including humans), the environment, and the processes thatcontrol its dynamics” (NOAA Strategic Plan, 2004). An **ecosystem approach tomanagement** is one that is “geographically specified, adaptive, takes account of ecosystemknowledge and uncertainties, considers multiple external influences, and strives to balancediverse societal objectives” with implementation needing to be “incremental andcollaborative” (NOAA Strategic Plan, 2004). The U.S. Ocean Action Plan prescribes that ifEAM is not undertaken, then management of the Nation’s coastal and marine resources willcontinue to be insufficient to handle current and future ecosystem stressors.The transition to an ecosystem approach to management needs to be incremental andcollaborative. Although scientists have been studying ecosystem processes for decades, long term scientific research is still needed. Ecosystems provide multiple benefits, and are vital to human wellbeing. Many of these benefits, such as clean air to breathe, fresh water to drink,fuel for warmth and cooking, and food to eat, have historically been free to all humans as theresult of the working of nature. However, many of these ecosystem services are over-used,mismanaged, or degraded. NOAA's transition to an EAM is a large step towards sustainable managing the Nation's resources.

HISTORY OF ECOSYSTEM APPROACHES TO MANAGEMENT

In 1995, Vice President Gore's National Performance Review called for agencies of the federal government to adopt a proactive approach to ensuring a sustainable economy and environment through principles of ecosystem management (Interagency Ecosystem Management Task Force, 1995). The Interagency Ecosystem Management Task Force was established in August of 1993 to carry out this mandate. The Task Force formed a working group which conducted case studies to learn about ecosystem efforts to date, to identify barriers toimplementing the ecosystem approach, and to identify ways the federal government could assist in overcoming these barriers. Currently, twenty-one federal agencies, including NOAA, have committed to the principles of ecosystem management. Numerous international agencies and groups have adopted EAM strategies in their conservation and management efforts. For example, the International Conservation Union (IUCN) Commission on Ecosystem Management (CEM) was one of the first agencies to articulate the notion of sustainable use of ecosystems. The IUCN's CEM aims to enhance understanding and to promote conservation and sustainable use in an equitable way (Convention on Biological Diversity, 2003). The underlying principles advocated by CEM are to strive for flexibility to address management issues in different social contexts.

DEFINITIONS OF ECOSYSTEM APPROACHES TO MANAGEMENT

Since EAM's inception, numerous scholars, environmental managers, and conservationgroups have developed EAM definitions to fit their respective needs and missions and withvarying philosophies. Listed below are some of the major EAM definitions found in theliterature; these definitions illustrate the range of interpretations different groups have madetowards EAM:

…integrating scientific knowledge of ecological relationships within a complex sociopoliticaland values framework toward the general goal of protecting native ecosystem integrity overthe long term (Grumbine, 1994).

…ecosystem and natural habitats management seeks to meet human requirements to usenatural resources, whilst maintaining the biological richness and ecological processesnecessary to sustain the composition, structure and function of the habitats or ecosystemsconcerned (The United Nations Convention on Biological Diversity, 1992).

…to restore and sustain the health, productivity, and biological diversity of ecosystems andthe overall quality of life through a natural resource management approach that is fullyintegrated with social and economic goals (Interagency Task Force on EcosystemManagement, 1995).

…managing ecosystems so as to assure their sustainability (Franklin, 1994).

… is a strategy for the integrated management of land, water and living resources thatpromotes conservation and sustainable use in an equitable way (IUCN, 2000).

…is an integrated approach to management that considers the entire ecosystem, includinghumans.

NEED OFECOSYSTEM BASED FISHERIES MANAGEMENT

The collapse of many marine fisheries is widely believed to be the result of mismanagement. The mismanagement of marine fisheries is not only dueto poor enforcement but also because marine fishery management traditionally focusses on managing a single target species and often ignores habitat, predators, the prey of thetarget species, and the physical components of marine ecosystems.The conventional single-species marine fishery management approach has failed and new approaches are needed. A major element of the proposed new approach is a move from the conventionalsingle-species marine fishery management to ecosystem-based marine fisherymanagement (EBFM), which seeks to include in the management plan not only all affectedspecies but also abiotic factors such as water pollution, the effects of weather andclimate on the ecosystem, and the effects of fishing activity on the habitat itself. An ecosystem approach has been viewed in many ways.In addition, management, regardless of the context is driven by human values and whatpeople care about. Thus, the values by which an ecosystem is managed will vary widely,depending on where a person is in the world—the environmental setting of the ecosystem,political context of the relevant agencies, and economic prosperity of the local communities.It is hard to find a standardized approach that fits all possible situations. As a result,the concept of EBFM is still evolving and has no universal definition or consistent application. Ecosystem-basedmarine fishery management has also been criticized as being nonspecific, immature, invalidas a basis for decision making, and not fully supported by science.

BASIC ECOSYSTEM PRINCIPLES AND GOALS

Based on the Panel's experience and review of the fisheries ecosystem literature, we suggest that the following Principles, Goals and Policies embody key elements for ecosystem-based management of fisheries.

PRINCIPLES

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

GOALS

The goal is to maintain an ecosystem in a healthy, productive and resilient conditions that it can provide the services humans want and need. A wealth of literature has been written on both the interpretation of EAM and practical considerations in implementing EAM strategies, although most conservation biologists and practitioners of natural resource management have accepted EAM as an emerging philosophy. Grumbine (1994) examined current and past literature on EAM and identified five main goals of EAM that have been dominant in the scientific literature:

- Maintain viable populations of all native species.
- Represent (with protected areas) all native ecosystem types across their natural range
- of variation.
- Maintain evolutionary and ecological processes.
- Maintain the evolutionary potential of species and ecosystems.
- Accommodate human use and occupancy.

ECOSYSTEM-BASED MARINE FISHERY MANAGEMENT

Managers are now considering ecosystem-based management approaches because of theincreasing pressures that coastal and marine ecosystems face.3 Ecosystem management isa framework that has been officially implemented in the United States since the early 1990s. Fundamentally, ecosystem management consists of managing ecosystemsto assure their sustainability (Franklin 1997). Ecosystem management is a responseto deepening loss of important ecosystem qualities, such as biodiversity and fish yields,and is still a evolving concept. Grumbine (1994) summarized 10 dominant themes of ecosystem management:

- Hierarchy
- Ecological boundaries
- Ecological integrity
- Data collection
- Monitoring
- Adaptive management
- Interagency co-operation
- Organizational change
- Humans embedded in nature
- Values

These 10 themes form the basis of a working definition:

Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward thegeneral goal of protecting native ecosystem integrity over the long term. Ecosystem services may include the followingservices

- Provisioning services are products that people take from the ecosystems, such asfish and fuel.
- Regulating services are benefits that people gain from the regulation of ecosystemprocesses, such as air quality maintenance and climate regulation.
- Cultural services are nonmaterial benefits people obtain from ecosystems, suchas recreational, spiritual, and religious benefits.
- Supporting services are those that are necessary for the production of all otherservices, such as primary production and nutrient cycling

In an effort to accelerate the ongoing paradigm shift in fisheriesscience from the traditional single-species mindset toward more ecosystem-based approaches, we offer the following “commandments” as action items for bridging the gap between general principles and specific methodologies.

1. Keep a perspective that is holistic, risk-averse, and adaptive.
2. Question key assumptions, no matter how basic.
3. Maintain old-growth age structure in fish populations.
4. Characterize and maintain the natural spatial structure of fish stocks.
5. Characterize and maintain viable fish habitats.
6. Characterize and maintain ecosystem resilience.
7. Identify and maintain critical food web connections.
8. Account for ecosystem change through time.
9. Account for evolutionary change caused by fishing.
10. Implement an approach that is integrated, interdisciplinary, and inclusive.

The ecosystem-based approach has more recently been applied in marine fisheries management, compared to other sectors such as land or forestry management. Ecosystem-based fishery managementhas been defined as “a holistic approach to maintaining ecosystem quality andsustaining associated benefits” (National Marine Fisheries Service 1998; Brodziak & Link 2002). The term ecosystem-based management is clearly relevant to fishery systems becausefish products are important provisioning ecosystem services. Therefore, the conceptof EBFM is also developing and has no universal definition or consistent application. Arkema et al. (2006) reviewed the definitions of marine ecosystem-based management (including EBFM) and found that scientists used 17 criteria todescribe an ecosystem-based approach. These criteria were divided into three categories:
1) ecological factors, 2) the human dimension, and 3) management. Ecological criteriafocus on one or more aspects of ecosystem complexity, such as the composition, structure, and function of ecosystems. Ecological criteria also recognize that ecological processesoccur on multiple temporal and spatial scales. The human dimension integrates economicfactors and stakeholders into the ecosystem planning processes. Management criteria includeco-management and the precautionary approach, as well as the use of science and technology. Thus, ecosystem-based management and EBFM are different,but complementary. Ecosystem-based management is viewed in a broader contextand applied in managing across sectors, whereas EBFM is applied in managing only thefishing sector.

COMPONENTS OF ECOSYSTEM APPROACHES TOMANAGEMENT

Although definitions of EAM vary depending on discipline and infrastructure (i.e., local,state, federal, academic), a general consensus on the meaning of EAM has developed in thelast decade. The International Conservation Union (IUCN) and Grumbine (1994) identifiedthe following 10 dominant components to an EAM:

1) Hierarchical Context: Biodiversity must be examined on multiple scales in order toseek the connections between all levels (ecosystems, landscapes, etc.). An EAMreflects a departure from traditional species-level management schemes and embraces the complexity of ecosystems by utilizing contextual thinking to solve multidimensional ecosystem problems. Different spatialand temporal scales must also be given extensive consideration.

2) Ecological Boundaries: First, the complexities of ecosystem boundaries (includingsub-ecoregions) must be defined based on current political, ecological, andgeographic boundaries. Some boundaries do not occur naturally but are a humanconcept imposed for the purpose of quantifying what goes on inside the chosensystem (Pirot et al., 2000). When defining ecological boundaries, ecological featuresshould be characterized using ecosystem indicators to identify major factors andstressors that affect ecosystem health and productivity. Clar (1999) identified twomain challenges to defining boundaries: a lack of knowledge on ecosystem functionand the fact that human demand often exceeds management possibilities on bothspatial and temporal scales.

3) Ecological Integrity: The usage of sound ecological models can facilitate our understanding of ecological boundaries and an understanding of what constitutes sound ecological integrity. The best current models of ecosystem function should bethe basis for ecosystem management. An emphasis on the interconnections and basic ecological principles of a system should be a major focus of EAM in order to maintain ecological integrity.

4) Data Collection: Managers must identify research and information needs and develop a data collection system that integrates data (both information andmonitoring data) from various stakeholders. In order to integrate data from stakeholders, managers must first cultivate working relationships with outside agencies and work to identify appropriate expertise for supplying data for management goals. Grumbine (1997) emphasizes that data collection should not only focus on science, but also on the social factors related to resource management.

5) **Monitoring:** Results of management must be systematically monitored using clear,operational goals that are explicatively stated in terms of specific "desired futuretrajectories" for the ecosystem. It is important that these goals be stated in

terms thatcan be measured and monitored and, most importantly, that monitoring programsfocus on long-term goals.

6) Adaptive Management: Managers must decide on how to implement plans and achieve long-term goals, including ways to implement management based on lessonslearned from previous action. Management must be viewed as experimental andallow managers to remain flexible, adapt to uncertainty, evaluate the significance ofchange, and establish appropriate mechanisms to periodically reconsider project aimsand objectives (McNeely, 2003).

7) Cooperation: Interagency cooperation is essential in order to integrate managementgoals and legal mandates. Such cooperation is also based on the identification ofstakeholders based on shared concern for a problem. Sharing power amongstcooperating agencies will facilitate the development of interagency relationships.

8) Organizational Change: EAM requires significant deviation from traditional species-focused management; therefore, the structure of management agencies needsto also reflect the priorities of EAM. For example, NOAA recently reorganized toreflect different "goals," one of which was the Ecosystem Goal. This reorganizationreflects NOAA's desire to align its scientific expertise with various aspects ofecosystem science.

9) Humans as Part of Nature: An EAM must identify the economic issues, humanbenefits, incentives, and values that will affect the ecosystem and its inhabitants.Humans are fundamental influences on ecological processes and patterns and in turnare affected by ecosystems; thus, human values play a dominant role in EAM goals.

10) Values: The ideals of stakeholders are an important consideration when developingan EAM. Grumbine (1994) concludes that the main long-term implication of the concept of EAM is a transformation of personal and social values towards a moreintegrative and holistic way of thinking. An EAM must take into account thenaturally varying values of stakeholders and values must also be acknowledged andrespected during the planning process.

ADDRESSING ECOSYSTEM-BASED FIHERIES MANAGEMENT

In recent years, there have been many calls for much wider use of MarineProtected Areas to address the need for ecosystem-based management. The useful part of fishery regulation, but they are not a universal solution because unless the basic issues of capacity, regulation, and rights are solved, protected areas willsimply displace the problem elsewhere. In recent reviews that emphasize the primary importance of conventional measures to control fishing mortality and the secondary but essential role that marine protected areas (or other area-based management, such as local prohibitions on particular gears such as bottom trawls) have in dealing with specific issues of ecosystem conservation, such as bycatch and habitat damage. The simple creation of rights-based incentives does not automatically deal with ecosystem problems, because fishers have little incentive to minimize bycatch or habitat damage that does not affect their target species. An interesting recent development is the creation of additional incentives for fishers through market measures, such as the creation of sustainable fisheries certification schemes and pressure from environmental nongovernmental organizations for responsible fisheries. Fishers have a major incentive to improve fisheries to satisfy certification conditions, and so far most of the conditions raised in Marine Stewardship Council certifications have concerned the ecosystem effects of fishing, often related to quantifying and reducing deaths of bycatch species and damage to habitat (see supporting online material). Even in the statistics documented for some of those states with appreciable management capacity,what is striking is for how many stocks, the status is uncertain or not determined. In the United States, the stock status of 30% of the 230 major (FSSI) stocks and stock complexes was undetermined in 2006; in Australia (48%), NewZealand (78%), and the Northeast Atlantic (61%), the numbers are even higher (38). Given the problems that most authorities have in deriving reliable quantitative assessments of their stocks of major commercial importance, the large numbers of small, commercially unimportant stocks present in most areas, usually as bycatch, cannot realistically be assessed. Under a comprehensive ecosystem approach, risk assessment methodologies should be used to identify those bycatch species in need of special measures, and monitoring programs, for instance usingscientific observers, need to be implemented to monitor trends in all bycatch species. The application of these approaches is in its infancy even in the most advanced management schemes; many simply respond by setting untested buthopefully precautionary effort or catch limits .These considerations apply evenmore strongly to fisheries operators in developing countries. In a situation of little or no management capacity, some form of bioeconomic equilibrium is the likely result, but in such cases the management priorities may be different. Indeed, high employment with relatively modest economic rent, as long as it is compatible with the sustainability of the resource, may be a perfectly legitimate management goal. In other cases, the development of Territorial Use Rights (TURFS) within local communities can lead to effective management control and rights-based operations, resulting in successful management.

ECOSYSTEM RESTORATION

The "restoration ecology" was not first formally identified and coined until the late 1980s, by John Aber and William Jordan .The idea of restoring the land dates back centuries, but modern restoration ecology and its practice began in the early 1900s when people such as renowned conservationist Aldo Leopold began promoting the movement. It has since grown to include a wide variety of ecological restoration activities that range from large-scale projects (e.g., of the Everglades, Louisiana wetlands, or the Mau Forest in Kenya) to small-scale projects (e.g., tree planting). It is a defining characteristic of ecological restoration that many projects are locally initiated and implemented by community volunteers. Because restoration projects generally involve complex collaborations and negotiations among a diverse group of interested parties, social science is an integral part of restoration at all scales. The study of restoration ecology has only become a robust and independent scientific discipline over the last two decades, and the commercial applications of ecological restoration have tremendously increased in recent years.

- **Restoration** – bring back to pre-disturbance condition
- **Rehabilitation** – partial replacement of original ecosystem
- **Enhancement** – alternative ecosystem

HABITAT RESTORATION

Habitat restoration seeks to repair areas that have been subjected to habitat destruction. Habitat destruction is one of the primary factors involved in causing species of plants and animals to be threatened with extinction. Activities important to maintaining civilization such as agriculture, development, mining, oil drilling, logging, and road building alter natural ecosystems. Habitat destruction can be obvious, such as clearing old-growth forests for timber and draining wetland areas to use the land for raising crops, but it can also be more insidious. Habitat destruction alters the normal abundance and distribution of species in the habitat. All of these types of disturbances require restoration if the land is to be viable in the future.

Habitat restoration is important for reasons varying from aesthetic and recreational to economic and pragmatic. Wild lands and wilderness have aesthetic properties that help to maintain mental health for millions of people every year. Restoring habitats can facilitate the return of wildlife to disturbed areas for its own sake or for the sake of recreational activities such as hiking, hunting, fishing, and birdwatching. Returning disturbed land to health can add to existing habitats, making them larger and thereby helping to protect species against the dangers of small population sizes. Restoring areas that have been damaged through human use can allow an area to be used again for another purpose. For example, areas that have been mined are often acidic and have high heavy-metal concentrations, making it difficult for native plants to be reestablished in the area. Restoring these areas can help to make the habitat healthy again. In the future, the same land could be available for timber harvesting or recreational parkland, or as a wildlife refuge. Healthy forests and riparian zones help control erosion and maintain good water quality in streams and lakes. Reforestation and restoring damaged riparian zones helps ensure clean drinking water, control floods, and maintain healthy fish and amphibian populations.

RESTORATION METHODS

Habitat restoration is accomplished through management, protection, and reestablishment of plants by returning abiotic factors (e.g., soil chemistry, water content, disturbance) and biotic factors (e.g., species composition, interactions among species) to historical levels. Properly restored ecosystems demonstrate the historical species diversity of the area instead of one species in monoculture. Reestablishing plants provides a food source for animals and thus helps restore animal populations. In reestablishing plants, soil conditions are very important, because they will determine what will grow and where. Soil moisture and mineral content, aeration, and presence of microorganisms are important factors that must be considered. Most plants are associated with fungi called mycorrhizal fungi (also called mycorrhizae), an association that is integral to a plant's system for absorbing nutrients and water. These fungi associate with the roots of the plants and help in gathering and transporting nutrients and minerals to the plant. These symbiotic relationships are often species specific, and this makes them essential in reestablishing native plants. Without their symbiotic fungi, many native plants are weak competitors with nonnative species. Therefore, it is often necessary to introduce the correct mycorrhizal fungus into the plants through inoculation. In addition, members of the soil community such as bacteria and earthworms, which create healthy soil food chains and aid in soil aeration, respectively, may also be added to disturbed habitat. Knowledge of the appropriate fungus, bacteria, and worm species for each habitat is necessary. The organisms must also be available for inoculation. In severely disturbed or unique habitats, knowledge of the proper organisms may not exist, or the organisms themselves may unavailable, resulting in an inability to restore the habitat properly. Situations where the native flora is intact but is not functioning normally because of human activities require management and protection to accomplish restoration. In some cases removal of dense underbrush and thinning young trees is necessary to restore a habitat to health. Another method to restore habitats is controlled fire. In habitats historically subjected to fire, some species require occasional fires to set seed and to thin out young trees that are otherwise stunted as a result of competing for limited resources. Without periodic fire the densely growing trees will be stressed and subject to pest outbreaks that do more damage than the fire.

Drainage patterns and soil water content can be altered to facilitate natural reestablishment of native vegetation. Large earthmoving machines can alter drainage patterns while smaller tools can help shape water movement in the soil. Wetlands can be restored by flooding drained areas. Once the water is in place, revegetation can proceed with species appropriate for the area. Waterfowl and wetland bird species may assist in seed dispersal from nearby wetlands. Stream habitats may also be restored through appropriate management. For example, flooding can be problematic for inhabitants of small streams, particularly the eggs and young of salmonid fishes in the northwestern United States. Large-scale timber harvesting can add silt to streams, and with fewer trees, heavy rains reach streams more rapidly and with more force. This can lead to the covering of fish eggs by silt, which suffocates them, and the removal of young fish and eggs from protected areas into the main stream channel, which results in increased rates of predation. Restoration projects aimed at redirecting the streambed to slow floods and the placement of in-stream obstructions such as large rocks and logs can prevent these problems while creating spawning habitat at the same time. Maintenance of adequate riparian zones can eliminate the need for such restoration measures by reducing the impact of floods.

RESTORATION DIFFICULTIES

Habitat restoration is difficult and problems are often encountered. Exotic and invasive species, problematic soils, and variation in populations can make habitat restoration a challenge. Exotic or invasive species may outcompete natives for nutrients in the early stages of restoration. Inoculation with mycorrhizal fungi can alleviate this by helping the natives absorb nutrients, but often the problem persists. This is because habitat destruction releases nutrients into the soil that may be used by the exotic species. Sometimes, fertilizers are added with the intent of helping the native species grow, but the excess nutrients encourage exotic species to grow instead. One solution to this problem is to limit the nutrients available to the exotic species by removing excess nutrients. Removing excess nutrients, not adding them, allows the native species to persist with assistance from their mycorrhizal associates, while not giving the invasive species the nutrients they require to compete with the natives. Subtle differences in moisture, altitude, slope aspect, and other variables over species' ranges may make some restoration projects difficult. Individuals of a species from one area may be difficult to establish in another area because they may be adapted to local conditions.

A caveat of habitat restoration is that to do it properly one must have a thorough understanding of the ecological requirements, both abiotic and biotic , for the species involved. Also necessary for proper restoration is an understanding of historical land-use patterns coupled with the knowledge of what locally similar, pristine habitat looks like. This knowledge can be difficult to collect and can require substantial investment of money, time, and energy. The result, however, is a better understanding of ecosystems, and with this, one can make educated decisions about how to restore habitats. Habitat restoration is important for the health of the planet and the human race, and continued research on ecosystems and restoration techniques is vital.

Restoration need not only take place in rural settings. Suburban gardens of native plants encourage beneficial native insects and bird species that can act as bio control for pests. Gardening with native species also conserves water, increases awareness and appreciation of regional diversity, and can create small islands of habitat for local species to use as gateways to larger habitat areas. This type of habitat restoration can be done individually on a local level and can turn the tide from wildlife in a sea of people to people in a sea of wildlife.

LARGE MARINE ECOSYSTEM

A total of 50 of the GIWA(Global International Water Assessment **)**sub areas are LMEs. At present, NOAA is completing a series of briefs of the contemporary conditions within each of the 64 Large Marine Ecosystems (LMEs). The briefs are prepared according to a modular approach for assessing ecological conditions with respect to: (1) productivity, (2) fish and fisheries, (3) pollution and ecosystem health, (4) socioeconomics, and (5) governance of the LME. Briefs for 27 LMEs have been completed under contract to NOAA by Dr. Marie Christine Aquarone. She is presently preparing briefs for the remaining 37 LMEs. NOAA would be pleased to make the information available to GIWA when the analysis is completed. Other LME products in production in collaboration with the Fisheries Centre at the University of British Columbia are:

- The bathymetry of the LME areas
- The % of the world's coral reef area within the LME
- The % of the world's gazetted seamounts within the LME
- Productivity in g C/M2/yr asSeaWifs derived median values
- Hot link to lists of fish found in the LME as recorded in Fish Base
- Hot link to Lindeman pyramid (trophic levels) of species in LMEs
- Access to graphs showing multidecadal trends in catch composition (currently 12 groups: anchovies, herring-like, perch-like, tuna & billfishes, cod-like, salmon/smelt, flatfishes, Scorpionfishes, sharks & rays, crustaceans, molluscs, and 'others') for LMEs from 1950 to 1999
- Images of selected oceanographic features within LMEs including SST and temperature profiles.

At present, 60 countries in Asia, Africa, Latin America, and eastern Europe are engaged in the planning and implementation of $150 million in GEF and donor-supported LME projects. Continued over-fishing, destruction of habitats, and accelerated pollution loading have dramatically reduced biomass and diversity of the coastal oceans to the point that several ecosystems are collapsing, national economic benefits from the marine systems are falling, and communities depending on the resources for livelihoods and protein are being stressed. When mismanagement of freshwater resources is added to these concerns, along with new threats from fluctuating climatic regimes, it becomes clear that the global life support system is at risk placing the socio-economic future of coastal regions in jeopardy.

Developing country officials responsible for coastal and marine resources have understood the ramifications of the declining trends in their natural resources. Across Africa, Asia and the Pacific, Latin America and the Caribbean, and in Eastern Europe, country officials have been experimenting through assistance from the Global Environment Facility (GEF) with strategies for reversing the decline of their marine ecosystems, restoring once abundant biomass for sustaining growing populations of coastal communities, and conserving highly fluctuating systems to ensure continued benefits for future generations. Since the early 1990s, these nations have approached the GEF and its implementing agencies (the UN Development Programme, UN Environment Programme, and World Bank) and executing agencies like the UN Industrial Development Organization, for assistance in its international waters focal area to restore and protect their coastal and marine ecosystems.

One of the two principal processes used to engage the science community in each of the participating countries for establishing ecosystem-based priorities for transboundary issues is the Transboundary Diagnostic Analysis (TDA). The other process, known as the Strategic Action Programme (SAP), enables cooperating nations to jointly determine what policy/legal/institutional reforms and investments they need to make to address the TDA priorities. Once such country-driven commitments to actions are established, the GEF may also fund incremental costs of implementing the action programme or SAP to accelerate adoption of management regimes based on the concept of adaptive management for the LMEs as a whole rather than the management of specific sector by sector issues in isolation.

The five-module approach to LMEs (described below) that has proven useful in other settings is essentially customized to fit the situation within the context of the TDA process and the SAP process for particular groups of nations sharing an LME based on available information and capacity. These processes are critical to integrate science into management and this concept is being demonstrated in eight funded projects, four known as Comprehensive LME Demonstrations and to a lesser extent in four other LMEs based on country interests in certain transboundary issues. This demonstrates flexibility of the LME approach.

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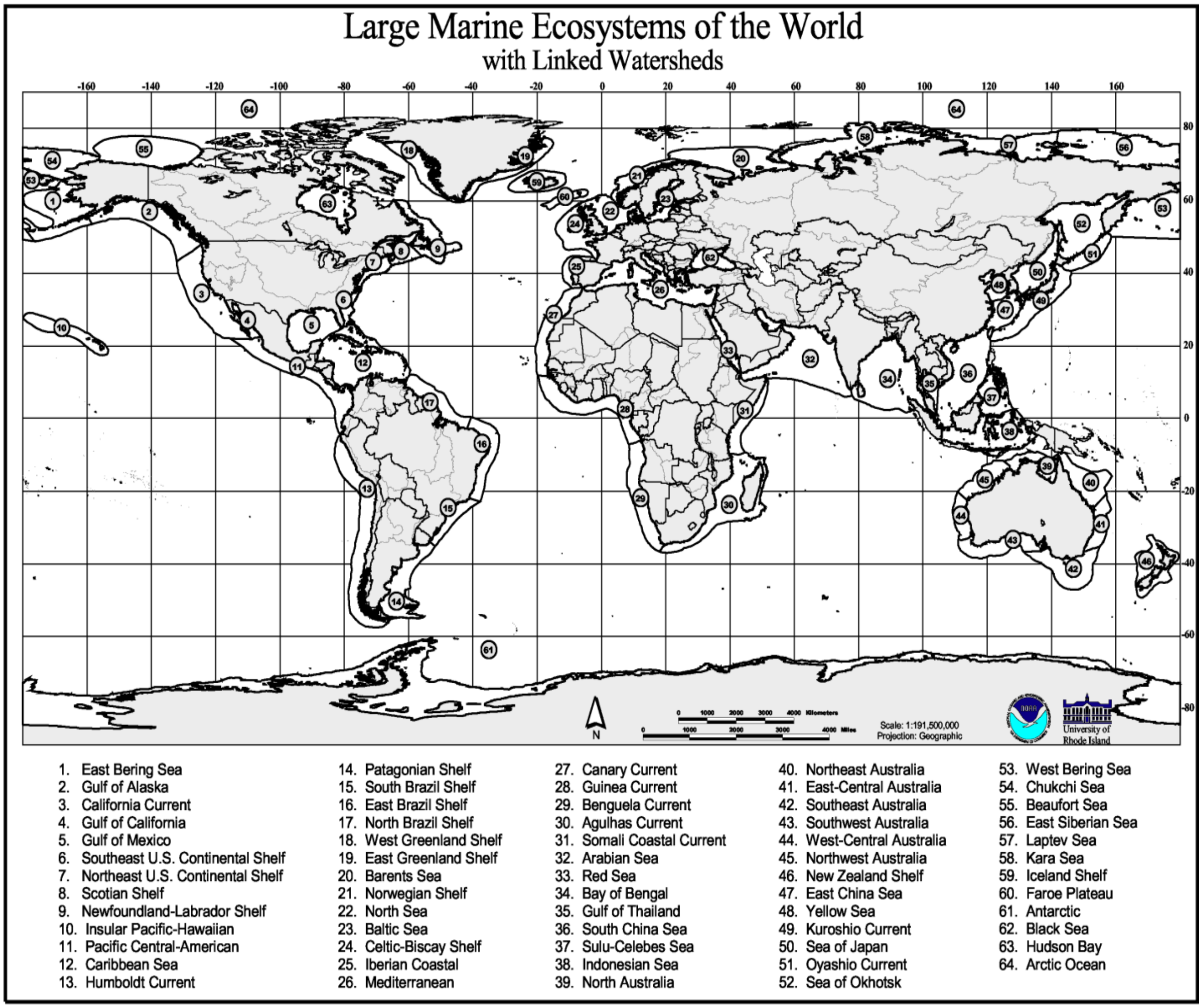
Based on lessons learned from the LME case studies, a five module strategy has been developed to provide science-based information for the monitoring, assessment, and management of LMEs. The modules are focused on LME:

- Productivity
- Fish and fisheries
- Pollution and health
- Socioeconomics
- Governance



Large Marine Ecosystems are areas of the oceans characterized by distinct bathymetry, hydrography, productivity, and trophic interactions. The annually produce 95 percent of the world’s fish catch. They are national and regional focal areas of a global effort to reduce the degradation of linked watersheds, coastal resources and environments

FIVE MODULE LME APPROACH

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major current systems. They are relatively large regions on the order of 200,000 km^2 or greater, characterized by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations. (Annex 1) On a global scale, 64 LMEs produce 95 percent of the world's annual marine fishery biomass yields. Within their waters, most of the global ocean pollution, overexploitation, and coastal habitat alteration occur. For 33 of the 64 LMEs, studies have been conducted of the principal driving forces affecting changes in biomass yields. They have been peer-reviewed and published in nine volumes.

This approach builds on an earlier application of “an ecosystem approach” to management of the Great Lakes Basin Ecosystem, and more recent efforts in developing an ecosystem assessment approach for the management of the North Sea, the Northeast Shelf of the U.S., the Gulf of Mexico, the Baltic Sea, and the Yellow Sea. The ecosystem approach recognizes humankind and economic/social systems as being integral parts of the ecosystem. The Great Lakes approach led to agreements between the U.S. and Canada to follow longer-term pathways for sustainable use of ecological resources. The two decades of experience in struggling to operationalize this ecosystem approach has resulted in management programs to reverse the trend in coastal degradation.

Productivity Module

Productivity can be related to the carrying capacity of an ecosystem for supporting fish resources. The ecosystem parameters measured in the productivity module are zooplankton biodiversity and information on species composition, zooplankton biomass, water column structure, photo synthetically active radiation (PAR), transparency, chlorophyll-a, NO_2, NO_3, and primary production. Plankton of LMEs have been measured by deploying Continuous Plankton Recorder (CPR) systems monthly across ecosystems from commercial vessels of opportunity over decadal time scales. Advanced plankton recorders can be fitted with sensors for temperature, salinity, chlorophyll, nitrate/nitrite, petroleum, hydrocarbons, light, bioluminescence, and primary productivity, providing the means to monitor changes in phytoplankton, zooplankton, primary productivity, species composition and dominance, and long-term changes in the physical and nutrient characteristics of the LME and in the biofeedback of plankton to the stress of environmental change.

Fish and fisheries module

Changes in biodiversity among the dominant species within fish communities of LMEs have resulted from: (1) excessive exploitation, (2) naturally occurring environmental shifts in climate regime, or (3) coastal pollution. Changes in the biodiversity of a fish community can generate cascading effects up the food chain to apex predators and down the food chain to plankton components of the ecosystem. These three sources of variability in fisheries yield are operable in most LMEs. They can be described as primary, secondary, and tertiary driving forces in fisheries yields, contingent on the ecosystem under investigation. The Fish and Fisheries module includes fisheries-independent bottom-trawl surveys and acoustic surveys for pelagic species to obtain time-series information about changes in fish biodiversity and abundance levels. Standardized sampling procedures, when deployed from small calibrated trawlers, can provide important information on diverse changes in fish species. Fish catch provides biological samples for stock assessments, stomach analyses, age, growth, fecundity, and size comparisons; data for clarifying and quantifying multispecies trophic relationships; and the collection of samples for monitoring coastal pollution. Samples of trawl-caught fish can be used to monitor pathological conditions that may be associated with coastal pollution. Trawlers also can be used as platforms for obtaining water, sediment, and benthic samples for monitoring harmful algal blooms, virus vectors of disease, eutrophication, anoxia, and changes in benthic communities.

Pollution and ecosystem health module

In several LMEs, pollution has been a principal driving force in changes of biomass yields. To be healthy and sustainable, an ecosystem must maintain its metabolic activity level and its internal structure and organization, and must resist external stress over time and space scales relevant to the ecosystem. These concepts were discussed by panels of experts at two NOAA workshops convened in 1992. Five of the indices discussed by the participants are being considered as experimental measures of changing ecosystem states and health: (1) biodiversity; (2) stability; (3) yields; (4) productivity; and (5) resilience. Fish, benthic invertebrates, and other biological indicator species are used in the Pollution and Ecosystem Health module to measure pollution effects on the ecosystem, including the bivalve monitoring strategy of “Mussel-Watch;” the pathobiological examination of fish; and the estuarine and near shore monitoring of contaminants and contaminant effects in the water column, substrate, and in selected groups of organisms.

Socioeconomic module

This module is characterized by its emphasis on practical applications of its scientific findings in managing an LME and on the explicit integration of economic analysis with science-based assessments to assure that prospective management measures are cost-effective. Economists and policy analysts will need to work closely with ecologists and other scientists to identify and evaluate management options that are both scientifically credible and economically practical with regard to the use of ecosystem goods and services.

Governance module

The Governance module is evolving based on demonstrations now underway among ecosystems to be managed from a more holistic perspective than generally practiced in the past. In projects supported by GEF- for the Yellow Sea ecosystem, the Guinea Current LME, and the Benguela LME - agreements have been reached among the environmental ministers of the countries bordering these LMEs to enter into joint resource assessment and management activities. Among other LMEs, the Great Barrier Reef ecosystem is being managed from an holistic ecosystems perspective along with the Northwest Australian Continental Shelf ecosystem being managed by the state and federal governments of Australia. The Antarctic marine ecosystem is being managed from an ecosystem perspective under the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and its 21-nation membership. Movement toward ecosystems management is emerging for the North Sea, Barents Sea, Black Sea and Baltic Sea. Recent reports from the University of Rhode Island examine options for improving linkages between the science-based productivity, fish and fisheries, and pollution-ecosystem health modules and the socioeconomic and governance modules, including the use of governance profiles.

OCEAN HEALTH INDEX

The ocean plays a critical role in supporting human well-being, from providing food, livelihoods and recreational opportunities to regulating the global climate. Sustainable management aimed at maintaining the flow of a broad range of benefits from the ocean requires a comprehensive and quantitative method to measure and monitors the health of coupled human–ocean systems. We created an index comprising ten diverse public goals for a healthy coupled human–ocean system and calculated the index for every coastal country. Globally, the overall index score was 60 out of 100 (range 36–86), with developed countries generally performing better than developing countries, but with notable exceptions. Only 5% of countries scored higher than 70, whereas 32% scored lower than 50. The index provides a powerful tool to raise public awareness, direct resource management, improve policy and prioritize scientific research.

The Ocean Health Index was developed with the contributions of more than 65 ocean experts including the National Center for Ecological Analysis and Synthesis and the University of British Columbia’s Sea Around Us project. The founding partners of the Index Are Conservation International, National Geographic, and The New England Aquarium. The Found Presenting Sponsor of the Ocean Health Index is the Pacific Life Foundation.

GOALS OF OCEAN HEALTH INDEX

The Ocean Health Index defines a healthy ocean to be one that sustainably delivers a range of benefits to people now and in the future. Ocean benefits delivered to humans are called goals within the OHI framework, and are widely recognized for supporting human well-being and sustainable ocean ecosystems. The OHI framework can be used to assess ocean health in many different contexts (see examples on the Projects and Publications pages). The goals included in any OHI assessment will depend on the context such that OHI scores represent the goals that are relevant to the assessment area. Global OHI assessments categorized and scored ten goals and eight sub-goals representing ocean-derived benefits to people. These goals and sub-goals are listed below, along with the philosophy of the goal, an ‘ideal’ approach to how it would be represented, practical guidance for modeling, and examples from completed assessments.

The Ocean Health Index defines a healthy ocean as one that can sustainably deliver a range of benefits to people both now and in the future. A healthy ocean in this definition is not necessarily a pristine ocean, although the Index allows for pristine systems as well as sustainably used systems to score highly .The benefits provided by the ocean are captured by the following 10 broadly held public goals:

1. **Food provision** from sustainably harvested or cultured stocks

2. **Artisanal fishing opportunities** for local communities from sustainable practices

3. **Natural products,** including pharmaceuticals and decorative materials that are sustainably extracted

4. **Carbon storage** in coastal habitats

5. **Coastal protection** from inundation and erosion

6. **Sense of place** from culturally valued iconic species, habitats, and landscapes

7. **Livelihoods and economies** from coastal and ocean dependent communities

8. **Tourism** and recreation opportunities

9. **Clean waters** and beaches for aesthetic and health values

10. **Biodiversity** of species and habitats

The Ocean Health Index is a valuable tool for the ongoing assessment of ocean health. By providing a means to advance comprehensive ocean policy and compare future progress, the Index can inform decisions about how to use or protect marine ecosystems. More than 65 scientists and partners worked together to develop the Index, which provides an annual assessment of ocean health using information from over 100 scientific databases.

India is ranked 139 out of 221 EEZs.A global score is 70 out of 100 .The Index Combines biological, physical, economic and social indicators that are fundamental for healthy oceans. The scores, which range on a scale from 0 to a 100, assess how sustainably people are using this ecosystem in a given region. It was designed to be scalable to national and regional levels to provide governments a holistic tool to measure their health and promote action to maintain healthy oceans. The 2015 update showed continued low global scores for the Food Production (58) and Natural Products (52). On the other end of the spectrum, Biodiversity (88) and Coastal Protection (87) were the highest scores, though their distance from a perfect score of 100 indicates that that species and habitats remain well below the target goal for sustainability.

The 2015 update showed continued low global scores for the Food Production (58) and Natural Products (52). On the other end of the spectrum, Biodiversity (88) and Coastal Protection (87) were the highest scores, though their distance from a perfect score of 100 indicates that that species and habitats remain well below the target goal for sustainability.In our country the 2015 update showed the scores for the Food Production (46),Artisanal fishing opportunities (45),Natural Products (84),Carbon storage (87),Coastal protection (97), Sense of place (42), Tourism and recreation (53),Coastal Livelihoods and economies (69), Clean waters (32), Biodiversity (89).

IMPLEMENTING ECOSYSTEM-BASED FISHERY MANAGEMENT

There is widespread agreement about the need to implement EBFM because the historic focus on single speciesmanagement has had the unintended consequence of declining populations of many other species. Several guidelines for implementing EBFM have been published, such as in thepapers by the National Marine Fisheries Service (1998), Ward et al. (2002), and the FAO (2005). These guidelines supply detailed instructions for implementing the principles, goals, and policies of fishery management in an ecosystem context. Nevertheless, the effectiveapplication of these guidelines in practice is questionable. Pitcher et al. (2008)showed that of 33 countries representing 90% of the world’s fish catch, no countriesachieved good performance for EBFM implementation steps, while two-thirds (21 countries)were unlikely to carry out EBFM implementation steps (fail grades). Canada and the United States are the only two countries in this study with acceptable performance ofEBFM implementation steps, while Russia and Thailand have the worst performance ofEBFM implementation steps. One of the reasons for ineffective implementation is that itis easier to publish good intentions for EBFM principles than to actually achieve its goalsand objectives in practice (Pitcher et al. 2008). Another reason is that EBFM implementationmay require a lot of resources. Pitcher et al. (2008) showed that EBFM performance ratings correlate quite well with the United Nations Human Development Index. Implementationmay also require co-operation among diverse groups, including scientists, resource users,
and other significant stakeholders. In addition, EBFMcan be an important complement to existing fishery management approaches, but it cannotbe effective if the political will to stop fishing and to protect habitat is removed (NationalMarine Fisheries Service 1998). All conditions for effective implementation of EBFM may not be available for many fisheries. As a result, managers are just beginningto put some EBFM principles into practice, and this implementation needs to occur on amuch greater scale. Goodman et al. (2002) believe the move from single-species fishery management to EBFM may involve three stages. The first stage focuses on managing the target speciesand its predators and prey. The second stage takes into account more traceable environmental effects such as the direct effects of fishing activities other than those on the

targetspecies (e.g., by-catch, incidental mortality, and effects on habitat). In the third stage, thetarget stock and its predators and prey as well as more traceable and less traceable environmenteffects, such as climate change and the indirect effects of fishing (e.g., modifyingecosystem structure), are taken into account in fishery management plans.Some fisheries have been managed to the second stage of the EBFM process, whichtakes into account the direct effects of fishing (e.g., by using turtle excluder devices andby-catch reduction devices such as shrimp trawls in the United States). In BritishColumbia, some fisheries have also reached the second stage of EBFM because traceableenvironmental effects are included in their management plans. For instance, commercial ground fish bottom trawling has high impacts on benthic habitats of Canada's Pacificmarine waters .These impacts have been taken into account in theintegrated fisheries management plan of in Pacific Region. Numerous studies have looked at the less traceable environment effects onfisheries, such as those by Pauly et al. (1998), Knowler et al. (2001), and Smith (2007). Itis hard to find these effects taken into account in fishery management plans and BritishColumbia is no exception. Climate change is one of the key factors affecting fisheries inthe province. The Strait of Georgia has warned almost 1°C over the past 40 years, whichmay result in declining production of Pacific salmon (Beamish & Riddell 2009); however, this impact has not been included in the integrated fisheries management plans of salmonfisheries in Pacific Region.

MERITS OF EBFM

More effective coordination of management actions for fisheries,protected resource species biodiversity conservation ,habitat protection.Direct accounting for fishery interactions and biological considerations.Rebuild the stocks to long term target levels and evaluation of compatibility with stock specific recovery plan.Increased stewardship from broader participation of stakeholders. Sharing of ecological and fisheries knowledge.Developing place –based governance approches , co-management .Stability and predictability by focusing on higher level ecosystem processes.

DEMERITS OF EBFM

EBFM is by no means a well defined process with set protocols and formulas. The complexity of ecosystems makes this impossible.EBFM cannot work without up to date scientific data on population level, ecosystem conditions. It Involves heavy expenditure of money.Effective EBFM policy will require significant regional and international cooperation.

CONCLUSION

Ecosystem-based marine fishery management is a new direction for fishery management that prioritizes the management of the entire ecosystem rather than the target species individually.Although the literature does not present a single agreed upon EAM definition, natural resource scientific and management communities agree that the following elements are needed for successful EAM: collaboration, adaptive management, ecological integrity, integrated data and information, and the connection between all landscape levels.Most ecological economic models for EBFM follow the population approach, which ignores the interaction between the biological and physical components of marine ecosystems. It may be necessary to apply the process-functional approach for ecological economic models. Nutrients may be chosen as the currency for ecological economic models because nutrient flow connects biological and physical components of marine ecosystems. The move from single-species marine fishery management to EBFM may require several stages, and it is important to include the physical component of the ecosystem in fishery management plans in addition to the target stock and its predators and prey. The less traceable environment effects on fisheries such as climate change should be also investigated and included in the management plans. Managers are just beginning to put some EBFM principles into practice because implementation may require a lot of resources, co-operation among diverse groups, and political will. Implementation of EBFM needs to occur on a much greater scale**.**This management strategy will provide a tool for a comprehensive approach to governing the Nation’s marine and coastal resources. No single agency can implement EAM alone; therefore, collaboration and cooperation with other natural resource agencies, the public, and private sectors will foster a stewardship of the coastal and marine resources in which future generations can enjoy.

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