NOAA Technical Memorandum NMFS-NE-184

A Large Marine Ecosystem Approach to Fisheries Management and Sustainability: Linkages and Concepts towards Best Practices

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

August 2004

Recent Issues in This Series:

167. **Assessment and Characterization of Salt Marshes in the Arthur Kill (New York and New Jersey) Replanted after a Severe Oil Spill.** By David B. Packer, ed. December 2001. x + 228 p., 54 figs., 58 tables, 6 app. NTIS Access. No. PB2004-106067.

168. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2001**. By Gordon T. Waring, Janeen M. Quintal, and Steven L. Swartz, eds., Phillip J. Clapham, Timothy V.N. Cole, Carol P. Fairfield, Aleta Hohn, Debra L. Palka, Marjorie C. Rossman, U.S. Fish and Wildlife Service, and Cynthia Yeung, contribs. December 2001. vii + 310 p., 43 figs., 54 tables, 2 app. NTIS Access. No. PB2002-104350.

169. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2002**. By Gordon T. Waring, Janeen M. Quintal, and Carol P. Fairfield, eds., Phillip J. Clapham, Timothy V.N. Cole, Lance P. Garrison, Georgia Department of Natural Resources, Aleta A. Hohn, Blair G. Maise, Wayne E. McFee, Debra L. Palka, Patricia E. Rosel, Marjorie C. Rossman, U.S. Fish and Wildlife Service, Frederick W. Wenzel, and Cynthia Yeung, contribs. September 2002. vii + 318 p., 42 figs., 56 tables, 4 app. NTIS Access. No. PB2003-104167.

170. **Interaction of Shelf Water with Warm-Core Rings, Focusing on the Kinematics and Statistics of Shelf Water Entrained within Streamers.** By Ronald J. Schlitz. March 2003. v + 35 p., 26 figs., 3 tables. NTIS Access. No. PB2005-100158.

171. **Length-Weight Relationships for 74 Fish Species Collected during NEFSC Research Vessel Bottom Trawl Surveys**. By Susan E. Wigley, Holly M. McBride, and Nancy J. McHugh. March 2003. vi + 26 p., 1 fig., 3 tables. NTIS Access. No. PB2003-106486.

172. **Variability of Temperature and Salinity in the Middle Atlantic Bight and Gulf of Maine Based on Data Collected as Part of the MARMAP Ships of Opportunity Program, 1978-2001**. By Jack W. Jossi and Robert L. Benway. March 2003. vi + 92 p., 74 figs., 5 tables. NTIS Access. No. PB2004-100835.

173. **Essential Fish Habitat Source Document: Barndoor Skate, *Dipturus laevis*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 23 p., 14 figs., 1 table. NTIS Access. No. PB2003-104257.

174. **Essential Fish Habitat Source Document: Clearnose Skate, *Raja eglanteria*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 50 p., 25 figs., 2 tables. NTIS Access. No. PB2003-104260.

175. **Essential Fish Habitat Source Document: Little Skate, *Leucoraja erinacea*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 66 p., 27 figs., 2 tables. NTIS Access. No. PB2003-104259.

176. **Essential Fish Habitat Source Document: Rosette Skate, *Leucoraja garmani virginica*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 17 p., 11 figs., 1 table. NTIS Access. No. PB2003-104258.

177. **Essential Fish Habitat Source Document: Smooth Skate, *Malacoraja senta*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 26 p., 15 figs., 1 table. NTIS Access. No. PB2003-104256.

178. **Essential Fish Habitat Source Document: Thorny Skate, *Amblyraja radiata*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 39 p., 18 figs., 2 tables. NTIS Access. No. PB2003-104255.

179. **Essential Fish Habitat Source Document: Winter Skate, *Leucoraja ocellata*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 57 p., 25 figs., 2 tables. NTIS Access. No. PB2003-104254.

180. **Variability in Blood Chemistry of Yellowtail Flounder, *Limanda ferruginea*, with Regard to Sex, Season, and Geographic Location**. By Renee Mercaldo-Allen, Margaret A. Dawson, Catherine A. Kuropat, and Diane Kapareiko. September 2003. vi + 20 p., 1 fig., 10 tables. NTIS Access. No. PB2004-107074.

181. In press.

182. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2003.** By Gordon T. Waring, Richard M. Pace, Janeen M. Quintal, Carol P. Fairfield, and Katherine Maze-Foley, eds., Nicole Cabana, Phillip J. Clapham, Timothy V.N. Cole, Gregory L. Fulling, Lance P. Garrison, Aleta A. Hohn, Blair G. Maise, Wayne E. McFee, Keith D. Mullin, Debra L. Palka, Patricia E. Rosel, Marjorie C. Rossman, Frederick W. Wenzel, and Amy L. Whitingham, contribs. May 2004. vii + 287 p., 47 figs., 58 tables, 4 app., index. NTIS Access. No. PB2004-106431.

183. In press.

NOAA Technical Memorandum NMFS-NE-184

This series represents a secondary level of scientific publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are -- by design -- transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

A Large Marine Ecosystem Approach to Fisheries Management and Sustainability: Linkages and Concepts towards Best Practices

Frank J. Gable

University of Rhode Island, The Coastal Institute, Narragansett, RI 02882

U. S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary
National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., USN (ret.), Administrator
National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries
Northeast Fisheries Science Center
Woods Hole, Massachusetts

August 2004

Editorial Notes

Editorial Production

This document is the fulfillment of research and analyses performed under funding from both the Northeast Fisheries Science Center's Office of Marine Ecosystem Studies, and the Center's Social Sciences Branch. This document has been editorially processed as other contract reports issued in the *NOAA Technical Memorandum NMFS-NE* series: the document as a whole has been formatted to resemble other issues, but no copy or technical editing has been performed.

Content Disclaimer

Internet Availability

This issue of the *NOAA Technical Memorandum NMFS-NE* series is being copublished, *i.e.*, as both a paper and Web document. The Web document can be accessed at: *http://www.nefsc.noaa.gov/nefsc/publications/tm/tm184/*.

Contents

Tables

Figures

Abstract

This technical memorandum addresses interdisciplinary aspects of fisheries assessments as linkages for adaptive management and sustainability of large marine ecosystems (LME). Natural and human-induced impacts of living marine resources are considered. Management and the ecological aspects of fish stock populations in the United States Northeast Continental Shelf ecosystem are examined for prospective and emerging "best practices" from a synthesis of the scientific literature. In accordance with the passage of the domestic Oceans Act of 2000 (Public Law 106-256; e.g., Watkins, 2002) this manuscript further develops linkages through natural and social science for an interdisciplinary science policy and governance practice for LMEs. It is meant to provide background information and promote dialogue on ecosystem-oriented management of living marine resources. Consideration is given to the precautionary approach in the introduction of ecosystem-oriented management of the fish stocks of the Northeast Shelf ecosystem.

INTRODUCTION

The concept of LME's emerged from an American Association for the Advancement of Science (AAAS) selective symposium in the mid 1980's concerning variability and management of large marine ecosystems (Sherman et al., 1991; Alexander, 1993). "Marine ecosystems may be defined as major units of ecological function in the marine environment. Ecosystems are communities of organisms and their physical, chemical and geological environment – distinct assemblages of species coevolved with a particular environment over long periods of evolutionary history – interacting as an ecological unit" (Grassle, 2001).

This study incorporates the "tools" of a *policy orientation* approach (Gable, 2003) for commercial marine fisheries management consistent with the LME concept using the case study approach. The focus is on the multi-method modular plan linked to the "precautionary principle" (approach) in relation to the authorities of the New England Fishery Management Council (NEFMC), the Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC) as well as state agency jurisdictions. The Northeast Shelf LME can be considered as a part of the Northwest Atlantic Fisheries Organization (NAFO) statistical areas, and NEFMC, MAMFC, and ASMFC management locales (see Figure 1). The study advances an ecosystem approach to living marine resources science policy.

ORIGINS OF OCEAN MANAGEMENT REGIMES

Following the September 1945 Truman Proclamations (nos. 2667 & 2668) in the United States concerning U.S. policy with respect to the natural resources of the subsoil and seabed of the continental shelf and coastal fisheries in certain areas of the High Seas, several ocean law measures were discussed and debated in a series of international fora. One of them, the Convention on the Continental Shelf was agreed to in April of 1958 in Geneva (signed by the U.S. in June 1964). It contains 15 codified articles. A related agreement, the 1958 Convention on the Territorial Sea and the Contiguous Zone, was also codified at Geneva and was ratified by the U.S. Senate in 1961. This agreement contains 32 articles that included preexisting rules regarding international customary law that provided a greater degree of precision and clarity. The Convention on the High Seas contains 37 mostly short articles and Annex III (Convention on Fishing and Conservation of the Living Resources of the High Seas). It was also adopted in 1958. According to Merrell, et al., (2001) "in 1958, the United Nations convened the first international conference of plenipotentiaries to examine the law of the sea, and to embody the results of its work in one or more international conventions. The 1958 conference produced four conventions that codified, to a great extent, customary law and brought international attention to the oceans." Years later, the Third United Nations Conference on the Law of the Sea (UNCLOS) began its substantive work in 1974 two years after the first U.N. Conference on the Human Environment in Stockholm (see Emmelin, 1972). UNCLOS III, consisting of 319 articles plus several annexes, was signed on December 10th, 1982. It was ratified by the requisite number of countries (60) and entered into force on November 16th, 1994.

Domestically, the U.S. Congress enacted the Marine Resources and Engineering and Development Act of 1966 (Public Law 89-454) that created a blue ribbon executive-level commission on marine science activities later known as the Stratton Commission, named for the chairman of the 15 member panel. Their report, *Our Nation and the Sea* issued in January of 1969, reviewed the status of American ocean policy and provided specific recommendations for improving marine resource and ocean management practice. One of the major outcomes from those recommendations was the creation of the National Oceanic and Atmospheric Administration (NOAA; est. October 1970; Nelson, 1969). Merrell, et al., (2001) also mention that among many public laws that can be traced to the Commission's 1969 report was the original Magnuson Fishery and Conservation Management Act of 1976 (Public Law 94-265).

Two other noteworthy American actions pertinent to ocean management were (1) the Presidential Proclamation of December 27, 1988, (No. 5928) in accordance with international law as reflected in the applicable provisions of the 1982 United Nations Convention on the Law of the Sea and customary international law extending the U.S. territorial sea to 12 nautical miles. Earlier, (2) the Presidential Proclamation (5030) of March 10, 1983 established the Exclusive Economic Zone (EEZ) of the U.S. designating sovereign rights over natural resources out to 200 nautical miles from the baseline from which the breadth of the territorial sea is measured in accordance with international law. In addition, the Oceans Act of 2000 (P. L. 106-256; effective January 20, 2001) was passed by congress with the task of reviewing the importance of American oceans and marine resources and formulating a "scientifically based strategy for protecting and sustaining our oceans" and that this "requires a coordinated and comprehensive national ocean policy" (Watkins, 2004). One of the ocean governance approaches advocated by the U.S. Ocean Commission is the principle of ecosystem-based management (Watkins, 2004; see also Witherell, 2004).

LARGE MARINE ECOSYSTEMS: AN INSTRUMENT TO FOSTER REGIONAL FISHERIES MANAGEMENT AND SCIENCE ARRANGEMENTS

LME's are regions of ecological unity of ocean space comprising coastal locales from river basins and estuaries to the outer margins of continental shelves and seaward boundaries of coastal current systems (Griffis and Kimball, 1996). A combination of ecological criteria including unique bathymetry, hydrography, productivity and trophic relationships characterize LME's (Sherman, 1989). LME's are areas yielding 90 percent of the annual catch of global marine fisheries (Garibaldi and Limongelli, 2003; Sherman and Duda, 2001). Thus, the LME approach considers accommodating human utilization of its resources while maintaining ecosystem integrity. Some areas of the globe have embraced *ecosystem considerations* as part of fisheries ecosystem management within the scale of an LME (Sherman, 1994; Done and Reichelt, 1998; Duda and Sherman, 2002).

English, et al., (1988) discussed Southeast Asia where the emphasis was on studies of Large Marine Ecosystems (LME's) using a multispecies approach for the management of resources. Initiated in 1983, as a response to the Third United Nations Conference on the Law of the Sea (UNCLOS), was the Southeast Asian Project on Ocean Law, Policy and Management (SEAPOL). It was designed to promulgate a network of regional specialists in ocean development and management as a part of the Law of the Sea. These regional specialists selectively incorporated information on coral, mangrove and soft-bottom benthic communities in the coastal living resources project (English, et al., 1988). These authors noted on page 372 of their manuscript, "science is a central issue in any attempt to manage LME's;" "the management of LME's involves political, socio-economic, scientific and technical aspects." The ASEAN Coastal Living Resources Project was an early example of a multinational approach to the management of LME's (English, et al., 1988).

In Australia and New Zealand the LME approach was selected as a means for introducing an ecosystem-based approach to the assessment and management of marine resources because of its focus on resource management. Done and Reichelt, (1998) emphasize that in the Oceania LME, "the scope of the focus on fishery management is placed on optimization of catch per unit of effort (CPUE) for targeted commercial species along with bycatch and discard minimization." Integrated within the LME approach, as utilized in Australian and New Zealand jurisdictional waters, is also a focus on both coastal zone and watershed catchment management. Here, the scope of emphasis for coastal zone management (CZM) is "directed toward habitat protection for both catch and bycatch species (prohibited and non-specified species bycatch) as well as water quality maintenance. The reduction of polluted land-based runoff into surface waterways that drain towards the shore is the principle scope of emphasis for watershed catchment management" (Done and Reichelt, 1998). Thus, in Oceania, "the quest for resource sustainability may best be achieved through the combination of management effort directed towards coastal habitats and catchment watersheds as well as the fishery" (Done and Reichelt, 1998).

The governments of the Republic(s) of Angola, Namibia and South Africa in their desire to manage development and protect for future use the Benguela Current LME in an integrated and sustainable manner committed themselves to establishing the "Benguela Current Large Marine Ecosystem" (BCLME) program with specific ecosystem-based actions, principles and policies (O'Toole, 2002). The reasons for the establishment of the BCLME, included: (1) significant transboundary implications of unsustainable practices of harvesting of living marine resources (fish stocks), (2) increasing habitat degradation and alteration which may have contributed to increased incidence of harmful algal blooms, as well as (3) inadequate governance capacity to assess and monitor ecosystem status and trends, either nationally or regionally. The original Strategic Action Program (SAP) was adopted by signature by government ministers at the end of February of 2000 in the spirit of the United Nations Conference on Environment and Development (Rio Declaration) and Agenda 21 principles. The BCLME program was established as an international body under the terms and conditions of the United Nations Convention on the Law of the Sea (entry into force November 1994) and international customary law principles (see e.g. Belsky, 1985). At the outset, for example, the United Nations Development Programme (UNDP) is represented on the Interim Benguela Current Commission for the initial five year BCLME program development phase. Original start-up funding was secured from the Global Environment Facility (GEF) in partnership with the United Nations Development Programme (UNDP), and scientific and technical assistance coming from the National Oceanic and Atmospheric Administration (NOAA) of the U.S., and ocean science agencies in France, Germany, and Norway.

In another regional setting north of the BCLME, according to Ukwe et al., (2003) the countries of the Gulf of Guinea littoral "adopted an integrated and holistic approach using the LME concept to sustainably manage the environmental and living resources of the region." The genesis for the Guinea Current LME was founded in 1995 with a pilot project initiative by six littoral nations regarding biodiversity conservation and water pollution control. Ministers representing the six countries responsible for the LME project signed the Accra Declaration as an expression of support for internation cooperation in fostering sustainable management practices. Donor agency funding was secured via the GEF with implementation provided through the UNDP in concert with the U.N. Industrial Development Organization (UNIDO) with technical support from NOAA/NMFS and the U.N. Environment Programme. "The project is anchored in the concept of LME's as geographic units for improving the assessment and management of marine resources" (Ukwe, et al., 2003). The overriding goal of the ongoing Guinea Current LME Strategic Action Plan (SAP) centers on biological diversity and the control of aquatic pollution with regard to restoring and sustaining the health of the living marine resources of the region. Ukwe, et al., (2003) mention four specific objectives to achieve the goal revolving around five LME modules (see Figure 2) including governance capacity building along with ecosystem management database development as well as living marine resources assessment and long-term monitoring and protection strategies. Sherman (1995) illustrated the ecosystem level "energy matrix" which is comprised of interactions of individuals, populations, or communities of organisms. In general, the concept of LME's has been embraced by the world's coastal developing nations, but the "predominant variables" for any given LME may be different even from its neighbor, depending upon the results of issue prioritization based on consensus reached through a Transboundary Diagnostic Analysis (Sherman and Duda, 1999b).

ECOSYSTEM-ORIENTED MANAGEMENT AS A LINK FOR FOSTERING SUSTAINABLE FISHERIES

More recently, at the United Nations General Assembly in New York, "resolutions" have been crafted for adoption by member nations to apply by 2010 the "ecosystem approach" to the conservation, management and exploitation of, highly migratory (pelagic) and "straddling" fish stocks (Jahnke, 2003). Resolution A/57/L.49 concerning a number of fisheries issues was introduced by the United States of America through Ambassador Mary Beth West, the then Deputy Assistant Secretary of State for Oceans and Fisheries to the fifty-seventh session of the General Assembly on December 10th 2002 (West, 2003). Resolution A/57/L.50 regarding the conservation and management of straddling fish stocks and highly migratory fish stocks was also introduced at the same time by Ambassador West. In her remarks before the General Assembly, she indicated that "the fisheries draft resolutions are an assemblage of current ocean issues drawn from the priorities and interests of Member States." And "they represent consensus… in making the oceans safe and healthy environments for sustainable development" (Jahnke, 2003).

Ambassador West's statement also contained an emphasis on the agreed to Johannesburg World Summit on Sustainable Development Plan of Implementation adopted on September 4th of 2002. She remarked that the Plan calls on the world community to establish by 2004, a regular United Nations process for global reporting and assessment of the state of the marine environment based on existing regional assessments. The Plan suggests the world community to elaborate regional programmes of action and to improve links with strategic plans for the sustainable development of coastal and marine resources (Jahnke, 2003). Thus, the prescribed benefits of an in-place LME approach to living marine resources conservation biology and management can be seen at work in the international arena (Alexander, 1999; Belsky, 1985).

The introduced "Resolution (on Oceans and the Law of the Sea, A/57/L.48) similarly calls upon States to develop national, regional and international programmes aimed at halting the loss of marine biodiversity. The United States welcomes this emphasis on integrated regional approaches to oceans issues." While at the podium, Ambassador West went on to state, "in that context (regarding integrated, regional approaches to ocean issues), we would like to bring to this body's attention the White Water to Blue Water oceans partnership initiative currently being planned for the Caribbean… it aims for an integrated approach to the management of freshwater watershed and marine ecosystems." "We hope it might serve as a successful model for similar efforts in other regions of the world." Moreover, "the United States also looks forward to collective efforts to establish an inter-agency coordination mechanism on oceans and coastal issues within the United Nations system" (UNGA, 2002)[1] .

Specifically, the written draft resolution A/57/L49 introduced by Ambassador West, noted also, with particularity, "the importance of implementing the principles elaborated in Article 5 of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (entered into force on December 11th 2001), including *ecosystem considerations* in the conservation and management of straddling fish stocks and highly migratory fish stocks." Draft resolution A57/L.49 as adopted (now known as 57/142) "encourages all States to apply by 2010 the ecosystem approach… and supports continuing work under way at the Food and Agricultural Organization of the United Nations (FAO) to develop guidelines for the implementation of *ecosystem considerations* in fisheries management…" (UNGA, 2003).

Similarly, Resolution 57/141 Oceans and the Law of the Sea (formerly draft A/57/L/48) "calls upon States to promote the conservation and management of the oceans in accordance with Chapter 17 of Agenda 21 (i.e., Earth Summit, Rio De Janeiro, June 1992; e.g. Garcia and Newton, 1994) and other relevant international instruments, to develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas (MPA's) consistent with international law and based on scientific information, including representative networks by 2012 and time/area closures for the protection of nursery grounds and periods, proper coastal and land use and watershed planning, and the integration of marine and coastal areas management into key sectors." In Section XI Marine Environment, marine resources & sustainable development of said Resolution 57/141 of December 12th 2002 calls upon States, "to improve the scientific understanding and assessment of marine and coastal ecosystems as a fundamental basis for sound decision-making through the actions identified in the Johannesburg Plan of Implementation, including that of relevant data collection of the marine environment" (UNGA, 2003).

In late November of 2003 an analogous resolution was adopted by the General Assembly. Demonstrating a pattern of agreement by the international community towards sustainable fisheries another *marine affairs* oriented instrument was placed on the table at the U.N. General Assembly. Reaffirming its resolutions, *inter alia*, 57/142 and 57/143 of December 12th 2002 (see above), draft resolution A/58/L.18 was on the agenda at the fifty-eighth session in New York. After a successful roll-call adoption of the "sustainable fisheries… and related instruments resolution" (adopted as RES/58/14 on November 24th 2003) there was affirmation that in seeking "responsible fisheries in the (large) marine ecosystem" (Section IX) there is the encouragement for Member States to apply by 2010 the ecosystem approach. This ecosystem approach and its relevant guidelines, in part, developed by FAO (Rome, Italy) would provide for the "implementation of *ecosystem considerations* in fisheries management" (UNGA, 2004).

Resolution 58/14 of 2003 also "notes with satisfaction" the activities of the World Bank housed Global Environment Facility (GEF) aimed at "promoting the reduction of bycatch and discards in fisheries activities." Discards add to the effect of fishery landings, for example, "a mid-1990's assessment suggested that about 25 percent of marine catch is discarded" (Hanna, 1999). Moreover, the GEF has adopted the LME approach to ocean stewardship of living marine resources (Duda and Sherman, 2002). Resolution 58/14 of 2003 in Section VIII "encourages States to develop ocean policies and mechanisms on integrated management, including at the subregional and regional levels;" the LME approach is just such a mechanism and policy program. The flexible LME approach can aid in achieving sustainable fisheries by addressing *ecosystem considerations* like: fishing overcapacity, large-scale pelagic drift-net fishing, fisheries bycatch and discards, aid in accomplishing subregional and regional cooperation in fostering responsible fisheries in the marine ecosystem, as well as address capacity-building and cooperation as it relates to science policy technical assistance and financial aid mechanisms (see: UNGA, 2004).

As regards "good governance" for the environment, West (2003) emphasizes the promotion of "sound science-based decision-making" within legal, programmatic, and regulatory frameworks while stating, "changes in marine and coastal systems can undermine the basic economic and environmental services provided by the oceans." She also writes, "when it comes to the coastal environment, however, we have learned that regional approaches are often most effective (West, 2003). The large marine ecosystem (LME) paradigm provides just such an effective approach both internationally and/or domestically in the U.S. The LME approach or initiative provides and promotes science-based decision making for the ocean and coastal activities, especially in the realm of commercial fisheries science policy. The LME modular assessment approach (Figure 2) is an improved science-based application to best practices of integrated coastal management (e.g., West, 2003; Ajayi, et al., 2002; Done and Reichelt, 1998).

CUSTOMARY INTERNATIONAL LAW AND THE MANAGEMENT OF LARGE MARINE ECOSYSTEMS

While the adoption of ocean affairs related resolutions by the Member States of the United Nations General Assembly demonstrate a willingness to move towards ecosystem-based fisheries management (as a tenet of adaptive management), more importantly "this acceptance may be emerging into customary rules of international law which promote consideration of total ecosystems and the establishment of standards for those systems" (Belsky, 1985)[2]. Knecht, (1994) recognized "that the use of the ecosystem approach in dealing with large marine ecosystems is already close to becoming international law." "Soft laws essentially are statements of international cooperation, usually in the form of an international treaty or agreement, which are not binding on (all) States but have the capacity to promote evolving notions of customary law, they have great importance in the evolution of customary law" (MacDonald, 1995). He reiterates that "customary international law consists of 'rules' and 'norms,' written and unwritten, that may or may not find expression in treaties … precisely because of its informal nature that customary law is central to international dialogue; often custom will be on the basis on which to forge ahead in international disagreements in an attempt to find common ground" (MacDonald, 1995). Alexander (1999) postulates, "the articles of the 1982 United Nations Conference on the Law of the Sea (UNCLOS) generally support the principles of ecosystem management for living marine resources. Most indications now point toward a general acknowledgement of the benefits of integrated ecosystem management in the world's oceans and seas." The objectives of UNCLOS are parallel to those of LME management (Alexander, 1999). Moreover, Cole (2003) asserts that "there have been structural changes in fisheries decision-making, notably a transformation from a state-led approach towards multi-leveled decision-making procedures due to key developments in, *inter alia*, international law." Further, she asserts that "there have been considerable shifts in authority dealing with fisheries regulation and a new, distinct, global structure is emerging in essence attributed to globalization" (Cole, 2003).

The European Community has recently enacted reforming legislation for its Member States proscribing a "road map" towards their Common Fisheries Policy. The Council of the European Union, a regional body of Member States, enacted Council Regulation (EC) No. 2371/2002 of December 20th 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy (COEU, 2002). This regulation is binding in its entirety and directly applicable in all Member States. In some respects, the Europeans seem to be in-sync with the United States by establishing Regional Advisory Councils (Article 31) to enable fisherfolk and other stakeholders the benefit of providing their local knowledge and experience concerning diverse conditions throughout European Community jurisdictional waters. This appears somewhat analogous to the idea for the creation of non-regulatory regional ocean councils in the U.S. (see Watkins, 2004). Though the European Regional Advisory Councils are not designed to be independent management bodies with the authority to make decisions (Gray and Hatchard, 2003) unlike the eight regional fishery management council's structure in the U.S.A that do.

The scope and objectives of EC No. 2371/2002 (Article 2(1)) include the provision to "aim at a progressive implementation of an ecosystem-based approach to fisheries management." Included here is the "good governance" objective of a "decision-making process based on sound scientific advice which delivers timely results. Broad involvement of stakeholders at all stages of the Common Fisheries Policy from conception to implementation" is another objective under the "principles of good governance" (Article 2(2)). Specifically, the Regional Advisory Councils were established to "contribute to the objectives of Article 2(1), that is, "ecosystem-based approach to fisheries management" and in particular to advise the European Commission on matters of fisheries management with respect to certain sea areas or fishing zones.

Under the heading "conservation and sustainability, Article 5(3) recovery plans" and Article 6 (3) "management plans" "may cover either fisheries for single stocks or fisheries exploiting a mixture of stocks, and shall take due count of interactions between stocks and fisheries." Therefore, objectives or aims of the European Commission's "new" approach to fisheries management refocuses policy towards a long-term view to fostering higher yield sustainable fisheries while moving towards an ecosystem-based approach to fisheries management. Curiously under Article 3 "definitions," none was provided for what is meant by an ecosystem-based approach! Though, however, it may be gleaned from the wording above as it relates to both Recovery and Management Plans. Gray and Hatchard, (2003) suggest that for coherence with other European Community environmental policies, the principle of ecosystem management applies to gear regulations under the Common Fisheries Policy.

ECOSYSTEM CONSIDERATIONS: THE FORMULATION OF A BEST-PRACTICES LME APPROACH

"There is a need to enhance the conservation objectives of fisheries management plans to include explicitly *ecosystem considerations*. Internationally, Wagner (2001) affirms that the recent Reykjavik Declaration of Responsible Fisheries in the Marine Ecosystem (October, 2001) includes "ecosystem considerations in fisheries management that provides a framework to enhance management performance." These "considerations" incorporate increased attention to predator-prey relationships and understanding of the impact of human activities as well as the role of habitat and factors affecting ecosystem stability and resilience, among others (Figure 3). The effects of fishing from an ecosystem perspective, and the effects of environmental change or alterations on fish stocks is one intent in providing the New England Fishery Management Council (NEFMC) and other similarly situated regulatory agencies this kind of information[3]. In general, due to data limitations and the lack of breadth and complexity of most single species models, the effects of fishing on ecosystems have not been incorporated into most stock assessments (Livingston, 2001; Figure 4). "Predation on pelagic fish and squids is an important and large component of the overall dynamics of the Northeast Shelf Ecosystem. Herring, except at very large sizes (>30cm), seldom grow out of the window of predation by fish over most of their life history" (Overholtz, et al., 1999). "Consumption of pelagic fish and squid by predatory fish appears to equal or exceed landings in most years from 1977-1997." In the 1990's, "for herring, consumption also exceeds the current value of MSY for this stock" (Overholtz, et al., 1999).

The North Pacific Fishery Management Council (NPFMC) utilizes as *ecosystem consideration* indicators: physical oceanography indices (e.g., temperature and decadal regime shifts); habitat (e.g., groundfish bottom trawling effort by subregion, closed areas to trawling, and biota bycatch by all gears in habitats of particular concern (HAPC's)); target groundfish (e.g., total biomass, total catch by subregion, groundfish discards including target species discards, recruitment by subregion); fleet size – analogous to humans as a part of the ecosystem – (e.g., total number of vessels actually fishing); forage (e.g., forage species such as herring et al., bycatch by subregion); other species (e.g., spiny dogfish, various shark species, jellyfish and prohibited, other, and nonspecified species bycatch – example(s) of prohibited bycatch include halibut mortality, herring, crab and salmon species, among others); marine mammals (e.g., seals, sea lions); seabirds (e.g., population trends and bycatch as well as breeding chronology and species productivity); and, aggregate indicators (such as possible regime shifts and trophic-level food web catch by subregion). All of these categories come under the rubric of ecosystem considerations (Livingston, 2001) at an LME scale whether in the Gulf of Alaska or the U.S. Northeast Shelf ecosystem (Sherman, 1994; e.g., Giordano, 2003).

Regarding precautionary and conservative catch limits, the North Pacific Fishery Management Council (NPFMC) mandates that "all fish caught in any fishery (including bycatch), whether landed or discarded are counted towards the TAC for that stock" (Witherell, et al., 2000). As a further management precautionary approach it is assumed that there is 100 percent mortality for all discards regardless if some fish actually survive. Species are discarded by a fishing vessel because they are either unwanted "economic discards" or they are regulatory "prohibited species" (Witherell, et al., 2000). In the North Pacific, a "best practices" approach institutionalizes that a "comprehensive and mandatory observer programme" requires 100 percent coverage on any vessel more than 49m in length overall (Witherell, et al., 2000). This has been adopted as a "best practice" to provide limits on bycatch and discards, it does not necessarily address "ecosystem concerns" (Witherell, et al., 2000).

Other emerging "best practices" (Figure(s) 5 & 6; see also Sainsbury and Sumaila, 2003) utilized in the American waters of the North Pacific for limits on bycatch and discards include certain gear restrictions, for example, to prevent ghost fishing and reduce bycatch of non-target species gillnets for groundfish are prohibited (Witherell, et al., 2000). Further, the NPFMC "adopted an improved retention and utilization programme 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" (Witherell, et al., 2000). By 2004, the NPFMC expects that for most regulated species, the discard rate will be about five percent (Witherell, et al., 2000). It is a plausible way to manage commercial fisheries while incorporating, with time, *ecosystem considerations*.

Ecosystem considerations may also translate to specific concerns in a given LME or subarea. Examples of these concerns may entail harvest rate(s) fishery effects on species composition. Significant differences exist in the rate of harvest of groundfish species in the New England Region. Some are harvested close to their F_{abc} (acceptable biological catch) levels while other species are taken at variable lower levels. Perhaps some trawl fisheries are constrained by bycatch limitations for prohibited species (e.g., yellowtail flounder) and commercial landings prices for flatfish. As witnessed in the Northeast United States Continental Shelf LME (Sherman, et al., 1996; Sherman and Skjoldal, 2002) shifting or resulting high biomasses of predator species (e.g., dogfish and skates) can have substantial impacts on the trophodynamics of the marine ecosystem and shift the species assemblages. Disproportionate harvest rates require constant analysis for lasting season-to-season implications on the commercial groundfishery. "Fish populations on Georges Bank changed from dominance by commercially important groundfish species to less desirable species such as dogfish and sandlance. Concurrent with a decline in the desirable groundfish from overfishing were increases in pelagics (herring, mackerel) and elasmobranches (spiny dogfish, skates)" (Boehlert, 1996).

Witherell, et al., (2000) emphasize that for the North Pacific, "the basic ecosystem consideration is a precautionary approach to extraction of fish resources." They suggest that the "precautionary principle was developed over the past 10 years as a policy measure to address sustainability of natural resources in the face of uncertainty" (e.g. Kinzig, et al., 2003; Hilborn, 1987). One of their main hypotheses concerning integrating ecosystem considerations in fisheries management is that "if fisheries are managed sustainably using a precautionary approach, it is likely[4] that the overall ecosystem processes, ecosystem integrity, and biodiversity are also protected to some degree" (Witherell, et al., 2000; see also Figure 7). Witherell, (1999) mentions that specific "ecosystem consideration" chapters have been prepared as supplementary information in select annual stock assessment and fishery evaluation reports (e.g., North Pacific Fishery Management Council documents dated 1998 & 1999). In addition, the NPFMC established an Ecosystem Committee in 1996 who's mission was to suggest possible ecosystem-oriented approaches into the fishery management process (e.g., hosting workshops, meetings and informal discussions) whereby the Committee utilized the scientific literature to identify elements and prospective principles of ecosystem-oriented management (see Figure(s) 8 & 9; Table 1). Witherell (1999) stresses that the NPFMC and the National Marine Fisheries Service have used a precautionary approach, incorporated as part of ecosystem considerations, by: a) relying on scientific research and advice, b) conservative catch quotas, c) comprehensive monitoring and enforcement, d) bycatch controls, e) habitat conservation areas, and f) additional ecosystem considerations (see Figure(s) 10 & 11; Restrepo, et al., 1999).

Other "considerations" result from the impacts of fishing gear on habitat and ecosystems. From numerous articles on this subject that appear in the open scientific literature, most research appears performed on trawl gear. Though not the focus of this research, bottom trawls, as well as other gear types can alter the benthic structure, sediments and nutrient cycling in certain situations (Witherell et al., 1997). Now internationally banned pelagic drift nets or "ghost fishing" created significant bycatch discard issues as well as marine debris problems. Climatic changes are another "consideration." Related to oceanic temperature conditions are year class strengths of commercially important species (e.g. Sainsbury et al., 2000). Herring and Cod appear to respond favorably with strong year classes with the onset of warm current regimes. Declines in stocks may be seen, however, for other finfish (Witherell, 1998; Mountain, 2002; Fogarty, 2001). More "retrospective" ecosystem change research on this topic might prove valuable when trying to prepare optimal yield (OY) and maximum sustainable yield (MSY) figures from biomass estimates for a commercial species. Witherell, (1998) writes about the occurrence on a decadal or longer frequency in the North Pacific Ocean, of shifts between warm and cool periods and the compelling links between ocean conditions and living marine resources production. Significant, rapid and sometimes unexpected changes may be fostered by variable ocean conditions (Skud, 1982; McFarlane, et al., 2000). These shifting oscillations in the ocean are characterized as "regime shifts" (Steele, 1998; see e.g., Figure 12).

The NPFMC also incorporates select marine protected areas (MPA's) as a tool for managing bycatch and habitat protection as well as time/area closures (e.g., Lubchenko, et al., 2003; Botsford, et al., 2003; Hastings and Botsford, 2003; Carr, 2000). Agardy (2000) reckons in regard to MPA's that "the ideal situation seems to be establishment of closed areas within the context of a larger multiple-use protected area such as a coastal biosphere reserve, marine sanctuary (as in the U.S.), or other large-scale MPA." She does hypothesize, however, that "closures having a scientific basis may be viewed by the fishing community as exclusionary practices that are somehow rooted in social discrimination." She also mentions, "the spatial dispersal of the harvesting sector is just as important to the health and character of the ecosystem as biological dispersal processes, virtually all analysis of marine reserves ignores the inevitable response of the harvesting sector to closures" (Agardy, 2000; see also Agardy, et al., 2003).

Other ecosystem-oriented management approaches include the NPFMC's adopted regulation prohibiting a directed fishery for select forage fish that are found to be important prey for higher trophic level species (such as groundfish) (Witherell, et al., 2000). These authors discuss continuing progress towards ecosystem-based management that the NPFMC is trying to fulfill. A draft approach for introducing ecosystem-oriented management for the Northeast U.S. Continental Shelf LME (see Figure(s) 8 & 9) has been crafted to foster dialogue. The approach is grounded in elements and principles of ecosystem-based management identified in the scientific literature. The approach provides a prospective definition for fisheries ecosystem-based management as well as a presentation on objectives, goals, guidelines, assumptions and understanding (see also Witherell, 1999). A "mission statement" of an agency, as it relates to *ecosystem considerations*, also would be an important component of an emerging policy (see: Lynch, et al., 1999).

THE ECOSYSTEM APPROACH AND BEST PRACTICES

Apollonio (1994) mentioned, "any community of fish species is part of a larger marine ecosystem." The ecosystem concept necessitates that all components cannot be maximized simultaneously. Apollonio (1994) adds "that variability in fisheries population biomass increase as fishing mortality (F) increases toward the fishing mortality at MSY (F_{msy})." The New England experience indicates that "as the high-value species have been fished down, increasing attention has been focused on species of lower value, such as squid" and dogfish (Apollonio, 1994). Sutinen (1999) has uncovered, "fisheries harvesting multiple species are expected to be more difficult and costly to manage than single-species fisheries. This expectation is supported in the evidence, with a high proportion of multi-species groundfish fisheries experiencing poor resource conservation and economic performance" (see Figure 13). Therefore, it is important to consider fiscal resources needed to adequately address additional information needs related to ecosystem-based fisheries management.

Sainsbury and Sumaila (2003) proffer that best practice management of combined effects of all users achieved through integrated management of appropriately defined local ecosystems. They suggest that their listing of potential "best practice reference points" and components "provide a starting point to accommodate ecosystem considerations in fisheries management and that evolving substantially in the near future will be best practice reference points – including those related to LME's concerning effects of non-fishery uses on the marine environment" (Sherman and Duda, 1999a&b; Table 2; Figure 5; see also e.g. Vandermeulen, 1998).

Ward (2000) identified "gaps and uncertainties" in the process of deriving his draft key marine ecosystem sustainability indicators. These included problems with (a) limited ecological knowledge; (b) limited scientific understanding of credible cause-effect environmental issues; (c) resolving capacity of monitoring system data capture and analysis processes; (d) the synthesis and aggregation of data; (e) implementation issues (case study trials, reference sites, interpretive models); and (f) adapting and revising sustainability indicators. "Indicators focused mainly on inputs such as financial or human resources, input loads of pollutants, size of human population or on outputs, such as number of permits, size of quota, or number of areas brought under formal management (e.g. MPA) are unlikely to be suitably robust" (Ward, 2000). "Outcome-based indicators are crucial components of any effective management system, and are needed for compliance with ISO 14001 (International Organization for Standardization, Switzerland) 'best practice' and international standards for environmental management" (Ward, 2000). Similarly, Villa and McLeod (2002) point out that "no rigorous experimental testing of vulnerability estimates is possible given our current state of knowledge of the structure and functions of the environment." These authors support the view of ecosystem integrity as "the maintenance of the community structure and function characteristic of a particular locale - deemed satisfactory to society" (Villa and McLeod, 2002).

One way that fishery management practitioners may bring to bear a "precautionary approach" in their work, and a recommended management action provided here, is by agreeing to voluntary environmental standards that provide value to business and other operations. Thus, the ISO 14000 family of international Standards on environmental management supports the objective of "sustainable development" (e.g., Table 3) of a wide-ranging portfolio of standardized methods that provides business entities and government with best available scientifically valid data on the environmental effects of economic activity; a precursor to the technical basis for environmental (fishery) regulations. The ISO 14000 Series, first printed in September of 1996, meets the needs and concerns of those interested in the environmental management of organizations. Specifically, the ISO 14000 family of Standards is comprised of a systematic approach of documents related to environmental management systems (EMS; i.e., ISO 14001 and ISO 14004) and procedures and documents related to environmental management tools, such as, EMS audits and environmental performance evaluations. In the issue at hand, for example, how much is "allowable" discard and bycatch in a given fishery? The former Chairman of the New England Fishery Management Council proclaims, "we have not been able to adequately calculate bycatch in most of our fisheries because of the lack of information or the funds to collect it" (Hill, 2002). Careful consideration will need to be given to the scientific and financial commitment required to introduce ecosystem-based fisheries management of the Northeast Shelf Ecosystem.

Thus, establishment and implementation of an organization's environmental and ecological based management system is central in ascertaining its ecosystem policy, objectives, and targets providing a benchmark frame of reference for continuous adjustment and improvement of environmental performance. Tools for environmental management exist to assist the organization in fostering and promoting its ecologically oriented policy, objectives and targets. The ISO 14000 compliance standards are practical tools for the manager (boat captain; fishery permit holder, regulator, etc.) who isn't satisfied with compliance to legislation and directives, they're for the proactive organization providing a strategic approach to conducting, implementing and evaluating environment and ecosystem-related measures that can bring a sustainable return on investment. Under ISO 14001, the fishing and public administration sectors have their own codes. Sainsbury, et al., (2000) also depict the ISO 14000 standards as important operational strategies for achieving fishery ecosystem objectives. More information on ISO 14000 EMS usage in the private sector is found in Coglianese and Nash (2002 & 2001). Therefore, adoption of ISO 14000 compliance standards appear compatible to a sustainable "precautionary approach" paradigm.

THE PRECAUTIONARY PRINCIPLE/ APPROACH AS ADAPTIVE MANAGEMENT (CONTROL RULES AND REFERENCE POINTS)

Dovers and Handmer (1995) provide one salient definition for on-the-ground usage of the precautionary principle (approach) "where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental (ecological) degradation. In the application of the precautionary principle, public and private decisions should be guided by: (i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment (ecosystem), and (ii) an assessment of the risk-weighted consequences of various options." These authors suggest that other elemental themes for the precautionary principle may be found in the open literature. Two salient interpretations may be added for LME usage through the following commentary: (iii) "the precautionary principle recommends an anticipatory or preventive approach rather than a defensive one which simply reacts to environmental (ecological) damage when it becomes apparent; and (iv) uncertainty as to the severity of the environmental impacts resulting from a development decision or an ongoing human activity should not be an excuse to avoid or delay environmental protection measures" (Dovers and Handmer, 1995). These authors also address the issue of the "shifting burden of proof" towards those proposing a possible harmful action rather than those advocating environmental (ecological) protection, such as designated stewardship agencies. Similar in nature to the philosophy of these authors, this manuscript presents a view believing that the "shifting burden of proof" conundrum is "beyond official definitions of the precautionary principle" (Dovers and Handmer, 1995) and workable on-the-ground reality considering democratic governmental sectoral regulation(s) especially when considering the overall scale and scope of an LME setting.

It should be noted that the "shifting burden of proof" is neither a goal nor objective of an LME approach to living marine resources sustainability. Another view of the "precautionary principle" (approach) is an "idea that speaks to the interest of maintaining the integrity of complex ecosystems and their dynamics" while taking into accord "the great number of fisheries today depleted or threatened with commercial crashes" (Scheiber, 1997). In order to facilitate better sustainable governance of the oceans and its attendant living resources, Costanza et al. (1998), posit their viewpoint, with respect to fisheries, even under controlled access, management decisions are often made at scales that do not consider all sources of ecological information. They also suggest that management fails to consider public owners relying instead to focus on user groups. They say this has led to fishery management decisions that encompass more risk than caution. MacDonald (1995) does proffer, however, that two international arrangements that may formalize the strictest interpretation of the precautionary principle (including that of the shifting burden of proof) despite scientific uncertainties are the protection of the ozone layer found in the Montreal Protocol of 1988, and decisions prohibiting certain whaling practices implemented through the International Whaling Commission (IWC). Most other documents encompass nonbinding agreements like the FAO Code of Conduct for Responsible Fisheries and the Rio Conference (UNCED) declaration(s).

Gerrodette et al., (2002) mention with "regard to the standards of proof required that must be met" (e.g., Charles, 2002) "it would be impossible to demonstrate 'no harm' given the large uncertainties in making any predictions about marine ecosystems." "A basic feature of any precautionary or risk averse approach to natural resource management is that the less certain we are about the effects of an action, the more cautious we should be. The Magnuson Stevens Fishery Conservation Management Act National Standards Guidelines clearly say so. 'Criteria used to set target catch levels should be explicitly risk averse, so that greater uncertainty regarding the status or productive capacity of a stock or stock complex corresponds to greater caution in setting target catch levels'" [50 CFR 600.310 (f) (5) (iii)] (Gerrodette, et al., 2002). These authors advocate, "for current U.S. fishery management precautionary buffers (the difference between targets and limits) should therefore be a positive function of uncertainty."

Charles (2002) states "with regard to the impact of fishing gear on the ocean habitat the key issue is whether a conservation rationale exists to favor one technology over another." He mentions that the traditional status quo approach is treating all fishing gears equivalently. Charles (2002) also brings to light the problematic issues surrounding, if, when, and how fishing areas and closed targeted fisheries will reopen to fisherfolk. He suggests that one "robust management" policy measure includes adaptive management "involving suitable monitoring processes, integration of knowledge (notably traditional ecological knowledge and fisher knowledge), and mechanisms for incorporating new information, so management actions can be reassessed as needed to adapt to unexpected circumstances, to avoid compromising conservation goals" (Charles, 2002). Holling (1996) proffers, "in adaptive management, policies are designed as hypotheses and management implemented as experiments to test those hypotheses" with "consequences of the (management) actions potentially reversible and that the experimenter learns from the experiment (see also Figure 14). In another view, Lackey (1997) asserts that the "hypothesis testing approach works well in research for narrow, mechanistic questions in science, but not for more complex and typical research and policy questions." Despite the foregoing commentary regarding hypothesis testing, the present problems in commercial fishery catch are unsustainable from season to season and from species to species. The culprit for this fishery unsustainability is pointed at "overfishing (e.g. Figure 15) or inefficient harvesting" (e.g., Repetto, 2001).

Gislason et al., (2000) mention, however, "the power to detect indirect effects of fishing in marine ecosystems is low, and therefore some such impacts may be masked." They further state, "it is often difficult to separate out the effects of fishing from other anthropogenic influences (e.g., pollution, habitat modification) and from natural environmental variability - this is particularly the case in nearshore ecosystems" (Gislason et al., 2000). Willmann and Insull, (1993) conclude that environmental changes brought about in other sectors seemingly unrelated to fisheries can result in concomitant loss of fish habitat and water quality deterioration, "for example, land-based pollution providing a toxic effect on fish." Thus, they suggest that coastal fisheries management ought to encompass other sectors into integrated policy making. Much research indicates, however, that present global exploitation patterns (as well as regional) do not necessarily employ a precautionary approach and are consequently unsustainable (Pauly, et al., 2002; Pauly et al., 2000; Pauly et al., 1998).

Akin to adaptive management is the policy orientation framework or cycle (Gable, 2003). Using science in adaptive management necessitates providing explicit expectations of the outcome of policies in order for designing methods to measure their effectiveness. It also involves collection and analysis of data so that the actual outcomes can be compared with hypothesized expectations. Berkes et al., (2000) suggest that adaptive management "may be viewed as the scientific analogue of traditional ecological knowledge because of its integration of uncertainty into management strategies and its emphasis on practices that confer resilience. Adaptive management emphasizes processes – including resource uses that are part of ecological cycles of renewability."

Costanza et al., (1998) subscribe to the paradigm of "adaptive management" that includes cross-disciplinary stakeholder groups, and intergenerational considerations wherein uncertainty is acknowledged as a core principle (Figure 16). They state that "precaution" is already well accepted in the international community where decisions concerning the use of marine living resources incorporate uncertainty about potentially irreversible environmental impacts, and thus are risk-averse. Adaptive management as defined by Grumbine (1994) "assumes that scientific knowledge is provisional and focuses on management as a learning process or continuous experiment where incorporating the results of previous actions allows managers to remain flexible and adapt to uncertainty." Christensen et al. (1996) subscribe to a definition of adaptive management that to manage resources sustainably in an environment of uncertainty it is a process that combines democratic principles, scientific analysis, education, and institutional learning (see also Table 2). Both definitions are analogous to the *policy orientation* concept (Lasswell, 1951).

Richards and Maguire (1998) profess that the "precautionary approach is now embodied in several international agreements, including the United Nations Straddling Fish Stocks and Highly Migratory Fish Stocks Agreement and the voluntary FAO Code of Conduct for Responsible Fisheries. Article 6 of the "Straddling Stocks" Agreement, which was ratified by the requisite number of countries as of December 11th 2001, and thus incorporated into the Law of the Sea Treaty, provides "the essence of the precautionary approach whereby 'States shall be more cautious when information uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures' and improved methods are required for dealing with risk and uncertainty" (Richards and Maguire, 1998).

Stock-specific reference points provide the principle mechanism for applying the precautionary approach for harvest management strategies for developed fisheries. The "Straddling Stocks" Agreement, in Article 6, provides that signatory States "shall determine, on the basis of the best scientific information available, stock-specific reference points and the action to be taken if they are exceeded. Two types of reference points are identified: limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield while target reference points are intended to meet management objectives" (Richards and Maguire, 1998). "Reference points have been generally defined in terms of the fishing mortality rate F and expressed as targets rather than limits. Although reference points have been applied mainly in the context of biological science, economic or social reference points could and should also be developed and adopted" (Richards and Maguire, 1998).

"The Straddling Stocks Agreement clearly specifies F_{msy}, the fishing mortality that can produce maximum sustainable yield (MSY), as a limit reference point that should not be exceeded. In addition, $B_{msy,}$ the biomass that can yield the long-term average MSY on application of $F_{msy,}$ is suggested as a rebuilding target for overfished stocks – a specific limit reference point for stock biomass is not defined. However, given $F_{msy,}$ as a limit reference point, B_{msy} could also be interpreted as a limit reference point" (Richards and Maguire, 1998; see also Restrepo, et al., 1999). "The question of appropriate reference points for a variable environment has received limited scientific attention to date (Richards and Maguire, 1998). Hollowed et al., (2000) found that for Georges Bank harvest strategies "it was impossible to derive a single fixed value for F_{msy}." Decadal variability can lead to abrupt changes suggesting evidence for "environmental forcing is strong in most marine systems" (see Figure 12).

Regarding implementing the precautionary principle (approach) through limit reference points is, "they allow specification of simple quantitative objectives with measurable criteria for determining whether they are met. This is essential for practical (workable) fisheries management" (Hall, 1999) and, "such reference points typically will need to be set for localized regions." Hall, (1999) hypothesizes that when science "uses multispecies fisheries models to help derive suitable reference points for management, they are almost always more conservative – more precautionary – than the conclusions one draws using only single species models." Hall suggests that more promising system level reference points for medium-term performance measures may be the trophic status or size structure of the catch – these could be equated to "ecosystem health and integrity." In principle, simpler to understand, augment and implement are traditional single species management approaches of target and non-target reference points. Thus, the reference point characteristically retains the capacity for proper regulatory performance measures according to Hall, (1999; but see: Sutinen, et al., 2000). Basically, "the status of an ecosystem can be assessed" according to Link, et al., (2002) and that it is "not novel to assess the status of single species fish stocks." For the assessment and management of "large marine ecosystems," lessons from single species stock assessment, environmental impact assessment (EIA), and ecological risk assessment tools and procedures provide appropriate management decision criteria (Link et al., 2002). Indeed, May et al. (1979) found, "MSY cannot serve as a guide when applied to each species individually" especially since many harvested species have robust interactions.

"It is time to propose a wider range of conservation and ecosystem objectives for fisheries management, as well as corresponding indicators and reference points that trigger management action. The reference points for a fishing plan could be the total permissible bycatch level of the species at risk" (Gislason, et al., 2000). "The indicators for directly impacted species (target and bycatch species) are well established. They include, for example, measure for exploitation rate (using size and age structure changes), spawning stock biomass and geographic distribution. Reference points for forage species (such as herring) may include consideration of prey requirements in addition to spawning stock biomass requirements for safeguarding recruitment" (Gislason, et al., 2000).

For fisheries management, "tools to achieve ecosystem objectives – gear restrictions, closed areas and seasons, including MPA's, quotas and bycatch limits and restrictions on days-at–sea, are the same as those already in use to achieve single species related conservation objectives" (Gislason, et al., 2000). These are also referred to as input-output controls and technical measures. "The similarity between single-species fisheries management and an ecosystem approach should not come as a surprise" (Sissenwine and Mace, 2003; Figure 17). "Fisheries management science refers to the broad integration of fisheries science, fisheries management and management science." "The development of fisheries management science incorporates biological, ecological, economic, social and political aspects. Currently, the scientific field is dominated by the biological sciences" (Richards and Maguire, 1998). The use of a *policy orientation* approach to LME oriented fisheries management is somewhat analogous and would incorporate the disciplinary subdivisions listed above (see: Gable, 2003; Clark, 1992).

Restrepo et al. (1999; see Figure(s) 10 & 11) helps to "succinctly" define a version of the precautionary approach whereby "in fisheries, the precautionary approach is about applying judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively (to avoid or reverse overexploitation) rather than reactively (once all doubt has been removed and the resource is severely overexploited) to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future as well as current generations." These authors also suggest that the precautionary approach can be categorized into fisheries research, fisheries management and fisheries technology. Considering if the precautionary principle is science based, "international environmental policy ultimately relies on scientific evidence to identify issues of concern and, of course, 'scientific evidence is rarely, if ever, absolute'" (MacDonald, 1995).

MacDonald (1995) emphasizes that with "respect to fisheries management, the risk of management error can never be completely eradicated. Scientific uncertainty is the accepted norm in fisheries management. A zero risk strategy would imply no development at all. A strategy hardly viable." Restrepo et al., (1999) proffer that the "basic idea of using reference points in a precautionary approach to fisheries management is that targets should be set sufficiently below limits so that the limits will be avoided with high probability and targets will be attained on average." Domestically the Sustainable Fisheries Act of 1996 "redefined optimum yield to be no greater than maximum sustainable yield. The new definition of optimum yield also included the protection of marine ecosystems as a national benefit to be considered in setting targets." These authors argue that "conservation constraints should be met before other objectives" under the precautionary approach. Young (2003) cautions, however, "applications of the precautionary principle can be expected to lead to lowering of total allowable catches. Carried to extremes, the precautionary principle can become a weapon in the hands of those who wish to terminate consumptive uses of living resources, regardless of the consequences for human welfare." He then suggests that this situation has already transpired within the aegis of the International Whaling Commission.

MacDonald (1995) emphasizes that the precautionary principle "is not a scientific risk assessment device and should not be recognized as such – it is principally applied for its value-laden character. It is up to the policy maker to determine how to apply the principle. In fisheries management a flexible precautionary principle clearly is needed." Domestically in the United States the turtle excluder device (TED) employed in the Atlantic and Gulf of Mexico shrimp fisheries, "though at the time not labeled a 'precautionary approach,'" may be just that kind of sustainable fisheries policy measure or tool. "The precautionary principle is not yet recognized as accepted customary law" (MacDonald, 1995), but it is appears to be heading that way during the last decade or so (see e.g., Belsky, 1989).

Presently, there is a proposed Northwest Atlantic Fisheries Organization (NAFO) Precautionary Approach Framework that places an emphasis on risk analyses for selected stocks employing fishing mortality and stock biomass reference points "security margins" (F_{buf} and B_{buf}) whereby the "more uncertain the stock assessment, the greater the buffer (F_{buf} & B_{buf}) should be" (NAFO, 2003). In effect, in the Northeast United States Continental Shelf LME fisheries managers have already established zoning areas for fisheries management. As described in several United Nations agreements (e.g. Annex II of the UN Straddling Stocks Agreement to which the United States is a signatory) F_{lim} equals F_{msy} because "F_{msy} as a limit is in conformance" with the prescribed precautionary approach. In the September 2003 adopted "Precautionary Approach" framework NAFO points out that "fishing somewhat below F_{msy} results in a relatively small loss in average catch, but a large increase in average biomass (which, in turn, results in a decreased risk to the fish stock, and increase in Catch Per Unit Effort (CPUE), and a decrease in the costs of fishing)." There is now consideration of multi-species situations with the desirability for a stable as possible total allowable catches (TAC's). That is, the NAFO Scientific Council adopted a precautionary approach that takes into account concerns expressed by fisheries managers. For example, F_{msy} has been recommended as a positive "first step towards ecosystem-based management" objectives ensuring that no principle fish stock is "fished harder than the single species." NAFO, (2003) states, "ecosystem-based management will likely require even more conservative fishing mortality targets than 'traditional' single-species management." This precautionary approach may also include a deemphasis of B_{msy} that attempts to avoid the impossible problem of "maintaining all stocks in a multi-species assemblage simultaneously at their respective single-species B_{msy}."

Among the precautionary management measures placed on the table by Caddy (1999), he suggests that "several simple size-based (fishery) reference points should be formulated assuming that a precautionary approach oriented fishery should allow for species to spawn at least once in life history." He adds that "a precautionary reference point is one allowing the cohort a reasonable probability of spawning at least once before capture, and this criterion can be used to test other F-based reference points for their conformity with this principle – those reference points or indices are not easily intercalibrated." See also Caddy (1999) for a review of his "traffic light" approach for employing graduated precautionary management responses in fisheries policy.

Restrepo and Powers (1999) discuss the United States NOAA/NMFS utilized strategy of control rules (CR). Following on the preceding discussion(s), some control rules, that is, fishing mortality (*F*), should be altered depending on the spawning biomass of the resource (*B*). They suggest control rules to mean a description of a variable by which managers have some direct control as a function of some other variable related to the resource (i.e., *F & B*). They employ a "precautionary control rule default target optimum yield (OY) consisting of setting the TAC target *F* (mortality) 25 percent below the limit (F_{lim}) or also referred to as the "maximum fishing mortality threshold" (Restrepo and Powers, 1999).

Darcy and Matlock (1999) state that with regard to the Sustainable Fisheries Act of 1996 (Public Law 104-297) or its predecessor Magnuson-Stevens Act of twenty years earlier, that Congress did not use the term 'precautionary approach' anywhere. They go on to mention, however, that the drafters of the National Standard Guidelines (found in the *Federal Register*; the MSFCMA requires, at section 301(b)), the Secretary of Commerce, through the Undersecretary of Oceans and Atmospheres, establish advisory "guidelines" based on the ten National Standards (see Table 4). The MSFCMA does not, however, explicitly mention, “control rules” to be promulgated as “guidelines.” These authors suggest that the precautionary approach is implicit in the Sustainable Fisheries Act of 1996 and explicit in the “guidelines” prepared for National Standard 1 – to prevent overfishing. Hsu and Wilen (1997) assert that the Sustainable Fisheries Act Standards do effectively “provide directives that are consistent with broad conservation goals and sensible ecosystem management.”

Considering the 10 National Standards in the Act, Hill (2002) comments that “avoiding or reducing significant social and economic impacts on communities dependent on access to the fishery, which is under a rebuilding program is impossible...There are inherent competing interests between the varying Standards depending on the perspective one might hold. This has inevitably led to lawsuits...as to whether the Council has properly complied with the law.” As a policy alternative, both Goethel (2002) and Hill (2002) suggest that they would have “Congress qualify or rank the 10 National Standards in order of importance.” An in-place ISO 14000 environmental management system would afford organizations the tools to carry out such a task themselves, and to amend it using the steps in the *policy orientation* process (Table(s) 5 & 6; see also Figure(s) 18 & 19) as appropriate.

Rosenberg (2002) discusses control rules stating they “essentially relate management action to control the fishing mortality rate to the status of the resource in terms of biomass or some other measure. A control rule provides a framework for preagreed management actions as called for in the precautionary approach. Uncertainty in the status of the resource can be included explicitly through the specification of management targets to be achieved on average and management thresholds that should never be exceeded.” “Control rules leave little room for negotiation and consideration of issues such as (stock) rebuilding timeframes and allocation between States, groups or gear types” (Rosenberg, 2002). Generally, these were designed by marine scientists before the managers had provided any precautionary management systems of their own. Indeed those described in Rosenberg, (2002) for example, have subsequently not been adopted by the regional international community because of concerns expressed by the managers (see NAFO, 2003). Perhaps the marine scientists got a bit ahead of themselves. Thus, Rosenberg (2002) concludes that “the mechanistic approach of control rules to implementation of precautionary management may be hindering agreement on conservation restrictions, simply because it leaves so little room for negotiation.”

Concerning the implementation of the precautionary approach domestically, Rosenberg (2002) indicates, “the Sustainable Fisheries Act of 1996 carries forward many of the ideas of the precautionary approach with regard to preventing overfishing, the use of reference points, reducing bycatch and protecting habitat.” And, “the burden of proof continues to be on managers to prove that restrictive measures are essential rather than to show that harvesting can be safely allowed.” Therefore, reference points to establish targets or thresholds for defining overfishing is a tool used to implement precautionary management in the USA, maximum sustainable yield (MSY) remains as a standard reference point. Garcia, (1994) theorizes, “in a way, the MSY could be considered a measure of the maximum assimilative capacity of the stock” (Table 7). “The need to reduce fishing pressure has resulted in (control) rules that do not allow fishers to shift from one fishery to another as easily as in the past” (Rosenberg, 2002). Thus, the need for an LME ecosystem-based approach to living resources biomass allocation in an adaptive management environment is necessary to foster sustainable yields. Rosenberg (2002) laments “as Regional Administrator for the National Marine Fisheries Service, I found it hard to understand all the rules and changes, and the fishermen certainly found it equally hard.”[5]

Garcia (1994) suggests that the precautionary principle refers to “the ‘hard line’ rule proposed for management of highly polluting activities. The ‘approaches’ refers to the practical ways and sets of measures which are precautionary in nature but may lead to more realistic application in fisheries.” “The burden of proof is traditionally on research and management with the rare exceptions where scientific work has been used to limit the development programmes on new fisheries” (Garcia, 1994). Internationally, “the precautionary principle requires nations to take preventive or corrective action even in the absence of sufficient scientific evidence of a causal link between a suspected factor and the adverse effects observed” (Garcia, 1994; Table 8). Thus, the United States in adopting the original Magnuson-Stevens Act enacted a precautionary action by restricting distant water fishing fleets from within the 200 nautical mile (pre-EEZ) fisheries zone.

Garcia (1994) believes, “although U.N. General Assembly resolutions are not legally binding, they can have enormous political significance” noting their resolutions in the early 1990’s on ‘large-scale pelagic driftnets.” “A U.N. General Assembly resolution may have an effect wider than that of a recommendation (its legal status) in revealing what State practice is, or pointing to what States might be willing to accept.” He also indicates that the “precautionary principle” is no more than a non-binding norm, operating within the framework of particular agreements, but it “may be on its way to becoming part of customary international law” (see also Belsky, 1985). Richards and Maguire (1998) hold that the precautionary approach is acquiring acceptance as a basis for fishery management.” Further, they maintain, on page 1546 of their article, “that regardless of the extent to which uncertainties can be quantified,” precaution dictates a different philosophical and practical approach to “fisheries management science.” MacDonald (1995) cautions however, that a more flexible “approach” is required with respect to fishery management and that a steadfast “principle” (or rule) cannot be applied in all management realms.

In a more up-to-date synopsis, the European Community on December 20th, 2002, regarding the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy (Council Regulation LEC No. 2371/2002, noted in the *Official Journal of the European Communities* dated 31/12/2002, this regulation entered into force on January 1st, 2003) has adopted objectives embraced by plurality by the Member States Community. They "shall apply the precautionary approach in taking measures designed to protect and conserve living aquatic resources, to provide for their sustainable exploitation and to minimize the impact of fishing activities on marine ecosystems. It should aim at a progressive implementation of an ecosystem-based approach to fisheries management"…etc., (Article 2 (1)). Article 3 (i) provides a description of the "precautionary approach to fisheries management means that the absence of adequate scientific information should not be used as a reason for postponing or failing to take management measures to conserve target species, associated or dependent species and non-target species and their environment. Precautionary reference points are biological reference points and are designed to mark the boundary between acceptable risks and unacceptable risks."

Further, Article 5 (3) and Article 6 (3) requires that "recovery plans and management plans," respectively, should be drawn-up on the basis of the precautionary approach, and, Article 6 (2) shall include conservation reference points, which under Article 3 (k) "means values of fish stock population parameters (such as biomass or fishing mortality rate) used in fisheries management, for example, with respect to an acceptable level of biological risk or desired level of yield." Three types of reference points are typically considered including limit reference points ("means values of fish stock population parameters such as biomass or fishing mortality rate) which should be avoided because they are associated with unknown population dynamics, stock collapse or impaired recruitment (Art. 3 (j)), precautionary or buffer reference points and target reference points. Thus, a precautionary approach has been linked to best practices for living marine resource capture and exploitation actions and it is therefore incumbent upon countries to apply it through customary international law and practice.

To Sissenwine and Mace (2003) the "precautionary approach means that, when in doubt, err on the side of conservation." Further, they state that "an ecosystem approach for responsible fisheries management requires taking into account trophic interactions in a precautionary fishing mortality rate strategy" which they define "is geographically specified fisheries management that takes account of knowledge and uncertainties about, and among, biotic, abiotic and human components of ecosystems, and strives to balance diverse societal objectives" (see also Figure 17). Sissenwine and Mace (2003) believe, "fisheries ecosystem plans (FEP) are useful vehicles for designing and implementing an ecosystem approach to responsible fisheries management." They list three key elements to consider in developing FEP's including (a) ocean zoning concepts; (b) specificity while authorizing fishing activities; and (c) hierarchical decision-making processes. Sissenwine and Mace (2003) suggest the creation of a new profession of fisheries and ecosystem practitioners that provide salient scientific advice.

MANAGING FISHERIES IN THE MARINE ECOSYSTEM (MORE "BEST PRACTICES")

Regarding responsible fisheries, Sinclair and Valdimarsson (2003) state "fish has become the most internationally traded food, as some 37 percent (by quantity) of all fish for human consumption is traded across borders." Related to the situation of governance for responsible domestic or international marine fisheries, Sinclair and Valdimarsson (2003) lament, "there is no complete global inventory of fisheries management systems and approaches, whether at the level of countries, stocks or fisheries." They go on to state, "several of the 31 regional fishery bodies (across the globe) implement policies based on total allowable catch (TAC) and national quotas… these approaches are complemented by a series of technical measures, including power and size regulation of vessels; size and mesh dimensions for gear; closed/open seasons/areas for fishing time encompassing effort ceilings; and catch characteristics involving minimum landing size, licensing schemes and stage of maturity/age characteristics." A movement towards ecosystem-oriented fishery management may heighten the urgency for addressing rights-based and limited access regimes (Sinclair and Valdimarsson, 2003; Sutinen at al., 2000).

Sinclair and Valdimarrson (2003) argue, "a first step in moving towards ecosystem-based fishery management is to identify and describe the different ecosystems and their boundaries, and then to consider each as a discrete entity for the purposes of management. Thereafter, ecosystem management objectives must be developed. The central objective of ecosystem-based fishery management is to obtain optimal benefits from all marine ecosystems in a sustainable manner." These authors, on page 401 of their paper, suggest, "once the objectives have been identified and agreed upon, it is necessary to establish appropriate reference points and/or sustainability indicators… which must be based on the best scientific evidence available" (see Figure 21). The general principles utilized in conventional single-species management will still apply regarding achieving objectives in suitable ecosystem-based fisheries management strategies. Degnbol (2002; Table 9) ascertains that a "reference point connects management action and outcomes; the reference point is the yardstick by which it is measured whether management has achieved its objectives and which indicates the direction for future management action." Sinclair and Valdimarsson (2003) claim that responsible fisheries invoke an "emphasis on application of the precautionary approach as central to ecosystem-based fisheries management" along with "assessing impact(s) of climate change."

Concerning the objectives for ecosystem approaches to fisheries management, Degnbol (2002) finds that unclear concepts reflect unresolved conflicts and that "the real challenge of ecosystem-based fisheries management is the implementation" stage. Degnbol (2002) asserts, "effective capacity reduction supplemented with measures to reduce habitat damage from fishing gear and to protect sensitive habitats may address most ecosystem concerns without requirements for detailed tracking of all interactions and addressing of all issues separately." Some practical obstacles to implementing ecosystem-based management include "defining the management unit, developing understanding and creating planning and management frameworks" (Slocombe, 1993). Defining new management units, such as an LME, is a critical step. It may be a "prerequisite for other steps toward ecosystem-based management. Oftentimes it may be best to just transcend existing administrative boundaries and management units" (Slocombe, 1993). Slocombe (1993) suggests, "the wide popularity of sustainable development is also becoming a major catalyst for ecosystem-based management. Cooperative management, management responses to complex demands and pressures, and protected areas are thought to be three common origins of ecosystem-based management" (Figure 22).

In terms of developing understanding, "natural-science information alone is not enough, if the goal is management of an entire watershed or (large marine) ecosystem. The management unit includes people, their social and economic activities, and their shared and individual beliefs" (Slocombe, 1993). In the marine environment, as a basis for future planning and management, "synthesis or existing information may be eminently useful in terms of developing understanding" (Slocombe, 1993). On page 621 of his paper, Slocombe states, "initial research priorities in most areas would be gathering and reviewing existing information, identifying and filling gaps, and integrating it." Holistic interdisciplinary study of ecosystems gained impetus in the 1970's from the UNESCO Man and Biosphere programs (including the marine biosphere reserve concept mentioned earlier (see: Kenchington and Agardy, 1990; Slocombe, 1993).

Slocombe, (1998) describes desirable characteristics of goals as those that should be broad and generally agreed upon, with a degree of normative implication and reflection of specific values and limits, whereas "objectives are the specific doable tasks needed to achieve the goal(s)" (see Figures 23 & 24). "Targets are readily observable, usually quantifiable, events or characteristics that can be aimed for as part of a goal or objective. Targets are a subset of the broad set of indicators, which are *a priori* identified system characteristics that can provide feedback on progress toward goals and objectives. Criteria are specific targets, often thresholds, that indicate when explicit, normative goals and objectives have been met" (Slocombe, 1998). "At a minimum, goals and objectives that address the biophysical environment and socioeconomic community in terms of structure, function, and process at an integrated ecosystem level are best" (Slocombe, 1998).

Garcia and Staples (2000; see Table 10) state that a criteria is "an attribute of the sustainability information system in relation to which indicators and reference points (targets) may be elaborated." These authors provide examples suggesting that revenue is a criteria related to the well being of humans in the fishery, spawning biomass is a criteria related to the well-being of the stock and fishing capacity is a criteria related to fishing pressure. "A reference point indicates a particular state of a fisheries indicator corresponding to a situation considered as desirable (Target Reference Point, TRP), or undesirable and requiring immediate action" (Limit Reference Points, LRP, and Threshold Reference Point, ThRP; Garcia and Staples, 2000).

GOVERNANCE ISSUES FOR ECOSYSTEM-ORIENTED FISHERIES MANAGEMENT

McGlade (2001) suggests that governance is a social function whose success is vital to our future viability; it centers on the management of complex interdependencies among individuals, corporations, interest groups, and public agencies who are engaged in interactive decision-making taking actions that affect each other's welfare." While the scientific basis for fisheries management is traditionally built around a series of models, the majority of which are aimed at single species, they are all "focused on the biological aspects of commercially important fish stocks rather than their status within the marine ecosystem or the marketplace" (McGlade, 2001). McGlade (2001) emphasizes, "by placing such a strong emphasis on the biological rather than human or economic aspects of fisheries and by concentrating only on commercially important species, fisheries managers have not succeeded in generating effective governance of fisheries or policies." She states that in activities such as fisheries, where direct scientific evidence is generally missing… "the concept of an expert as part of the system of governance has to be broadened to include those who have particular knowledge about a system" (McGlade, 2001; see also Figure 25). McGlade (2001) suggests, "the effectiveness of any form of governance depends on good communication, coordination, and integration between the various institutions, users, and beneficiaries. Time and again the importance of this has been underestimated in fisheries, leading to widespread dissatisfaction and skepticism about the ways and forms of intervention in management." International conventions, such as the Montreal and Kyoto Protocols, are often about the need to identify what the problem actually is and what opportunities exist for solving it" (McGlade, 2001).

"In many instances where responsible participation by stakeholders has been the paradigm for ocean resource governance, such as regional fishery management councils in the U.S., self-interests have overshadowed scientific assessments leading to unsustainable exploitation of the resources" (Boesch, 1999; see also Hanna, 1999; Figure 26). Regarding the precautionary principle, fundamentally it has its basis in policy not science. Scientific information is often marginalized or overwhelmed because of the dominance of economic ratcheting in fishery management decisions (Boesch, 1999; Ludwig, et al., 1993; see also Hennessey and Healey, 2000; Hanna, 1999). "Scientists should also have a better understanding of the policy-making process and the different roles they may play in the adaptive cycles linking crisis identification, weighing alternatives and the evaluation of implementation" (Boesch, 1999). Interdisciplinary science employing "ecosystem considerations" along with developing local and regional institutions and frameworks that can integrate scientific information into socioeconomic and political decisions are needed (Boesch, 1999; Botsford, et al., 1997). Concerning global climate change, there are likely to be many additional consequences to marine environments, resources and their governance. Science will be increasingly challenged by governance to forecast and predict short and long-term effects and develop means to cope (Boesch, 1999).

"Fishery governance as currently constructed is incompletely designed variable in multicomponent fishery systems. Instead of accounting for the multiplicity of ecosystem goods and services, it narrowly focuses on single species commodity production" ((Hanna, 1999). In fisheries, the overwhelming characteristic of the environment is variability (Hanna, 1999). Regarding governance issues, "great uncertainty exists about the distributional consequences of new forms of property rights such as individual transferable quotas" (Hanna, 1999). "Moving to ecosystem management requires an explicit consideration of multiple objectives not only for the production of commodity species but also for the protection of species that provide ecosystem services" (Hanna, 1999). "In some cases, fishery users are being given more responsibility for management without the corresponding transfer of skills related to information gathering and presentation, critical assessment or negotiation" (Hanna, 1999). Imperial (1999) asserts that ecosystem-oriented management "needs to develop low-cost mechanisms to facilitate communication, make decisions, and resolve conflicts between scientists, agency officials, interest groups, and the public in order to minimize information asymmetries (e.g. Figure 27). This may be one reason why many ecosystem-based management programs utilize collaborative approaches to decision-making." "Like many other government programs, ecosystem-based management is the result of an evolutionary process of experimentation, goal definition and redefinition, and the search for appropriate implementation strategies" (Imperial, 1999).

Morrissey (1996) asserts that ecosystem-based management was founded by biological scientists and its focus is upon "the healthy productivity of the place and the relationship of all its living elements." And that a "favorable science policy on ecosystem-based management would be "adaptive to individual situations," while at the same time having the same standards of measure stemming from "common scientific grounds." "Those involved in global change research study ecosystem functions at Earth System scale. For social scientists, the question of whether ecosystem management… is beneficial or detrimental is a human value judgement" (Morrissey, 1996). Domestically, Griffis and Kimball (1996) suggest that the regional marine fishery management councils "appear to have the breadth of responsibility and adequate structure needed for stakeholder input and involvement in decision making… some Councils have functioned better than others and there are lessons to be learned from both the successes and failures." Murawski (2000) emphasizes that in the U.S., "current management is characterized as being concerned with 'conservation of the parts' of systems, as opposed to the interrelationships among them." He suggests, "there is no specific ecosystem analogue to single-species definitions of overfishing." "For the Northeast USA Continental Shelf, the decline in the groundfish resource, combined with restrictive management directed to that component, has resulted in the predictable scenario of serial depletion. The practice of allowing many species to remain outside any management control until they show signs of overfishing encourages excess depletion (e.g., Hagfish) and serial depletion, and exacerbates bycatch problems" (Murawski, 2000). He reiterates, "situations such as those existing off the northeast USA could benefit greatly from a more formal mechanism to incorporate ecosystem perspectives (i.e., considerations or interactions) in the development of management goals and conservation measures (Murawski, 2000).[6]

"Ecosystem approaches, whether implemented as perspectives on traditional overfishing paradigms or through explicit ecosystem-based definitions, require research and advisory services not typically provided by fish stock assessment science. Nevertheless, additional ecosystem monitoring and research is necessary with increased emphasis on species interactions, diversity and variability – at various temporal and spatial scales" (Murawski, 2000). He suggests, "ecosystem considerations may increasingly be used to modify regulations intended primarily to conserve high-value species, to address bycatches (e.g. sea turtles and marine mammals are of significant concern), predator-prey demands and the side-effects of fishing effort" (Murawski, 2000). Both Goethel (2002) and especially Hill (2002) lament that "vessel capacity represents the most substantive and controversial issue facing fishery managers at this time" in the Northeast Continental Shelf area.

Yaffee (1996) emphasizes, "it is critical that innovations in influencing human behavior, managing organizations, and developing decision-making processes receive significant attention as ecosystem management develops, for it is these changes that will determine the future effectiveness and relevance of such approaches." He suggests that "what works is the use of collaborative decision-making approaches, developing information and info networks, mobilize organizational change and innovation, educate and be educated and empower individuals" (Yaffee, 1996), though, however, innovations in scientific knowledge and understanding may actually define and drive the debate.

Juda and Hennessey (2001) illustrated four kinds of governance related matrices for consideration of management of LME's. These included a human use matrix; the effects of human use on ecosystems; impacts of ecosystem alterations on human uses; and, a governance/use matrix example illustrating the Gulf of Maine as a geographical setting (see also Sutinen, et al., 2000). The use of matrices, coupled with careful analyses can illustrate integrated relationships between ecosystem effects from human uses and may also provide a conceptual tool to educate public stakeholders (e.g., Olsen 2000). Matrices may also be an appropriate comparative risk assessment LME approach to marine natural resource assessment (e.g., Gable, 2000; Harwell et al., 1992).

LARGE MARINE ECOSYSTEMS AS SUSTAINABLE SCIENCE (FISHERY) ECOSYSTEM-ORIENTED MANAGEMENT UNITS

A new field of "sustainability science" is evolving. The concept of sustainability relates to understanding the fundamental character of interactions between nature and society (Kates et al., 2001). For illustration here, nature refers to the greater Georges Bank area and society refers to, in part, fisherfolk, other stakeholders and government regulators of that "commons." The interaction of global processes with the ecological and social characteristics of particular places and sectors may foster a better overall understanding for ecosystem interactions (e.g., Olsen, 2000). Griffis and Kimball (1996) argue that a main ingredient of ecosystem approaches to resource management includes defining sustainability and making it the primary goal or objective.

A novel approach to coastal and nearshore ecosystems was applied by Sherman (1991). This concept is known as the large marine ecosystems (LME) approach to the assessment and management of marine resources and is considered to present an emerging international customary law paradigm for moving toward fishery sustainability (Belsky, 1985; Sherman and Duda, 1999b). Indeed, the LME approach provides for accommodating human use while maintaining ecosystem representation and integrity, among other goals (e.g., Grumbine, 1994). Machlis et al., (1997) describe five working principles that are central to LME management, though considerably less inclusive in actual practice. These principles include "(1) socially defined goals and management objectives, (2) integrated holistic science, (3) broad spatial and temperal scales, (4) adaptable institutions, and (5) collaborative decision making."

The Northeast Continental Shelf comprises 260,000 km^2 from Cape Hatteras, North Carolina to the Gulf of Maine. This region has contributed some $1 billion annually to the economy of the adjacent coastal states from yields of living marine resources such as, molluscs, crustaceans, fish and algae (Sherman, 1991; Pontecorvo et al., 1980). Historically throughout the United States in 1994, for example, $3.8 billion in dockside revenues from U.S. commercial fisheries was contributing to a total of $20.2 billion in value added to the Gross National Product (West Group, 1996). Further, by weight of catch, as a whole the U.S. is the fifth largest fishing nation in the world and the second largest seafood exporter, having shipped more than $3 billion worth of fishery products in 1994 (West Group, 1996). By 1999, U.S. commercial landings from marine fisheries provided some $3.5 billion with a value added estimated contribution of $27 billion to the U.S. economy (Scavia et al., 2001). These figures didn't include proceeds from recreational fishing efforts.

"Despite appeals for ecosystem management of ocean fisheries, development of multispecies stock assessment methods and new concepts of large marine ecosystems, few fisheries are actually managed on a multispecies basis" (Botsford, et al., 1997). "New assessment methods and management approaches account for both biological and technical (for example, through nets harvesting several species) interactions among species. However, ecosystem management of marine systems requires a sophisticated understanding of ecosystem dynamics and the organization of component communities. The development of marine ecosystem management lags significantly behind management of terrestrial and freshwater systems due to undersampling of the oceans, their three-dimensional nature and the difficulty in replicating and controlling experiments" (Botsford, et al., 1997; see also Rudd, 2004).

"Ocean ecosystems are influenced as much by changes in the physical environment as by humans. The effects of the physical environment on marine ecosystems make it difficult to define sustainability in the context of ecosystem management" (Botsford, et al., 1997; but see: Gislason, et al., 2000; Witherell, et al., 2000; Kates, et al., 2001; Busch, 2003; Busch, et al., 2003). A promising challenging "protocol for the development of ecosystem models for management involves use of adaptive management to identify strong interactions and erect interaction webs that include physical as well as biological components" (Botsford, at al., 1997). In the mid-1990's Boehlert, (1996) suggested, "research on multispecies or ecosystem management has come a long way, but the approach is not at a stage for implementation. Adaptive fisheries management uses management regimes in an experimental manner to learn about the processes regulating fish population size as well as interactions among species."

Young (2003) remarks, "analysts are increasingly aware that fish stocks clearly are components of larger ecosystems. Both abiotic and biotic processes operating in these larger systems can have dramatic impacts on the condition of individual stocks. Interdependencies between different species also can have major consequences for the condition of individual stocks. Consider the case of cod, which prey on herring and capelin. Significant changes in the size and location of herring and capelin stocks may go unnoticed by those focusing on cod stocks." Young, (2003) states, "the North Atlantic Oscillation, for instance, can make areas inhospitable to specific groups of fish. Shifts in the abundance of cod off New England and the eastern coast of Canada are thought by many observers to be associated with changes in water temperatures in the northwestern Atlantic Ocean. Large marine ecosystems are not the stable systems they were once thought to be. Ecosystems may not automatically return to equilibrium following relatively severe perturbations." Operating within and beyond the bounds of large marine ecosystems (LME's) are climate change and variability forces that affect the condition of individual fish stocks. Long-range transport of pollution from terrestrial runoff and from merchant vessels are other large scale exogenous forces exerting variability on individual fish stocks (Young, 2003). "Ecosystem approaches in fisheries management are still in their infancy" (Perry, at al., 1999; Figure 28).

"Considerable progress has been made in recent years in developing ecosystem-based approaches to large marine ecosystems… There have since been significant moves toward more such integrated approaches (pioneered for Antarctic waters with the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) to marine resource management that better recognize ecological linkages and attempt to take account not just of target species but also the ecosystem to which they belong. The CCAMLR has raised awareness of the interdependency of its various components" (Larkin, 1996). Belsky (1999) argues "that prevention of harm and 'rational and equitable use' mean that resources and uses must be studied and managed in a comprehensive manner, focusing on the large marine ecosystems in which resources exist." As such, "the concept of large marine ecosystems (LME's) is now widely accepted" (Probert, 2002). Belsky (1999) adds, "the evolution of the marine ecosystem approach from preferred policy to binding (international) customary law is demonstrated by the United Nations Convention on the Law of the Sea (UNCLOS, 1982), which came into effect in November, 1994." "The movement towards an ecosystem-approach is best represented by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) which was ratified in 1982. This treaty represents the first attempt to develop and apply an ecosystem management approach" (English, et al., 1988). And, as discussed and described in this manuscript, LME's are now a part of "best practices" international customary law (see: Belsky, 1985; Juda and Hennessey, 2001; Duda and Sherman, 2002). Knecht, (1994) proffers, "the ocean governance process and policymakers… need to take account of goals and principles emerging at the international level since these are likely to play a role in shaping future national ocean governance schemes" (see also Costanza, et al., 1998).

Sutinen and Sobeil (2003) state, "The World Bank and the Global Environment Facility (GEF) have adopted the LME approach to marine ecosystem research and management, viewing it as an effective way to manage and organize scientific research on natural processes occurring within marine ecosystems and to study how pollutants travel within marine systems." LME's also are an appropriate scale to conduct a comparative risk assessment (e.g., Gable, 2000). Longhurst, (2003) points out, "LME's are clearly an idea with which the international funding agencies are comfortable because it suggests formal structure (the standard five LME modules; Figure 2). It has achieved a high level of recognition and has become a symbol for generalized environmental concern among scientists and national environment agencies." And, as discussed and described in this manuscript, LME's are now a part of "best practices" international customary law (see: Belsky, 1985; Juda and Hennessey, 2001; Duda and Sherman, 2002).

Sutinen and Sobeil (2003) also remark, "LME's can be divided further into subsystems such as the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight in the case of the Northeast USA Continental Shelf" (see Figure 29; Sherman, et al., 1996). The LME approach to management links watershed catchment basins and intertidal coastal zones with continental shelves and littoral ocean currents." Rosenberg (2003) suggests, "the LME can extend from riverine and estuarine environments out into the coastal ocean, and even far offshore." The LME management approach, *inter alia*, provides a framework for research assessment, modeling and monitoring to potentially provide prediction for better policy decision-making. It also aids in focusing assessments and management on sustainable ecosystem oriented integrity. And, the LME approach addresses sustainable development of living marine resources in a holistic multi-faceted manner. (Sutinen and Sobeil, 2003). One jarring problem to successful implementation of the LME approach, according to Sutinen and Sobeil, (2003) may be the imperfect fit between the spatial and temporal scales of government jurisdictional agencies and ecosystems.

In the United States, for example, the eight regional fishery management councils resulting from the MFCMA of 1976 (applied March 1st 1977) provides a salient mechanism (but see Okey, 2003) for alliances and partnerships between and among private sector stakeholders such as the fishing and processing industries, non-federal agencies such as particular state marine resources divisions, interstate compacts such as the Atlantic States Marine Fisheries Commission and non-governmental for- profit and non-profit organizations. LME management also requires an increase in overall interagency coordination at all levels of government (federal, state and regional/local) (Sutinen and Soboil, 2003). Rosenberg (2003) states that the "LME concept is helpful for thinking of the linkages of biological, chemical and physical factors across large areas of the coastal ocean. Affecting any one part of the LME potentially can have repercussions throughout the region. The LME provides a framework for thinking about potential impacts." The impacts on fisheries ecosystems (the biological, oceanographic and physical environment that supports commercial and recreational species within a specified management area) of multiple ocean uses including, sand and gravel mining, submarine telecommunications cables, oil and gas energy development, marine transportation, contaminants disposal (also known as "ocean dumping"), recreational tourism and aquaculture, can occur at the scale of LME's or may be localized in scope (Rosenberg, 2003).

Rosenberg (2003) argues, "aquaculture may cause habitat degradation and competitive interactions between farmed and wild fish, which in combination reduce the productivity of the ecosystem and hence fisheries." "Aquaculture is considered by some to eventually mitigate global overfishing, yet those cultured fish which require more meal derived from wildfish per unit mass of aquaculture fish produced place even further pressure on already overexploited wild populations" (Verity, et al., 2002). From a management policy perspective, competing uses of the oceans are likely to be complex (Rosenberg, 2003). Verity et al., (2002) state, "it is well known that fish recruitment and fishery yield can vary 10 fold from one year to another, and that variability within one region over many years has scarcely been studied." "There is substantial evidence that climate influences long-term fluctuations in fish stocks that are also exploited commercially. The notion that climate changes and fisheries exploitation interact to cause more persistent changes in ecosystem structure and function than either would alone derives from evidence that climate and exploitation together accelerate species replacement" (Verity, et al., 2002; see also Skud, 1982). Verity et al., (2002) proffer, "one of the very reasons that it is so difficult to discriminate direct human impacts on fisheries from climate-induced changes is that the two may often be synergistic."

Considering the need for expanded perspective in the marine pelagic ecosystem, "a new conceptual framework is required around which to organize future research, data interpretation, and diagnostic prediction" (Verity, et al., 2002); the LME approach can now be considered as a best practice. Changing the paradigm about marine pelagic ecosystems will take time to implement (Verity et al., 2002). They conclude, "linking research and education is fundamental to achieving success in any endeavor where public policy, environmental conservation, and stewardship of natural resources are all equal players" (Verity et al., 2002). "'The ecosystem concept is very much like the concept of the hereafter: everyone understands what is meant by it but no one can define exactly what it is'" (Verity et al., 2002; but see Figures 8 & 9; see also Haeuber, 1996; Figure 30).

Schramm and Hubert (1996) suggest, "ecosystem management makes a lot of sense if we identify it as a philosophy, a set of values. It recognizes that humans – including their societies, technologies, economies, needs, and values – are part of the ecosystem." "Implementation of ecosystem management presents a basic hurdle: consideration of the environment and all its components such as ecosystem health, ecological integrity, biological diversity, and the values of people (e.g., the general public, private property owners, and elected officials" (Schramm and Hubert, 1996). "The essential components of ecosystem management are sustainable yield, maintenance of biodiversity and protection from the effects of pollution and habitat degradation. It is centered on managing the top-down or fisheries component in the context of special measures of protection for particular species" (Larkin, 1996). Larkin (1996) claims, "the development of the LME concept is a contemporary crystallization of broader perspectives in fisheries management."

Beamish and Mahnken (1999) suggest that ecosystem management "requires an understanding of the influences that regulate species naturally. Two of the most frequent news topics in recent years have been fisheries and climate. Climate will continue to be an important item in the news… but fisheries may become less so, as we stabilize our expectations through an improved understanding of the interrelationships among species and their ecosystems." "Regimes are large, linked climate-ocean ecosystems that shift in states over 10 to 30 year periods" (Beamish and Mahnken, 1999). These authors on page six of their manuscript find that "shifts in the mean carrying capacity occur when there are shifts in a regime." And carrying capacity is considered to be the mean biomass that can be supported in an ecosystem in a particular state or regime. "Ecosystem management is an exercise in long-term, precautionary thinking. It is acceptable not to know things" (Beamish and Mahnken, 1999).

Larkin (1996) laments that a perennial source of debate in fisheries management is "whether changes in the physical environment (bottom up) or the effects of harvesting (top down) are responsible for major changes in abundance. Applied to marine ecosystems, the term ecosystem management is scientific shorthand for the contemporary appreciation that fisheries management must take greater note of the multispecies interactions" (Larkin, 1996, see: Figure 31). "The point remains that the biological objective of ecosystem management must specify the species mix that is desired in the yield and this may only be possible in general terms" (Larkin, 1996). "The combined abundance of all species in a guild, that is, species that exploit the same class of resources in a similar way might more accurately reflect changes in resources or limiting factors. The relative abundance of species within a guild might change if only some species are harvested" (Larkin, 1996; see also Garrison and Link, 2000). Often the best way of ensuring acceptance and implementation of research findings – with special relevance to fishing – is through participatory research. Integrated fisheries management (IFM) "stress the interaction between the fish resources, the fishing industry and institutional structures" (Larkin, 1996). Larkin (1996) mentions "the North Pacific Fishery Management Council (NPFMC) has as the main goal of ecosystem management to ensure that human activities do not significantly alter the natural course of ecosystem dynamics" (see also Figure 32).

MacKenzie (1997) finds that the "complexity of the ecological system virtually demands an interdisciplinary approach to problem solving." Further, "scientific information must be translated into public policy and framed within the legal structures that govern society. Once agencies and individuals are enjoined in the process, a framework for decision-making must be created. This is the key procedural challenge of the ecosystem approach" (Figure 33) Using lessons learned from experience in the Great Lakes of North America, integrated resource management strategy demonstrates, "while consensus is viewed as important, most decisions are made through a formal voting procedure with majority rule" as it should. "The ecosystem approach is advocated as a promising tool for marine integrated resource management" (MacKenzie, 1997; see also Odum, 1969; Christensen, 2000; Slocombe, 1993 & 1998). MacKenzie (1997) declares, "the agency perspective is important because a basic challenge of the ecosystem approach is to bring different agencies, organizations, and interests into close working relationships." Procedural aspects and issues, such as agency participation, decision-making process and the (inter)disciplinary representation of individuals are important to integrated resource management. Challenges to an ecosystem approach, including that referring to program implementation include, funding or budgeting, demonstrating tangible results, tracking projects, and training, among others.

GOALS AND OBJECTIVES IN PROTOCOLS FOR FISHERIES MANAGEMENT

Pitcher (2001) states, "many fisheries ecologists call for ecosystem management but there have been few clear statements of what its objective should be. Trying to define alternative optimal sustainable yields for each stakeholder results only in confusion." McGinn (1999) posits that the fisherfolk community, fishery managers, politicians and the public (i.e., society) all need to coalesce to reshape fishery incentives (e.g., Figure 27). McGinn (1999) adds that in order to move toward sustainable fisheries, reshaping fishing practices behavior and incentives should be facilitated that are ecologically sustainable, economically viable and socially diverse. Barber and Taylor (1990) state, "objectives operationally support goals, that is, ideals, major accomplishments, ends, or states of affairs to be achieved, and are measurable." Further, "objectives are specific, measurable, and verifiable statements of intermediate tasks that must be accomplished to attain a goal." Objectives support goals, "they are verifiable, specific, and quantifiable, and have a performance measure attached through which the management agency can be evaluated for its progress and effectiveness" (Barber and Taylor, 1990). It is implied that a "fisheries management organization's goals and objectives are a reflection of the participants' values (those of the managers as well as the values of those trying to influence the decisions). Making these value judgements involves identifying, selecting, articulating, and ranking goals and objectives" (Barber and Taylor, 1990; see also Figure 34).

"The formalization of maximum sustainable yield (MSY) objectives undoubtedly involved values that formed the utilization ethic of managers and the belief that socioeconomic issues should not be considered (Barber and Taylor, 1990). The goal of maximum sustainable yield (MSY) can be challenged on several grounds, one of which is that "it did not account for species other than the focus of the fishery. It was not holistic MSY left out too many relevant features," such as *ecosystem considerations*. "Greater holism in fisheries management can be achieved by consideration of multiple species interactions, broad-scale physical forcing and the response of management to pressure for greater harvests under uncertainty" (Botsford, et al., 1997). "In more recent years, industry has become more involved in management with the advent of optimum yield (OY) goal, which has been legally formalized under the Magnuson Fisheries Conservation and Management Act (MFCMA) as amended in the United States. Based on the OY goal, the MFCMA recognized the importance of socioeconomic and political goals and objectives." "The goals and objectives of optimum yield management are more diverse than those established solely for conservation purposes" (Barber and Taylor, 1990). This seems true today with the three additional National Standards promulgated in October 1996 by way of the Sustainable Fisheries Act (P.L. 104-297) including sustainable communities and safety as sea (see Table 4).

The fisheries manager "may recognize that the short-term economic health of fishermen or political needs must be addressed, or to 'survive' in the organization, emphasis might be placed on values that weigh more heavily towards social or economic goals than towards conservation goals" (Barber and Taylor, 1990). "A common management action that typifies a suboptimal external focus is to set very broadly stated goals, without supporting objectives, that accommodate the values of many diverse external groups. We contend that fisheries management suffers from this common management error" (Barber and Taylor, 1990). The purpose of their paper is "a call to recognize that clearly defined goals, measurable objectives, and acknowledged values are necessary components of effective fisheries management" (Barber and Taylor, 1990).

According to De La Mare (1998) "fisheries management requires the collaboration of fisheries managers (decision makers), scientists, the fishing industry and other community interests. It requires, *inter alia*, the formulation of public policy and the development of scientific advice for its implementation. Objectives for fisheries management are usually expressed in vague terms which scientists find ambiguous or uninterpretable." He emphasizes, "fisheries management involves both biotic and abiotic factors. The biotic factors are the exploited stocks and their interactions with competitors, predators and prey, as well as the effects of the physical environment on them; the study of this complex forms the mainstream of fisheries science." Regarding the scientific approaches to fisheries management further progress is required in areas not well studied, "these lie largely in the management world and often involve the interface between science and policy" – some feel that management objectives and procedures are considered to be outside the realm of science (De La Mare, 1998).

A management-oriented paradigm (one that crosses the boundaries of traditional fisheries scientific, economic and policy research) would have decision makers pondering, "the objectives, the time scales over which they are to be achieved and considering the means and the path we choose to get there. Not considering the system as a whole tends to lead to myopic short-term solutions to problems" (De La Mare, 1998). Regarding the multiple objectives fisheries management structure, one solution, will lie in the "redefinition of 'ownership' away from single species to portfolios of species. The promotion of sustainable ecosystems does not necessarily depend on a particular property rights regime but rather on an institutional environment that promotes those basic functions" (Hanna, 1998). Burroughs and Clark (1995) remark that long-term sustainability of primarily commercial species, manipulation to improve higher value stocks, and maximizing economic benefits to the fisherfolk, are typical objectives for LME management. Greater holism for multispecies ecosystem management of fisheries as an agent of "human dominated" fisheries management is stressed by Botsford et al. (1997).

Brodziak and Link (2002) suggest that partly because of the nature of the fishery-management institutions and the lack of a management oriented paradigm reliable and effective management is probably the most difficult step in ecosystem-based fishery management. Further complicating the situation for managers are the multispecies nature of some fisheries and bycatch issues. Their contention is that although it may be sufficient to rebuild depleted groundfish resources, a single-species approach to fishery management does little to help rebuild the fishery (Brodziak and Link, 2002). Considering LME goals, Sherman and Duda (1999a&b) highlight a paradigm shift in ecosystem management from a) individual species to ecosystems; b) small spatial scale to multiple scales; c) short-term perspective to decadal long-term; d) human independent to humans as an integral part; e) management apart from research to adaptive management; and f) managing commodities to sustaining production for goods and services coming out of the ecosystems (see also Witherell, 2004 *at page 185*).

LMEs AS A PART OF INTEGRATED COASTAL MANAGEMENT

Alexander (1999) defines LME management as "the regulation of activities and resources to achieve certain objectives. The most common objective being sustainability of the living marine resources including ecologically sensitive areas preservation." Other prospective objectives for LME management may include, user conflict accommodation (e.g., "wind farms" in traditional/historical fisheries catch areas); obtaining wealth from the sea in greater values; and, or increasing (applied) scientific knowledge of regional or global phenomena to formulate better forecasts or predictions of weather and climate events on fisheries variability. The holistic or integrated approach to LME management would typically involve the drainage basins of rivers and lakes whose waters flow into the coastal zone that encompass and LME area (Alexander, 1999).

"Both integrated coastal management (ICM) and the management of large marine ecosystems (LME's) are concepts that were endorsed by the United Nations Conference on Environment and Development (UNCED) in June, 1992" (Olsen, 1999). Olsen goes on to say, "both LME management and ICM are based on the principle that an overt systems approach to resource management holds the greatest promise for defining sustainable intensities and types of human use at various scales. The focus should be on ecosystems defined as coherent, self-defined, and self-organizing units, comprising interacting ecologic, economic, and social components."

Olsen (1999) states, "ICM's emphasis on the process of governance (arrayed around the policy process), on participation, on public education, on (issue-driven) consensus building, and on voluntary compliance all can be of real use as the management of LME's and research on the ecosystem process become more important. Indeed, the evolution of domestic U.S. oriented LME's depicts the importance of problems raised by the interactions between human society (for example, the 10 National Standards found in the Sustainable Fisheries Act of 1996, see: Table 4) and the coastal ecosystems of which they are a part" (Olsen, 1999). Olsen (2001) states that integrated coastal management "is a form of adaptive management," and that it "requires understanding the interplay between social processes and ecosystem change." "Ecosystem governance of all kinds, and coastal governance in particular, are not nested across scales and are full of contradictions and gaps." Science gives legitimacy to particular policy options or lines of argument and makes the debate over contentious issues an informed one (Olsen, 2001).

Olsen (2003) argues, "the ultimate goal of sustainable forms of coastal development is today an undefined ideal." He further suggests, "sustainable development requires achieving yet to be defined equilibria among both social and environmental qualities" (Olsen, 2003). Regarding a framework and indicators for tracking the processes by which integrated coastal management initiatives evolve, Olsen (2003) states, "there are many variations to how the policy cycle model (e.g., Figure 18) can be adapted to integrated coastal management, but the central idea of a multiple step cycle of planning-commitment – implementation-evaluation remains constant" (see also e.g. Gable, 2003; Jones, 1984). "A culture of learning with high standards of accountability and professional excellence must be fostered within the emerging profession of coastal ecosystem governance" (Olsen, 2003).

Perrings (2000) states, "there is a general consensus that land-based processes pose a major threat to marine capture fisheries in many parts of the world, however, the linkages between terrestrial activities and the state of such systems are complex." Indeed, Perrings on page 514 of his manuscript also mentions, "other coastal developments, particularly for tourism also have had adverse effects on the productivity of hard-substratum marine systems such as coastal ecosystems." It is likely that the serial depletion of fish stocks is an example of environmental degradation linked to structural adjustment policies. Perrings (2000) suggests that from his analysis "four main categories of 'sustainability' indicators dominate the marine capture fisheries literature:" (a) stock catch levels; (b) biodiversity indicators; (c) ecosystem health indicators, and (d) indicators of socioeconomic stress. Ecosystem health indicators, for example, are oftentimes combined with biomass yield and biodiversity indicators (Perrings, 2000; Sherman, 1995 & 1994).

Conventional socioeconomic stress indicators (e.g. catch per unit effort (CPUE), employment, investment, prices, productivity and income distribution) are sometimes combined with biological indicators focuses on the industry rather than the underlying ecosystem (Perrings, 2000; see Figure 35). Under this rubric, "the indicators should make it possible to fit models of the causal linkage between terrestrial activities and capture fisheries" in integrated coastal area management (e.g. Figure 15). He proffers, "the problem in regulated fisheries lies in the fact that harvesting limits have been set in the context of negotiations that make little reference to fishery science" (Perrings, 2000). He cites as one example, the problem of the Atlantic Blue Fin Tuna (underreporting of catch issues) as well as the earlier collapse of North Sea and Atlantic Herring resources.

"An indicator is a statistic or parameter that tracked over time, provides information on trends in the condition of a phenomenon and has significance extending beyond that associated with the properties of the statistic itself. Environmental indicators focus on trends in environmental changes, stresses causing them, how the ecosystem and its components are responding to these changes, and societal responses to prevent, reduce or ameliorate these stresses" (Vandermeulen, 1998). As the basis for indicator development an 'issues' approach can be adapted. Vandermeulen (1998) acknowledges, "natural forces may also cause stresses, but the focus for indicators is on human causes since decision makers in society have more ability to do something about them." An example indicator of sustainable use or marine resources with links to coastal zone management includes commercial catch of all Atlantic herring stocks designated in a yearly trend series, in relation to spawning biomass trends and/or landed value of catch (Vandermeulen, 1998).

Bowen and Riley (2003) claim, "creating an indicator framework that has a place for both process and outcome indicators can help trace management efforts more directly to environmental and social conditions." They suggest that process indicators include, among others, laws written and passed, budget provided and money spent, licenses or permits issued or denied and management programs implemented. "Outcome indicators document the changes in social or physical conditions brought about by the activities of the public program (e.g. measures of organizational learning or progress; see e.g. Figure 4). "Achieving the goals (and objectives) of integrated coastal management (and LME approaches) requires a clear picture of programmatic progress, environmental conditions and influencing anthropogenic factors. Attempting to tease out the relative contributions of natural cycles, episodic events, and anthropogenic influence requires sophisticated statistical analysis and the occasional heroic assumption(s)." Socioeconomic, ecological, and management indicators all fit into a linked approach to (e.g. LME) program performance (Bowen and Riley, 2003).

Antunes and Santos (1999) claim, "the development of monitoring systems capable of providing information on (large) marine ecosystems and their response to pressures generated by human activities, is essential to improve ocean governance." Further, "interdisciplinary research is needed to develop linked physical-biological-chemical models and to integrate the socioeconomic dimension" (Antunes and Santos, 1999). The LME approach does this effectively. "Compared to other research areas, fisheries science started early to link the knowledge accumulated by natural and human science (economics and biology, in particular; Catanzano and Mesnil, 1995). "In many cases, the choice of gear is the primary factor in the fisherman's 'project,' even more so than the choice of target species." Since "most gears require a special vessel design or at least specific on-board equipment" (Catanzano and Mesnil, 1995).

Clay and McGoodwin (1995) state that a fisheries system involves the "physical environment, marine organisms, and the people who harvest, utilize and manage these resources." "Social scientists see fisheries as complex systems, involving harvesters, buyers, processors, wholesalers, retailers and consumers; support industries such as equipment, fuel and ice suppliers; families and community networks; and scientists, managers, administrators, and legislators. The interactions of these various individuals and groups, their knowledge bases, values and perceptions of the fishery, all contribute to the types of fisheries policies enacted, as well as to the success or failure of management systems." Social science studies examine both the structure of national, regional, and local management institutions and the adoption of formal and informal rules at the management/agency level by which fisheries policies are crafted (Clay and McGoodwin, 1995). "There is increasing recognition that fisheries management is as much a 'people management' problem as a biological or economic one. By definition, a fishery does not exist in the absence of human fishing effort. Effective fisheries management must be responsive not only to the biological and economic concerns, but to social and political ones as well" (Clay and McGoodwin, 1995).

Crance and Draper (1996) suggest that an important behavioral solution in coastal zone management resources decisions is "based on awareness of ecosystem resources, regional coordination for resource protection, and the use and development with due regard to needs of local populations." Trade-offs between economic, social and ecological components or resource management may become clearer when behavioral solutions are incorporated in (fishery) management plans" (Crance and Draper, 1996). "The central defining concept in integrated coastal management is the effective integration across sectors, disciplines, agencies, and stakeholders for the sustainable use of coastal areas and resources" (Poitras, et al., 2003). For the integration across sectors, they define consensus as "the building of agreement regarding integrated coastal management decisions among government agencies, user groups and local communities through informed discussion, negotiation and public participation" (Poitras, et al., 2003).

A *policy orientation* approach (e.g. Gable, 2003) within an LME paradigm may be quite complementary to the existing scientific and conservation rationale to management (units) of LME's espoused by Sherman (1991 & 1994) and the ecosystem elements for management described in Hennessey (1998; see: Table 2). Combining local and scientific knowledge, including the intuitions and experiences of fisherfolk (MacKinson and Noettestad, 1998; Wilen, et al., 2002) into a LME policy process framework may uncover the logical set of policy activities associated with government regulation of fisheries while simultaneously producing a learning-based approach to fisheries management from an overall *coastal area management* perspective (e.g., Crance and Draper, 1996; Olsen et al., 1998).

THE NEED FOR ECOLOGICAL STUDY: JELLYFISH AND CONTEMPORARY CLIMATE CHANGE

The North Pacific Fishery Management Council (NPFMC) noted, for example, "jellyfish in both the Gulf of Alaska and the Eastern Bering Sea have increased with the largest increases occurring in the 1990's in the Eastern Bering Sea and late 1980's for the Gulf of Alaska. Some relationship with oceanographic variables is hypothesized" (Livingston, 1999; see also Brodeur, et al., 1999). One "other species" indicator discussed as it relates to "non-specified species bycatch" was that there were large increases in jellyfish in 2000 relative to 1999 and they were dominant species in the "non-specified bycatch (Livingston, 2001). Pitcher, (2001) reports on huge jellyfish increases in the Adriatic, Bering, Black and South China Seas and the role gelatinous zooplankton play in destabilizing marine ecosystems.

Perhaps there are other factor(s) or threats at work in the temperate zone of the North Atlantic Ocean. Levitus et al. (2000) have found a "statistically significant" warming of the world ocean, in the last few decades, including temperate regions of the North Atlantic. Barnett, et al., (2001) more or less confirmed the ocean warming hypothesis discussed by Levitus and his colleagues. Moreover, Robinson (1994) has uncovered that there is a relatively constant predator-to-prey size ratio in littoral aquatic food chains and that large interannual variability in plankton production results from climatic atmospheric forcing in coastal nearshore environs. Therefore, this recent ocean warming trend in temperate oceanic regions could lead to a possible "regime shift" in the large marine ecosystem encompassing the Northeast United States Continental Shelf (Steele, 1998). "The regime concept forces scientists to examine the natural processes that regulate fish abundance, particularly those processes linked to climate-ocean conditions" (McFarlane, et al., 2000; see also Figure 12).

Steele and Schumacher (2000) have found that "pelagic invertebrate predators, such as "jellies" play a large role in present energy flow patterns for Georges Bank. They are also a dominant component of unexploited open ocean ecosystems." Mlot (1997) writes that hydroids, which are related to jellyfish and anemones, prey directly on Georges Bank fish larvae, and on copepods, which the fish also eat, they can reduce the survival of fish larvae by 50 percent. Further, Purcell and Arai (2001) found that gelatinous predators' selection for fish eggs and larvae has been positive for every species for which it has been calculated. They go on to mention that large gelatinous species while feeding on high densities of ichthyoplankton may eat tens to hundreds of fish eggs and larvae daily (Purcell and Arai, 2001). In the Gulf of Maine area Mills (2001) suggests that it seems that the numbers of 'jellies' may have increased in recent decades in important fishing grounds perhaps in relation to ocean warming. Quoting from Mills (2001) "the problem of ocean change is very real. It is unfortunate that we have so little population and ecological data about medusae and ctenophores in the field that we usually cannot presently distinguish between fluctuations and long term, possibly irreversible change."

Thus, an ecosystem-oriented hypothesis is that there is a natural experiment of interactions between pelagic invertebrate "jellies" with commercial fish species in the northwest Atlantic Ocean continental shelf area that may have equally deleterious regional effects on populations as that of overfishing (e.g. Safina, 2003; Repetto, 2001) or inefficient harvesting. Finding the ecological data that will either prove or find the null hypothesis as part of overall fisheries science and management in this large marine ecosystem is therefore necessary (e.g. Fogarty, 2001). Jackson et al. (2001) have illustrated some of the important top-down (food web) ecosystem interactions due to overfishing that in temperate estuarine environments, jellyfish have become more abundant trophically after anthropogenic fishing efforts to the detriment of zooplankton on which they feed. Thus, an assumption is that there is a synergistic effect between these "forcings." Earlier, Vitousek et al. (1997) found that 22 percent of recognized marine fisheries as of 1995 were over-exploited or already depleted, and 44 percent more were at their limit of exploitation. Further, they mentioned that world-wide commercial marine fisheries discard 27 million tons of non-target species annually, a quantity nearly one-third as large as total landings. Gelatinous marine invertebrates such as ctenophores, or comb jellies, are common predators in coastal waters (Madin, 2001; Moeller, 1984) and biological information needs to be found about them in order to ascertain sustainable harvest levels of commercial fishing from season to season.

Murawski (1993) has tested the sensitivity of marine fish distributions in the western North Atlantic to oscillations in ocean temperature for select commercial groundfish species and indications are fishery ranges may, in time, move poleward. This type of evolutionary global change marine science should be taken into account in fishery management plans (FMP's) and strategies (e.g., Scavia et al., 2002; Figure 20). The effects of increased carbon dioxide on marine fisheries are indirect rather than direct, and occur through changes in the physical and chemical characteristics of the ocean environment (e.g., Frank et al., 1990; Levitus et al., 2000). Indeed, climate induced alterations can best be discerned, and policies developed to mitigate unwanted effects, in a holistic ecosystem-oriented manner that an LME program provides. Climatic variability has a principal controlling influence on the structure of a littoral marine fish assemblage (Attrill and Power, 2002) and thus recruitment variability (e.g., Rothschild, 2000).

Gonzalez (1996) finds, "major ecosystem processes are climate-driven governed by broad regimes of temperature and precipitation" (see Figure 12). As a regulatory agency embraces the goal of protecting entire ecosystems "it will need to rank ecosystems at risk in order to set priorities." A "zoom-lens approach" (see also by example, Figure 19) affords an agency to see more clearly at which scale monitoring is appropriate and to "focus" or refine their efforts (Gonzalez, 1996). Thus, it is quite likely, "a high degree of interagency cooperation at various scales will be required for an ecosystem approach to be workable and successful" (Gonzalez, 1996; see also Grumbine, 1994).

DISCUSSION

Lasswell (1951) stated more than fifty years ago that "the pace of specialization in philosophy, natural science, biology, and the social sciences has been so rapid that colleagues...often complain that they cannot understand one another." Hayes (1992) believes "science has become more difficult for nonspecialists to understand is a truth universally acknowledged." Lasswell (1951) further commented that broad fields of knowledge (e.g. *marine affairs*) are needed in order to have a vision of the whole, thus, the ecosystem-oriented approach of the LME embraces such a view in living marine resource management. Lasswell (1951) points out that *policy sciences - policy orientation* can be considered "as the disciplines regarded with explaining the policy-making and policy-executing process." These are then combined with locating data and information and providing interpretations which are relevant to the policy problems of a given timeframe, scale, and domain (Lasswell, 1951; e.g., MacKinson and Noettestad, 1998; Longhurst, 1998). Hence, a *policy orientation* approach that provides a summary of Northeast Shelf LME living resources and their utilization practices (Gable, 2003) could serve for identifying the best practices record for the ecosystem while utilizing the best available science ecosystem-oriented indices (Link et al., 2002).

Lynch et al., (1999) suggest that a new "joint venture" strategy for ecosystem management is emerging among regulatory agencies (Figure 29). Management agencies "continue to struggle with the problem of how to define in operational terms, let alone implement an ecosystem-based framework for managing fisheries" (Hall, 2002). Haeuber (1996) suggests, "the evolution of scientific knowledge regarding the functioning of natural systems and the linkages between natural and human systems, has increased our understanding of the emerging generation of environmental problems." "Focusing events" in the marine environment have lifted the visibility of fishery related environmental problems (Haeuber, 1996). "Environmental events can change the carrying capacity for short or long periods and alter the competitive environment indirectly, or through direct mortality may change predator-prey proportions or the relative dominance of competing species" (Hollowed, et al., 2000; see also Skud, 1982).

"An interdisciplinary scientific effort is needed to develop methodologies for better understanding and detection of ecosystem change, as well as evaluation of different ecological functions" (von Bodungen and Turner, 2001; Figure 36). Ecosystem management "involves working across property boundaries and political jurisdictions, and requires intellectual, physical and monetary resources to address environmental issues which are not the exclusive domain of any one entity" (Michaels, et al., 1999). Knowledge of species life history parameters is perhaps a good starting point for ecosystem assessment and management approaches (King and McFarlane, 2003). "Environmental pressure builds up via socioeconomic driving forces and is augmented by natural systems variability, which leads to changes in environmental systems states and finally to the loss of goods and services. Although marine systems may be much more sensitive to changes in their environment, they also may be much more resilient more adaptable in terms of recovery response to stress and shock" (von Bodungen and Turner, 2001). These authors claim, "fisheries policies in most countries have reflected the schism between science and managers/users. It has not been straightforward for scientists to relate their science to the various stages in the policy cycle, and for policy makers to recognize what science is needed or what scientific results have to be incorporated at which time in the policy cycle (von Bodungen and Turner, 2001).

Talaue-McManus et al., (2003) suggest, "climate change, international trade and development, and mass tourism are among what may be considered as global factors affecting coastal areas." As regards to interpreting indicators, their interpretation in site-specific cases, however, requires as much knowledge as is available about the geophysical and biological processes taking place upstream in an LME estuary or watershed and within an estuary as well as downstream in the adjacent receiving waters of the coastal ocean, where the "quantity and quality of river discharge is a critical determinant of the status of continental shelf ecosystems" (Hall, 2002). Thus, this is important because out of 13,200 known species or marine fish, almost 80 percent are coastal (Belfiore, 2003). And as mentioned earlier, "no widely accepted and tested set of sustainable measures exists" for coastal waters (Belfiore, 2003; Figure 37).

LEGITIMACY FOR DOMESTIC ECOSYSTEM-ORIENTED FISHERIES MANAGEMENT

One may assume that the LME process is entering an advanced state of utilization if one employs the "policy process" found in Jones (1984). And it appears that facets of the LME paradigm, in combination with the precautionary approach, have taken root in international custom law. But has marine ecosystem-oriented management for the public domain explicitly seen legitimation through legislation by elected government in the United States (Keiter, 1996)?[7] The answer is a "qualified yes" since this research is pertinent to evolving Congressional policy as well as the findings of the Congressional mandated U.S. Ocean Commission (see e.g., Watkins, 2004 & 2002). In July of 2002, the U.S. House Resources Committee voted to pass a bill reauthorizing the Magnuson-Stevens (Sustainable Fisheries) Act wherein the language emphasizes the need for a move to ecosystem-based management. The 2002 House bill (H.R. 4749) emphasized movement toward ecosystem-based fisheries, as opposed to the traditional species-based management plans (e.g., Schiermeier, 2002).[8]

The bill, in section six, would require the Secretary of Commerce (likely through the Undersecretary for Oceans and Atmospheres, i.e., NOAA) in concert with the eight Regional Fishery Management Councils (established in 1977) to create a definition for "ecosystem" and "marine ecosystem." It would also necessitate an identification of specific marine ecosystems within each region, as well as a pilot ecosystem based fishery management plan on both the Atlantic and Pacific seaboard. Also required as a part of the House of Representatives bill, are criteria for the development of ecosystem-based management plans, and description and identification of areas of scientific understanding for which sufficient data are not yet available. And, the Secretary of Commerce would be required (when the bill becomes Public Law) to formulate research plans to meet the data deficit identified in a mandated report to Congress. Consequently, this study has attempted to introduce components of an "east coast" ecosystem-based fishery management plan design as potentially required by H.R. 4749, while taking into account sufficient data requirement needs of the regional Councils' policy managers and their constituent audience. This study has also attempted to begin to answer a question posed by Link (2002a) - "what does ecosystem-based fisheries management mean?" In addition, a 108th Congress Senate working draft bill was released on February 12th. Maine's Senator Olympia Snowe is the sponsor of the legislation referred to as the Fishery Conservation and Management Amendments Act of 2004. It too contains a section related to ecosystem research priorities with a pilot program for fishery ecosystem plans (e.g., Zabel, et al., 2003). Both bills, when passed, would need to be reconciled between the chambers in conference committee.

With the passage of the Oceans Act of 2000 (P.L. 106-256; e.g., Watkins, 2002) this study has sought to enhance fostering of sustainability natural and social science in forging linkages between best practices solutions to re-emerging living marine resources issues within the concept of sustainability and the "precautionary principle" (see Foster, et. al., 2000) that includes ecological considerations of fish stocks as component parts of a model large marine ecosystem. No single model is necessarily appropriate to all ecosystems because they are complex, dynamic and nonlinear (Low, et al., 1999). According to Jackson et al. (2001), all coastal ecosystems are already perturbed, and therefore in need of better and proper management. A shift in the current fisheries science paradigm toward more successful and integrated approaches utilizing the best available science to dealing with the fisheries problems is required now (Lane and Stephenson, 1999).

CONCLUSIONS

Presently, the LME systems approach utilizes a "five module framework." The modules include, a) productivity, b) fish and fisheries, c) pollution and ecosystem health, for example, collecting organisms as bioindicators of pollutants in finfish and bivalves, d) governance, (e.g., Juda, 1999; Hennessey, 1994; Juda and Hennessey, 2001) and e) socioeconomics (e.g., Charles, 1988; Dyer and Poggie, 2000; see Figure 2). The tool of comparative risk assessment may encompass aspects of the five module LME framework (e.g., Gable, 2000). As part of the LME framework, ecosystem services can be defined as "the conditions and processes through which natural ecosystems, and the species that comprise them, sustain and fulfill human life" (Batabyal, et al., 2003). Ecosystem resilience refers to the amount of disturbance that can be sustained before a change in (eco)system control or structure occurs (Batabyal, et al., 2003). Thus, it is appropriate to discuss fishery resources in concert with socioeconomics and adaptive management parameters in the framework described in Sherman (1995) into a *policy orientation* approach. Because domestically no legal requirement exists to implement an FMP for a stock that is not overfished, as a result, fisheries science and management is continuously playing catch up (Murawski, 2002). Combining coastal pollution, changes in biodiversity, the degraded states of fish stocks, and the deteriorating condition of coastal habitat fosters a limiting economic achievement of the full sustainable potential of coastal ecosystems (Sherman, 1995).

From the discipline of natural resource economics, it appears that people are prompted into action because of the perception or impending reality of economic loss (e.g., Swallow, 1996). In the Northeast Continental Shelf ecosystem, the New England groundfish fishery is often cited as not being managed optimally (Sutinen and Upton, 2000). The overall fisheries industry to the United States ocean sector economy remains quite viable and significant (Sherman, 1991; Pontecorvo, 1989; Pontecorvo et al., 1980). Kerry (2002) laments, however, "the combination of multiple statutory mandates, complicated regulatory procedures, and resource limitations have made it almost impossible for managers - or fishermen - to respond quickly, flexibly, or appropriately to address a management problem. In addition, implementation of the Sustainable Fisheries Act has been plagued by conflict, delays, and inconsistent interpretations of what we enacted in 1996." When fishing restrictions are lifted, after a period of time, oftentimes a "wave of lawsuits" follows (Braile, 2000). For example, as of May 1st, 2002 "there were 104 open docket cases against the agency," i.e., NMFS (Kerry, 2002). This would lead even the casual observer to suspect that fisheries resource management in the U.S. is principally driven in response to lawsuits. In general it is (Greene, 2002; Gade et al., 2002; Daley, 2002; Wilmsen, 2002). Greene (2002) comments that the willingness of fisherfolk, environmentalists, scientists, *and the courts* to find common ground will determine the future of the New England fishing industry.

Traditionally, in the U.S. littoral fishery resources have been 'common property' since ownership is held by all citizens" (Macinko and Raymond, 2001). Property rights regimes have been promulgated in the U.S. (e.g. Individual Fishery Quotas and Individual Transferable Quotas) and some researchers suggest these present a more long-term sustainable management method (Sutinen, et al., 2000; Edwards, 2003). While this may be true, research here indicates that an in-place transparent ecosystem-oriented fishery management science policy program is "very likely" better accomplished while living marine resources are held "in the public trust." Combining local and scientific knowledge, including the intuitions and experiences of fisherfolk (MacKinson and Noettestad, 1998) into a policy process framework for analysis with select functional activities with attendant potential product(s) and benefits (Jones, 1984; Clark, 1992) may uncover the logical set of activities associated with elected government legislative regulation of fisheries. This may be accomplished while at the same time producing a learning-based approach to fisheries management from an overall *coastal area management* perspective that has already encompassed property rights regimes for select species such as surf clam/ocean quahogs (e.g., Crance and Draper, 1996; Olsen et al., 1998).

A *policy orientation* formula (Gable, 2003; Table 5 & Figure(s) 18, 19 & 38) provides a view of fisheries professionals as participants immeasurably involved in decision making streams and actions over time that collectively determine what truly happens to fishery stocks within an identifiable marine ecosystem. Applying explicit knowledge of decision-making processes is essential to effective sustainability of living marine resources. An example of (local) knowledge in the policy process is public participatory awareness concerning the status of forage fisheries (herring; e.g. Gamble, 2003), consequences of optional harvest strategies, and economic rent returns derived from sundry transparent management options. Ocean science and ocean policy considerations can aid fisheries professionals in sorting through the mix of science, analysis and politics involved in important conservation and sustainability policies and programs (e.g., Clark, 1992). The present study has explored the legislation, marine policies, science, and the newly mandated ecosystem-based approach for furthering the implementation of the LME modular strategy to fisheries management, both domestically and internationally, while generically taking into accord themes and select "national standard" parameters found in the U.S. Sustainable Fisheries Act of 1996 and prospective amendments to that legislation.

ENDNOTES

1. At the 74th Plenary Meeting of the U.N. General Assembly, on December 12th 2002, 132 nations were in favor of A/57/L.48 adopted as Resolution A/57/141, only one against (Turkey) and two abstaining (Columbia & Venezuela). In their affirming statement before the General Assembly, Japan through Ambassador Akamatsu, explained its position prior to voting on the three resolutions. In essence, Japan decided to associate itself with "the consideration of the ecosystem in the conservation and management of marine living resources" regarding draft resolution A57/L.49. By voice vote draft resolution A/57/L.49 was adopted as resolution 57/142. Similarly, draft resolution A/57/L.50 was adopted as resolution 57/143. See: http:www.un.org/ga/57pv.html Online available November 10th 2003.
2. From Belsky (1985) "at a certain point, a series of state practices, codified in treaties or working agreements, and supported by the writings of legal scholars and the acknowledgement or acceptance of the world community, passes from mere examples of national action to a customary norm of international law. A total ecosystem approach to conservation and management of resources could become binding customary international law via this route."
3. From the NEFMC Executive Committee Minutes of January 9, 2004 (correspondence and reports document #10 of January 27-29, 2004) one of the discussion "problem statements" was that there is a need for advice on ecosystem management principles. "What is ecosystem-based management? We need to know what it is before

it is applied to our plans." Further, from the "minutes" it was mentioned that… "very primitive with ecosystem management… descriptive knowledge should be first step. Understanding ecosystem is difficult but right thing to do." In addition, one draft goal stated was to "improve ecosystem-based management integration of habitat and bycatch, and interactions between fishery management plans (FMP's)."

4. From *inter alia*, Mahlman (1997) & Easterling et al., (2000) & the U.S. Global Change Research Program (http://www.usgcrp.gov/) quantitative terminology used in global (climate) change and policy (and applicable here) includes:
   - "virtually certain projections" = > 99% probability or chance of being true
   - "very likely" or "very probable" = 90 to 99% or 9 out of 10 probability or chance
   - "likely" or "probable" = 67 to ~90% or 2 out of 3 chance of being true
   - "possible" = 33 to ~66% probability or chance of being true
   - "unlikely" or "some chance" = 10 to ~33% probability or chance of being true
   - "very unlikely" or "little chance" = 1 to 10% probability or chance of being true
   - "improbable" = < 1% probability or chance of being true.
5. From the NEFMC Executive Committee Minutes of January 9, 2004 under the discussion section on "problem statement" the present NOAA/NMFS Regional Administrator stated that "ecosystem management means something different to everyone; at some point all must agree as to what it means …need to have better linkage with everything we're doing and not working separately." This manuscript provides a baseline dialogue on the meaning of large marine ecosystem-oriented fisheries management (see also Figure 20).
6. NEFMC member Erik Anderson of New Hampshire at the November 4, 2003 Council meeting in Peabody, Massachusetts put forward a motion stating that population parameters used for groundfish would incorporate "ecosystem interactions" as a condition of (stock) status determination. This was the first Council meeting that an ecosystem-oriented approach was voted on and passed unanimously by the members. John Boreman, Director of the NMFS NEFSC (Woods Hole, MA.) aided when asked by vice-chairman Thomas Hill to elaborate, …"what we're going to be looking at is just all species, the whole ecosystem. So, it's all trophic interactions and competitors, predators, prey, anything that would affect the population growth of a given species." The word ecosystem is an "expression of carrying capacity in the system that may be less than the biomass target. If there are factors out there in the ecosystem that limit the carrying capacity of that particular species, we should know about that, or we should include that factor in the analysis." Thus, Erik Anderson's use of his terminology "ecosystem interaction(s)" is equivalent to the "ecosystem considerations" found in this manuscript. (Source: notarized written transcription of the audiographic tape dated March 5th, 2004 and received April, 2nd, 2004 by the NEFMC at pages 158-161).
7. It is important to note that according to Keiter (1996) "Congress is the ultimate policy-making institution; it establishes the nation's basic natural resource management policies and priorities,… with implementation coming through the executive branch of government."
8. The New England Fishery Management Council (NEFMC) at their scheduled Providence, Rhode Island public meeting provided excerpted copies for review and discussion of portions of the Preliminary Report of the U.S. Commission on Ocean Policy – Governors' Draft, April 2004. Distributed were the Executive Summary and Chapter 19, Achieving Sustainable Fisheries, as NEFMC Correspondence & Reports (May 11-13, 2004) documents.

ACKNOWLEDGMENTS

Funding for this study provided through a competitive contract from NOAA/NMFS/NEFSC Narragansett, Rhode Island Lab, P.O. No. EA133F-03-SE-0707. Additional support garnered through a U.S. National Academy of Sciences National Research Council Research Associateship Award (No. 0497420 - marine science & fisheries) performed at the NOAA/NMFS Narragansett Lab under the program on "marine ecosystems assessment and management." Thanks to Kenneth Sherman, Chief, NMFS Office of Marine Ecosystems Studies for comments on earlier versions of the manuscript as well as Dean Emeritus John A. Knauss of the University of Rhode Island (URI), Professor Timothy Hennessey of URI and Phil Logan, Chief, Social Sciences Branch (NMFS, Woods Hole, MA.) for discussions and review on aspects of the study and other anonymous reviewers. Portions of the project are a spin-off of my *marine affairs* Ph.D, graduate program of study at URI. The figures and tables were ably crafted in QuarkxPress software by Sarah Litchfield. The Social Science Branch of the NMFS-NEFSC covered publication costs for binding and distribution for the NEFSC "technical memorandum" series.

REFERENCES CITED

Agardy, T., 2000. Effects of Fisheries on Marine Ecosystems: A Conservationist's Perspective. *ICES Journal of Marine Science*, 57 (3), pp. 761-765.

Agardy, T., P. Bridgewater, M. P. Crosby, J. Day, P.K. Dayton, R. Kenchington, D. Laffoley, P. McConney, P.A. Murray, J.E. Parks, and L. Peau, 2003. Dangerous Targets? Unresolved Issues and Ideological Clashes Around Marine Protected Areas. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 13 (4), pp. 353-367.

Ajahi, T., K. Sherman, and Q. Tang, 2002. Support for Marine Sustainability Science. *Science*, 297 (5582), p. 772.

Alexander, L. M., 1999. Management of Large Marine Ecosystems: A Law of the Sea-Based Governance Regime. In: *The Gulf of Maine Large Marine Ecosystem: Assessment, Sustainability, and Management,* Kumpf, H., K. Steidinger, and K. Sherman, (eds.), Blackwell Sciences, pp. 511-515.

Alexander, L. M., 1993. Large Marine Ecosystems: A New Focus for Marine Resources Management. *Marine Policy*, 17 (3), pp. 186-198.

Antunes, P., and R. Santos, 1999. Integrated Environmental Management of the Oceans. *Ecological Economics*, 31 (2), pp. 215-236.

Apollonio, S., 1994. The Use of Ecosystem Characteristics in Fisheries Management. *Reviews in Fisheries Science*. 2 (2), pp. 157-180.

Attrill, M.J., and M. Power, 2002. Climatic Influence on a Marine Fish Assemblage. *Nature*, 417 (6886), pp. 275-278.

Barber, W.E., and J.N. Taylor, 1990. The Importance of Goals, Objectives, and Values in the Fisheries Management Process and Organization: A Review. *North American Journal of Fisheries Management*, 10 (4), pp. 365-373.

Barnett, T.P., D.W. Pierce, and R. Schnur, 2001. Detection of Anthropogenic Climate Change in the World's Oceans. *Science*, 292 (5515), pp. 270-274.

Batabyal., A.A., J.R. Kahn, and R. V. O'Neill, 2003. On the Scarcity Value of Ecosystem Services. *Journal of Environmental Economics and Management*, 46 (2), pp. 334-352.

Beamish, R.J., and C. Mahnken, 1999. Taking the Next Step in Fisheries Management. In: *Ecosystem Approaches for Fisheries Management*, Alaska Sea Grant College Program, AK-SG-99-01, Fairbanks, pp. 1-21.

Belfiore, S., 2003. The Growth of Integrated Coastal Managment and the Role of Indicators in Integrated Coastal Management: Introduction to the Special Issue. *Ocean & Coastal Management*, 46 (5), pp. 225-234.

Belsky, M.H., 1999. Using Legal Principles to Promote the "Health" of the Ecosystem. . In: *The Gulf of Maine Large Marine Ecosystem: Assessment, Sustainability, and Management,* Kumpf, H., K. Steidinger, and K. Sherman, (eds.), Blackwell Sciences, pp. 416-430.

Belsky, M. H., 1989. The Ecosystem Model Mandate for a Comprehensive United States Ocean Policy and Law of the Sea. *San Diego Law Review*, 26 (3), pp. 417-495.

Belsky, M.H., 1985. Management of Large Marine Ecosystems: Developing a New Rule of Customary International Law. *San Diego Law Review*, 22 (4), pp. 733-763.

Berkes, F., J. Colding and C. Folke, 2000. Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications*, 10 (5), pp. 1251-1262.

Boehlert, G.W., 1996. Biodiversity and the Sustainability of Marine Fisheries. *Oceanography*, 9 (1), pp. 28-35.

Boesch, D.F., 1999. The Role of Science in Ocean Governance. *Ecological Economics*, 31 (2), pp. 189-198.

Botsford, L.W., F. Micheli, and A. Hastings, 2003. Principles for the Design of Marine Reserves. *Ecological Applications*, 13 (1) Supplement, pp. S25-S31.

Botsford, L.W., J. C. Castilla, and C. H. Peterson, 1997. The Management of Fisheries and Marine Ecosystems. *Science*, 277 (5325), pp. 509-515.

Bowen, R.E., and C. Riley, 2003. Socio-economic Indicators and Integrated Coastal Management. *Ocean & Coastal Management*, 46 (5), pp. 299-312.

Braile, R., 2000. Wave of Lawsuits Follows Easing of Fishing Restrictions. *The Boston Globe*, 258 (24), p. B3.

Brodeur, R.D., C. E. Mills, J.E. Overland, G.E. Walters, and J.D. Schumacher, 1999. Evidence for the Substantial Increase in Gelatinous Zooplankton in the Bering Sea, with Possible Links to Climate Change. *Fisheries Oceanography*, 8 (4), pp. 296-306.

Brodziak, J., J. Link, 2002. Ecosystem-Based Fishery Management: What is it and How can we do it? *Bulletin of Marine Science*, 70 (2), pp. 589-611.

Brown, C.P., and S. Mumme, 2000. Applied and Theoretical Aspects of Binational Watershed Councils (*Consejos de Cuencas*) in the U.S.-Mexico Borderlands. *Natural Resources Journal*, 40 (4), pp. 895-929.

Burroughs, R.H., 1996. A Policy Orientation Toward Estuarine Shores. In: *Estuarine Shores: Evolution, Environments, and Human Alterations*, Nordstrom, K.F., and C.T. Roman (eds.), Chapter 19, John Wiley & Sons, pp. 435-448.

Burroughs, R.H., and T. W. Clark, 1995. Ecosystem Management: A Comparison of Greater Yellowstone and Georges Bank. *Environmental Management,* 19 (5), pp. 649-663.

Busch, W-D. N., B.L. Brown, and G.F. Mayer, (eds.), 2003. *Strategic Guidance for Implementing and Ecosystem-based Approach to Fisheries Management.* DOC/NOAA/NMFS, Silver Spring, MD., Technical Report, May 2003, 57 pp.

Busch, D., 2003. Ecosystem Approach to Fisheries Management Moves Forward. *The Coastal Society Bulletin*, 25 (3-4), pp. 1, 4-5, 8

Caddy, J.F., 1999. Deciding on Precautionary Management Measures for a Stock Based on a Suite of Limit Reference Points (LRPs) as a Basis for a Multi-LRP Harvest Law. *North Atlantic Fisheries Organization Scientific Council Studies*, 32, pp. 55-68.

Carr, M., 2000. Marine Protected Areas: Challenges and Opportunities for Understanding and Conserving Coastal Marine Ecosystems. *Environmental Conservation*, 27 (2), pp. 106-109.

Catanzano, J., and B. Mesnil, 1995. Economics and Biology Used in Fisheries Research or When Social and Natural Sciences Try to Depict Together the Object of Their Research. *Aquatic Living Resources*, 8 (3), pp. 223-232.

Charles, A.T., 2002. The Precautionary Approach and 'Burden of Proof' Challenges in Fishery Management. *Bulletin of Marine Science*, 70 (2), pp. 683-694.

Charles, A. T., 1988. Fishery Socioeconomics: A Survey. *Land Economics*, 64 (3), pp. 276-295.

Christensen, N.L., and 12 Others, 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecological Applications*, 6 (3), pp. 665-691.

Christensen, V., 2000. Indicators for Marine Ecosystems Affected by Fisheries. *Marine and Freshwater Research*, 51 (5), pp. 447-500.

Clark, T. W., 1992. Practicing Natural Resource Management with a Policy Orientation. *Environmental Management*, 16 (4), pp. 423-433.

Clay, P.M., and J. R. McGoodwin, 1995. Utilizing Social Sciences in Fisheries Management. *Aquatic Living Resources*, 8 (3), pp. 203-207.

Coglianese, C., and J. Nash, 2002. Policy Options for Improving Environmental Management in the Private Sector. *Environment*, 44 (9), pp. 10-23.

Coglianese, C., and J. Nash, 2001. Bolstering Private-Sectot Environmental Management. *Issues in Science and Technology*, 17 (3), pp. 69-74.

Cole, H., 2003. Contemporary Challenges: Globalisation, Global Interconnectedness and that 'There are not Plenty More Fish in the Sea;' Fisheries, Governance and Globalization: Is There a Relationship? *Ocean and Coastal Management*, 46 (1-2), pp. 77-102.

Costanza, R., and 15 Others, 1998. Principles for Sustainable Governance of the Oceans. *Science*, 281 (5374), pp. 198-199.

Council of the European Union (COEU), 2002. Council Regulation (EC) No. 2371/2002 of 20 December 2002 on the Conservation and Sustainable Exploitation of Fisheries Resources Under the Common Fisheries Policy. *Official Journal of the European Communities*, 358, pp. 59-71. Online Available, November 22nd, 2003 @ http://europa.eu.int/ .

Crance, C., and D. Draper, 1996. Socially Cooperative Choices: An Approach to Achieving Resource Sustainability in the Coastal Zone. *Environmental Management*, 20 (2), pp. 175-184.

Daley, B., 2002. Drastic Cuts Ordered in N.E. Fishing: Judges Decision Seen as Heavy Blow to Industry. *The Boston Globe*, 261 (117), pp. 1 & B4.

Darcy, G.H., and G. C. Matlock, 1999. Application of the Precautionary Approach in the National Standard Guidelines for Conservation and Management of Fisheries in the United States. *ICES Journal of Marine Science*, 56 (6), pp. 853-859.

De La Mare, W.K., 1998. Tidier Fisheries Management Requires a New MOP (Management-oriented Paradigm). *Reviews in Fish Biology and Fisheries*, 8 (3), pp. 349-356.

Degnbol, P., 2002. The Ecosystem Approach and Fisheries Management Institutions: The Noble Art of Addressing Complexity and Uncertainty with All Onboard and on a Budget. IIFET Paper No. 171 (Denmark), 11 pp. Online Available, January 12th, 2004, @ www.ifm.dk/reports/80.pdf.

Done, T.J., and R.E. Reichelt, 1998. Integrated Coastal Zone Management and Fisheries Ecosystem Management: Generic Tools and Performance Indices. *Ecological Applications*, 8 (1), Supplement, pp. S110-S118.

Dovers, S.R., and J.W. Handmer, 1995. Ignorance, the Precautionary Principle, and Sustainability. *Ambio*, 24 (2), pp. 92-97.

Duda, A.M., and K. Sherman, 2002. A New Imperative for Improving Management of Large Marine Ecosystems. *Ocean & Coastal Management,* 45 (11-12), pp. 797-833.

Dyer, C.L., and J. J. Poggie, 2000. The Natural Resource Region and Marine Policy: A Case Study From the New England Groundfish Fishery. *Marine Policy*, 24 (3), pp. 245-255.

Easterling, D.R., G.A. Meehl, C. Parmesan, S.A. Changnon, T.R. Karl, and L.O. Mearns, 2000. Climatic Extremes: Observations, Modeling, and Impacts. *Science*, 289 (5487), pp. 2068-2074.

Edwards, S.F., 2003. Property Rights to Multi-Attribute Fishery Resources. *Ecological Economics*, 44 (2-3), pp. 309-323.

Emmelin, L., 1972. The Stockholm Conferences. Ambio, 1 (4), pp. 135-140.

English, S.A., R.H. Bradbury, and R.E. Reichelt, 1988. Management of Large Marine Ecosystems – A Multinational Approach. In: *Proceedings of the 6th International Coral Reef Symposium, Australia*, Vol. 2, pp. 369-374.

Fluharty, D., 2000. Habitat Protection, Ecological Issues, and Implementation of the Sustainable Fisheries Act. *Ecological Applications*, 10 (2), pp. 325-337.

Fluharty, D., and 19 Others, 1999. Ecosystem-Based Fishery Management. A Report to Congress by the Ecosystems Principles Advisory Panel. U.S. Department of Commerce, NOAA/NMFS Technical Report, 54 pp.

Fogarty, M.J., 2001. Climate Variability and Ocean Ecosystem Dynamics: Implications for Sustainability. In: *Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference,* Amsterdam, Holland, 10-13 July, 2001, W. Steffen, J. Jaeger, D.J. Carson, and C. Bradshaw, (eds), Ch. 4, Springer, pp. 27-29.

Foster, K.R., P. Vecchia, and M.H. Repacholi, 2000. Science and the Precautionary Principle. *Science*, 288 (5468), pp. 979-981.

Francis, R.I.C.C., and R. Schotten, 1997. "Risk" in Fisheries Management: A Review. Canadian Journal of Fisheries and Aquatic Sciences, 54 (8), pp. 1699-1715.

Frank, K. T., R. I Perry, and K. F. Drinkwater, 1990. Predicted Response of Northwest Atlantic Invertebrate and Fish Stocks to CO_2 - Induced Climate Change. *Transactions of the American Fisheries Society*, 119 (2), pp. 353-365.

Gable, F.J., 2003. A Practice-Based Coupling of the Precautionary Principle to the Large Marine Ecosystem Fisheries management Concept with a Policy Orientation: The Northeast United States Continental Shelf as a Case Example. *Coastal Management*, 31 (4), pp. 435-456.

Gable, F. J., 2000. The Black Sea: An Environmental and Ecological Profile. *Ocean Yearbook*, 14, University of Chicago Press, pp. 420-467.

Gade, M.A., T.D. Garcia, J.B. Howes, T.M. Schad, and S. Shipman, 2002. *Courts, Congress, and Constituencies: Managing Fisheries by Default.* A Report by a Panel of the National Academy of Public Administration for the Congress and the U.S. Department of Commerce National Marine Fisheries Service, Washington, D.C. 160 pp.

Gamble, M., 2003. Public Information Document for Amendment 2 to the Interstate Fishery Management Plan for Atlantic Herring. Atlantic States Marine Fisheries Commission, December, Washington, D.C. 18 pp.

Garcia, S,M., 2000. The FAO Definition of Sustainable Development and the Code of Conduct for Responsible Fisheries: An Analysis of Related Principles, Criteria and Indicators. *Marine and Freshwater Research*, 51 (5), pp. 535-541.

Garcia, S.M., 1994. The Precautionary Principle: Its Implications in Capture Fisheries Management. *Ocean & Coastal Management*, 22 (2), pp. 99-125.

Garcia, S.M., and D.J. Staples, 2000. Sustainability Reference Systems and Indicators for Responsible Marine Capture Fisheries: A Review of Concepts and Elements for a Set of Guidelines. *Marine and Freshwater Research*, 51 (5), pp. 385-426.

Garcia, S.M., and C.H. Newton, 1994. Responsible Fisheries: An Overview of FAO Policy Developments (1945-1994). *Marine Pollution Bulletin*, 29 (6-12), pp. 528-536.

Garribaldi, L., and L. Limongelli, 2003. *Trends in Oceanic Capture and Clustering of Large Marine Ecosystems*. FAO Fisheries Technical Paper 435, 71 pp.

Garrison, L.P., and J.S. Link, 2000. Fishing Effects on Spatial Distribution and Trophic Guild Structure of the Fish Community in the Georges Bank Region. *ICES Journal of Marine Science*, 57 (3), pp. 723-730.

Gerrodette, T., P. Dayton, S. Macinko, and M. J. Fogarty, 2002. Precautionary Management of Marine Fisheries: Moving Beyond Burden of Proof. *Bulletin of Marine Science*, 70 (2), pp. 657-668.

Giordano, M., 2003. The Geography of the Commons: The Role of Scale and Space. *Annals of the Association of American Geographers*, 93 (2), pp. 365-375.

Gislason, H., M. Sinclair, K. Sainsbury, and R. O'Boyle, 2000. Symposium Overview: Incorporating Ecosystem Objectives Within Fisheries Management. *ICES Journal of Marine Science*, 57 (3), pp. 468-475.

Goethel, D.T., 2002. *Ocean Policy and Fisheries: A Discussion of Areas in Need of Change*. Statement before the U.S. Commission on Ocean Policy, Boston, Massachusetts, July, 2002, Online Available at: http://www.oceancommission.gov , 3 pp.

Gonzalez, O.J., 1996. Formulating and Ecosystem Approach to Environmental Protection. *Environmental Management*, 20 (5), pp. 597-605.

Grassle, J.F., 2001. Marine Ecosystems. In: *Encyclopedia of Biodiversity*, Vol. 4, Academic Press, San Diego, CA., pp. 13-25.

Gray, T., and J. Hatchard, 2003. The 2002 Reform of the Common Fisheries Policy's System of Governance — Rhetoric or Reality? *Marine Policy*, 27 (6), pp. 545-554.

Greene, K., 2002. Fishery Science: Bigger Populations Needed for Sustainable Harvests. *Science*, 296 (5571), pp. 1229-1230.

Griffis, R.B., and K.W. Kimball, 1996. Ecosystem Approaches to Coastal and Ocean Stewardship. *Ecological Applications*, 6 (3), pp. 708-712.

Grumbine, R.E., 1994. What is Ecosystem Management? *Conservation Biology*, 8 (1), pp. 27-38.

Haeuber, R., 1996. Setting the Environmental Policy Agenda: The Case of Ecosystem Management. *Natural Resources Journal*, 36 (1), pp. 1-28.

Hall, S.J., 2002. The Continental Shelf Benthic Ecosystem: Current Status, Agents for Change and Future Prospects. *nvironmental Conservation*, 29 (3), pp. 350-374.

Hall, S.J., 1999. Managing Fisheries Within Ecosystems: Can the Role of Reference Points be Expanded? *Aquatic Conservation: Marine and Freshwater Ecosystems*, 9 (6), pp. 579-583.

Hanna, S.S., 1999. Strengthening Governance of Ocean Fishery Resources. *Ecological Economics*, 31 (2), pp. 275-286.

Hanna, S. S., 1998. Institutions for Marine Ecosystems: Economic Incentives and Fishery Management. *Ecological Applications*, 8 (1) Supplement, pp. S170-S174.

Harwell, M.A., W. Cooper, R. Flaak, 1992. Prioritizing Ecological and Human Welfare Risks from Environmental Stresses. *Environmental Management*, 16 (4), pp. 451-464.

Hastings, A., and L. W. Botsford, 2003. Comparing Designs of Marine Reserves for Fisheries and for Biodiversity. *Ecological Applications*, 13 (1) Supplement, pp. S65-S70.

Hayes, D. P., 1992. The Growing Inaccessibility of Science. *Nature*, 356 (6372), pp. 739-740.

Hennessey, T. M., 1998. Ecosystem Management: The Governance Approach. In: *Ecosystems Management: A Social Science Perspective*, Soden, D., Lamb, B. L., and Tennert, J. R., (eds.), Kendall-Hunt, Dubuque, Iowa, Ch. 2, pp. 13-29.

Hennessey, T. M., 1994. Governance and Adaptive Management for Estuarine Ecosystems: The Case of Chesapeake Bay. *Coastal Management*, 22 (2), pp. 119-145.

Hennessey, T., and M. Healey, 2000. Ludwig's Ratchet and the Collapse of New England Groundfish Stocks. *Coastal Management*, 28 (3), pp. 187-213.

Hilborn, R., 1987. Living with Uncertainty in Resource Management. *North American Journal of Fisheries Management*, 7 (1), pp. 1-5.

Hill, T. R., 2002. Testimony by the Chairman, New England Fishery Management Council, before the U.S. Commission on Ocean Policy, Boston, Massachusetts, July, 2002, Online Available at: http://www.oceancommission.gov , 6 pp.

Holling, C.S., 1996. Surprise for Science, Resilience for Ecosystems, and Incentives for People. *Ecological Applications*, 6 (3), pp. 733-735.

Hollowed, A.B., N. Bax, R. Beamish, J. Collie, M. Fogarty, P. Livingston, J. Pope, and J.C. Rice, 2000. Are Multispecies Models an Improvement on Single-Species Models for Measuring Fishing Impacts on Marine Ecosystems? *ICES Journal of Marine Science*, 57 (3), pp. 707-719

Hsu, S-L, and J.E. Wilen, 1997. Ecosystem Management and the 1996 Sustainable Fisheries Act. *Ecology Law Quarterly*, 24 (4), pp. 799-811.

Imperial, M.T., 1999. Institutional Analysis and Ecosystem-Based Management: The Institutional Analysis and Development Framework. *Environmental Management*, 24 (4), pp. 449-465.

Jackson, J.B.C., and 18 Others, 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science*, 293 (5530), pp. 629-638.

Jahnke, M., (ed.), 2003. United Nations Activities: Environmental Policy Decisions. *Environmental Policy and Law*, 33 (1), pp. 2-13.

Jones, C. O., 1984. *An Introduction to the Study of Public Policy*, Third Edition. Harcourt Brace & Company, Orlando, Florida, 276 pp.

Juda, L., 1999. Considerations in Developing a Functional Approach to the Governance of Large Marine Ecosystems. *Ocean Development & International Law*, 30 (2), pp. 89-125.

Juda, L., and T. Hennessey, 2001. Governance Profiles and the Management of the Uses of Large Marine Ecosystems. *Ocean Development & International Law*, 32 (1), pp. 43-69.

Juda, L., R. H. Burroughs, 1990. The Prospects for Comprehensive Ocean Management. *Marine Policy*, 14 (1), pp. 23-35.

Kates, R. W., and 22 Others, 2001. Sustainability Science. *Science*, 292 (5517), pp. 641-642 + Supplementary Material.

Keiter, R.B., 1996. Toward Legitimizing Ecosystem Management on the Public Domain. *Ecological Applications*, 6 (3), pp. 727-730.

Kenchington, R.A., and M.T. Agardy, 1990. Achieving Marine Conservation Through Biosphere Reserve Planning and Management. *Environmental Conservation*, 17 (1), pp. 39-44.

Kerry, J. F., 2002. Statement of Senator John F. Kerry (MA.) Senate Subcommittee on Oceans, Atmosphere and Fisheries, Oversight Hearing on NMFS Management Issues, May 9, 2002, 5 pp.

King, J.R., and G.A. McFarlane, 2003. Marine Fish life History Strategies: Applications to Fishery Management. *Fisheries Management and Ecology*, 10 (4), pp. 249-264.

Kinzig, A., and 20 Others, 2003. Coping with Uncertainty: A Call for a New Science-Policy Forum. *Ambio*, 32 (5), pp. 330-335.

Knecht, R.W., 1994. Essay: Emerging International Goals and Principles and Their Influence on National Ocean Governance. *Coastal Management*, 22 (2), pp. 177-182.

Lackey, R.T., 1997. Ecosystem Management: In Search of the Elusive Paradigm. *Human Ecology Review*, 4 (2), pp. 107-113.

Lane, D. E., and R. L. Stephenson, 1999. Fisheries-management Science: A Framework for the Implementation of Fisheries-management Systems. *ICES Journal of Marine Science*, 56 (6), pp. 1059-1066.

Larkin, P.A., 1996. Concepts and Issues in Marine Ecosystem Management. *Reviews in Fish Biology and Fisheries,* 6 (2), pp. 139-164.

Lasswell, H.D., 1951. *The Policy Orientation*. In: The Policy Sciences, D. Lerner and H. D. Lasswell (eds.), Stanford University Press, Palo Alto, California, pp. 3-15.

Levitus, S., J. I. Antonov, T.P. Boyer, and C. Stephens, 2000. Warming of the World Ocean. *Science*, 287 (5461), pp. 2225-2229.

Link, J.S., 2002a. What Does Ecosystem-Based Fisheries Management Mean? *Fisheries*, 27 (4), pp. 18-21.

Link, J. S., 2002b. Ecological Considerations in Fisheries Management: When Does it Matter? *Fisheries*, 27 (4), pp. 10-17.

Link, J.S., J.K.T. Brodziak, S.F. Edwards, W.J. Overholtz, D. Mountain, J.W. Jossi, T.D. Smith, and M.J. Fogarty, 2002. Marine Ecosystem Assessment in a Fisheries Management Context. *Canadian Journal of Fish and Aquatic Science*, 59 (9), pp. 1429-1440.

Livingston, P., (ed.), 2001. Ecosystem Considerations for 2002. North Pacific Fishery Management Council, Anchorage, Alaska, November, 2001. Online Available, September 29th, 2003 @ http://www.fakr.noaa.gov/npfmc/ecosystem/ecobased.htm .

Livingston, P., (ed.), 1999. Ecosystem Considerations for 2000. North Pacific Fishery Management Council, Anchorage, Alaska, November, 1999. Online Available, September 29th, 2003 @ http://www.fakr.noaa.gov/npfmc/ecosystem/ecobased.htm .

Longhurst, A., 2003. The Symbolism of Large Marine Ecosystems. *Fisheries Research*, 61 (1-3), pp. 1-6.

Longhurst, A. R., 1998. *Ecological Geography of the Sea*. Academic Press, San Diego, California, 398 pp.

Low, B., R. Costanza, E. Ostrom, J. Wilson, and C.P. Simon. 1999. Human-Ecosystem Interactions: A Dynamic Integrated Model. *Ecological Economics,* 31 (2), pp. 227-242.

Lubchenco, J., S.R. Palumbi, S.D. Gaines, and S. Andelman, 2003. Plugging a Hole in the Ocean: The Emerging Science of Marine Reserves. *Ecological Applications*, 13 (1) Supplement, pp. S3-S7.

Ludwig, D., R. Hilborn, and C. Walters, 1993. Uncertainty, Resource Exploitation, and Conservation: Lessons from History. *Science*, 260 (5104), pp. 17 & 36.

Lynch, K.D., W.W. Taylor, J.M. Robertson, and K.D. Smith, 1999. Utilizing Ecosystem Concepts in Fisheries Management Strategies. In: *Ecosystem Approaches for Fisheries Management,* Alaska Sea Grant College Program, AK-SG-99-01, Fairbanks, pp. 353-366.

MacDonald, J. M., 1995. Appreciating the Precautionary Principle as an Ethical Evolution in Ocean Management. *Ocean Development & International Law*, 26 (3), pp. 255-286.

Macinko, S., and L. Raymond, 2001. Fish on the Range: The Perils of Crossing Conceptual Boundaries in Natural Resource Policy. *Marine Policy*, 25 (2), pp. 123-131.

Machlis, G.E., J.E. Force, and W. R. Burch Jr., 1997. The Human Ecosystem Part 1: The Human Ecosystem as an Organizing Concept in Ecosystem Management. *Society & Natural Resources*, 10, pp. 347-367.

Mackenzie, S.H., 1997. Toward Integrated Resource Management: Lessons from the Ecosystem Approach from the Laurentian Great Lakes. *Environmental Management*, 21 (2), pp. 173-183.

Mackinson, S., and L. Noettestad, 1998. Combining Local and Scientific Knowledge. *Reviews in Fish Biology and Fisheries*, 8 (4), pp. 481-490.

Madin, L., 2001. The Jellies vs. the Fish. Ocean Alive: Plain Talk on Current Topics in Marine Science Presented to the General Public. WHOI Sea Grant, April 24th, 2001, 1p.

Mahlman, J.D., 1997. Uncertainties in Projections of Human-Caused Climate Warming. *Science*, 278 (5342), pp. 1416-1417.

May, R. M., J. R. Beddington, C. W. Clark, S. J. Holt, and R. M. Laws, 1979. Management of Multispecies Fisheries. *Science*, 205 (4403), pp. 267-277.

McFarlane, G.A., J.R. King, and R.J. Beamish, 2000. Have There Been Recent Changes in Climate? Ask the Fish. *Progress in Oceanography*, 47 (2-4), pp. 147-169.

McGinn, A. P., 1999. Moving Toward Sustainable Fisheries. *Natural Resources Forum*, 23 (2), pp. 135-145.

McGlade, J.M., 2001. Governance and Sustainable Fisheries. In: *Science and Integrated Coastal Management,* von Bodungen, B., and R.K. Turner (eds.), Dahlem University Press, pp. 307-326.

McLain, R.J., and R.G. Lee, 1996. Adaptive Management: Promises and Pitfalls. *Environmental Management,* 20 (4), pp. 437-448.

Merrell, W.J., M.H. Katsouros, and J. Bienski, 2001. The Stratton Commission: The Model for a Sea Change in National Marine Policy. *Oceanography*, 14 (2), pp. 11-16.

Michaels, S., R.J. Mason, and W.D. Solecki, 1999. The Importance of Place in Partnerships for Regional Environmental Management. *Environmental Conservation*, 26 (3), pp. 159-162.

Mills, C.E., 2001. Jellyfish Blooms: Are Populations Increasing Globally In Response to Changing Ocean Conditions? *Hydrobiologia*, 451, pp. 55-68.

Mlot, C., 1997. Unusual Fish Threat Afloat in the Atlantic. *Science News*, 152 (21), p. 325.

Moeller, H., 1984. Reduction of a Larval Herring Population by Jellyfish Predator. *Science*, 224 (4649), pp. 621-622.

Morrissey, W.A., 1996. Science Policy and Federal Ecosystem-Based Management. *Ecological Applications,* 6 (3), pp. 717-720.

Mountain, D.G., 2002. Potential Consequences of Climate Change for the Fish Resources in the Mid-Atlantic Region. *American Fisheries Society Symposium*, 32, pp. 185-194.

Murawski, S.A., 2002. Scientific Challenges in Supporting Living Marine Resources Management. Statement to the U.S. Commission on Ocean Policy. July, Boston, Massachusetts, 11 pp.

Murawski, S.A., 2000. Definitions of Overfishing from an Ecosystem Perspective. *ICES Journal of Marine Science,* 57 (3), pp. 649-658.

Murawski, S. A., 1993. Climate Change and Marine Fish Distributions: Forecasting from Historical Analogy. *Transactions of the American Fisheries Society*, 122 (5), pp. 647-658.

NAFO (Northwest Atlantic Fisheries Organization), 2003. Proposed NAFO Precautionary Approach Framework from Scientific Council. NAFO SCR Doc. 03/23, 5 pp.

Nelson, B., 1969. Marine Commission Invokes NOAA, Urges Refitting of Nation's Ark. *Science*, 163 (3864), pp. 263-265.

Odum, E.P., 1969. The Strategy of Ecosystem Development. *Science*, 164 (3877), pp. 262-270.

Okey, T.A., 2003. Membership of the Eight Regional Fishery Management Councils in the United States: Are Special Interests Over-Represented? *Marine Policy*, 27 (3), pp. 193-206.

Olsen, S.B., 2003. Frameworks and Indicators for Assessing Progress in Integrated Coastal Management Initiatives. *Ocean & Coastal Management*, 46 (5), pp. 347-361.

Olsen, S.B., 2001. Inventing Governance Systems That Respond to Coastal Ecosystem Change. In: *Science and Integrated Coastal Management*, von Bodungen, B., and R.K. Turner (eds.), Dahlem University Press, pp. 327-339.

Olsen, S. B., 2000. Educating for the Governance of Coastal Ecosystems: The Dimensions of the Challenge. *Ocean & Coastal Management*, 43 (4-5), pp. 331-341.

Olsen, S., 1999. Linking Integrated Coastal Management with Large Marine Ecosystems Management. In: *The Gulf of Maine Large Marine Ecosystem: Assessment, Sustainability, and Management,* Kumpf, H., K. Steidinger, and K. Sherman, (eds.), Blackwell Sciences, pp. 626-633.

Olsen, S. B., J. Tobey, and L. Z. Hale, 1998. A Learning-based Approach to Coastal Management. *Ambio*, 27 (8), pp. 611-619.

O'Toole, M., 2002. Benguela Current Large Marine Ecosystem Programme Strategic Action Programme. Updated, November, 2002, Windhoek, Namibia, 23 pp.

Overholtz, W.J., J.S. Link, and L.E. Suslowicz, 1999. Consumption and Harvest of Pelagic Fishes and Squids in the Gulf of Maine - Georges Bank Ecosystem. In: *Ecosystem Approaches for Fisheries Management,* Alaska Sea Grant College Program, AK-SG-99-01, pp. 163-186.

Pauly, D., V. Christensen, S. Guenette, T.J. Pitcher, U.R. Sumaila, C.J. Walters, R. Watson, and D. Zeller, 2002. Towards Sustainability in World Fisheries. *Nature*, 418 (6898), pp. 689-695.

Pauly, D., V. Christensen, R. Froese, and M. L. Palomeres, 2000. Fishing Down Aquatic Food Webs. *American Scientist*, 88 (1), pp. 46-51.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr., 1998. Fishing Down Marine Food Webs. *Science*, 279 (5352), pp. 860-863.

Perrings, C., 2000. Sustainability Indicators for Fisheries in Integrated Coastal Area Management. *Marine and Freshwater Research,* 51 (5), pp. 513-522.

Perry, R.I., C.J. Walters, and J.A. Boutillier, 1999. A Framework for Providing Scientific Advice for the Management of New and Developing Fisheries. *Reviews in Fish Biology and Fisheries,* 9 (2), pp. 125-150.

Phillips, C.G., and J. Randolph, 2000. The Relationship of Ecosystem Management to NEPA and its Goals. *Environmental Management*, 26 (1), pp. 1-12.

Pielke, R. A., D. Sarewitz, R. Byerly, and D. Jamieson, 1999. Prediction in the Earth Sciences and Environmental Policy Making. *EOS, Transactions, the American Geophysical Union*, 80 (28), pp. 311-313.

Pitcher, T.J., 2001. Fisheries Managed to Rebuild Ecosystems? Reconstructing the Past to Salvage the Future. *Ecological Applications*, 11 (2), pp. 601-617.

Poitras, J., R. Bowen, and J. Wiggin, 2003. Challenges to the Use of Consensus Building in Integrated Coastal Management. *Ocean & Coastal Management*, 46 (5), pp. 391-405.

Pontecorvo, G., 1989. Contribution of the Ocean Sector to the United States Economy: Estimated Values for 1987 - A Technical Note. *Marine Technology Society Journal*, 23 (2), pp. 7-14.

Pontecorvo, G., M. Wilkinson, R. Anderson, and M. Holdowsky, 1980. Contribution of the Ocean Sector to the United States Economy. *Science*, 208 (4447), pp. 1000-1006.

Probert, P.K., 2002. Ocean Science and Conservation – Catching the Wave. *Aquatic Science: Marine and Freshwater Ecosystems*, 12 (2), pp. 165-168.

Purcell, J.E., and M.N. Arai, 2001. Interactions of Pelagic Cnidarians and Ctenophores with Fish: A Review. *Hydrobiologia*, 451, pp. 27-44.

Repetto, R., 2001. A Natural Experiment in Fisheries Management. *Marine Policy*, 25 (4), pp. 251-264.

Restrepo, V. R., and J. E. Powers, 1999. Precautionary Control Rules in US Fisheries Management: Specification and Performance. *ICES Journal of Marine Science*, 56 (6), pp. 846-852.

Restrepo, V.R., P.M. Mace, and F.M. Serchuk, 1999. The Precautionary Approach: A New Paradigm or Business as Usual? In: *Our Living Oceans: Report on the Status of Living Marine Resources, 1999*. NOAA Technical Memorandum NMFS-F/SPO-41, pp. 61-70.

Richards, L.J., and J-J. Maguire, 1998. Recent International Agreements and the Precautionary Approach: New Directions in Fishery Management Science. *Canadian Journal of Fisheries and Aquatic Science*, 55 (6), pp. 1545-1552.

Robinson, C. L., 1994. The Influence of Ocean Climate on Coastal Plankton and Fish Production. *Fisheries Oceanography*, 3 (3), pp. 159-171.

Rothschild, B. J., 2000. "Fish Stocks and Recruitment:" The Past Thirty Years. *ICES Journal of Marine Science*, 57 (2), pp. 191-201.

Rosenberg, A.A., 2003. Multiple Uses of Marine Ecosystems. In: *Responsible Fisheries in the Marine Ecosystem*, M. Sinclair, and G. Valdimarsson (eds.), pp. 189-196.

Rosenberg, A.A., 2002. The Precautionary Approach in Application From a Manager's Perspective. *Bulletin of Marine Science*, 70 (2), pp. 577-588.

Rudd, M.A., 2004. An Institutional Framework for Designing and Monitoring Ecosystem-based Fisheries Management Policy Experiments. *Ecological Economics*, 48 (1), pp. 109-124.

Safina, C., 2003. The Continued Danger of Overfishing. *Issues in Science and Technology*, 19 (4), pp. 49-51.

Safina, C., 1995. The World's Imperiled Fish. *Scientific American*, 273 (5), pp. 46-53.

Sainsbury, K, and U.R. Sumaila, 2003. Incorporating Ecosystem Objectives into Management of Sustainable Marine Fisheries, Including 'Best Practice' Reference Points and Use of Marine Protected Areas. In: *Responsible Fisheries in the Marine Environment*, M. Sinclair, and G. Valdimarsson (eds.), FAO and CABI Publishing, pp. 343-360.

Sainsbury, K.J., A.E. Punt, and A.D.M. Smith, 2000. Design of Operational Management Strategies for Achieving Ecosystem Objectives. *ICES Journal of Marine Science*, 57 (3), pp. 731-741.

Scavia, D., and 13 Others, 2002. Climate Change Impacts on U.S. Coastal and Marine Ecosystems. *Estuaries*, 25 (2), pp. 149-164.

Scavia, D., and 13 Others, 2001. *Coastal Areas and Marine Resources: The Potential Consequences of Climate Variability and Change.* A Report of the National Coastal Assessment Group for the U.S. Global Change Research Program, NOAA, Silver Spring, MD., 8 pp.

Scheiber, H.N., 1997. From Science to Law to Politics: An Historical View of the Ecosystem Idea and its Effect on Resource Management. *Ecology Law Quarterly*, 24 (4), pp. 631-651.

Schiermeier, Q., 2002. How Many More Fish in the Sea? *Nature*, 419 (6908), pp. 662-665.

Schramm, H.L., and W.A. Hubert, 1996. Ecosystem Management: Implications for Fisheries Management. *Fisheries*, 21 (12), pp. 6-11.

Sherman, K., 2000. Why Regional Coastal Monitoring for Assessment of Ecosystem Health? *Ecosystem Health*, 6 (3), pp. 205-216.

Sherman, K., 1995. Achieving Regional Cooperation in the Management of Marine Ecosystems: The Use of the Large Ecosystem Approach. *Ocean & Coastal Management*, 29 (1-3), pp. 165-185.

Sherman, K., 1994. Sustainability, Biomass Yields, and Health of Coastal Ecosystems: An Ecological Perspective. *Marine Ecology Progress Series*, 112, pp. 277-301.

Sherman, K., 1991. The Large Marine Ecosystem Concept: Research and Management Strategy for Living Marine Resources. *Ecological Applications*, 1 (4), pp. 349-360.

Sherman, K., 1989. Biomass Yields of Large Marine Ecosystems. *Ocean Yearbook* 8, University of Chicago Press, pp. 117-137.

Sherman, K., and H.R. Skjoldal (eds.), 2002. *Large Marine Ecosystems of the North Atlantic: Changing States and Sustainability.* Elsevier Large Marine Ecosystems Series, Amsterdam, Netherlands, 449 pp.

Sherman, K., and A. M. Duda, 2001. Toward Ecosystem-based Recovery of Marine Biomass Yield. *Ambio*, 30 (3), pp. 168-169.

Sherman, K., and A. M. Duda, 1999a. Large Marine Ecosystems: An Emerging Paradigm for Fishery Sustainability. *Fisheries*, 24 (12), pp. 15-26.

Sherman, K., and A. M. Duda, 1999b. An Ecosystem Approach to Global Assessment and Management of Coastal Waters. *Marine Ecology Progress Series*, 190, pp. 271-287.

Sherman, K., N.A. Jaworski, and T.J. Smayda, (eds.), 1996. *The Northeast Shelf Ecosystem: Assessment, Sustainability, and Management.* Blackwell Science, 564 pp.

Sherman, K., L. M. Alexander, and B. D. Gold, (eds.), 1991. *Food Chains, Yields, Models, and Management of Large Marine Ecosystems*. Westview Press, Boulder, Colorado, 320 pp.

Sinclair, M., and G. Valdimarsson, (eds.), 2003. Towards Ecosystem-based Fisheries Management. In: *Responsible Fisheries in the Marine Ecosystem*, FAO and CABI Publishing, pp. 393-403.

Sissenwine M.P., P.M. Mace, 2003. Governance for Responsible Fisheries: An Ecosystem Approach. In: *Responsible Fisheries in the Marine Environment*, M. Sinclair and G. Valdimarsson (eds.), FAO and CABI Publishing, pp. 363-390.

Skud, B.E., 1982. Dominance in Fishes: The Relation Between Environment and Abundance. *Science*, 216 (4542), pp. 144-149.

Slocombe, D.S., 1998. Defining Goals and Criteria for Ecosystem-Based Management. *Environmental Management*. 22 (4), pp. 483-493.

Slocombe, D.S., 1993. Implementing Ecosystem-based Management. *Bioscience*, 43 (9), pp. 612-622.

Sorensen, J. C., and S.T. McCreary, 1990. *Institutional Arrangements for Managing Coastal Resources and Environments*, Revised Second Edition. National Park Service, U.S. Department of the Interior, Renewable Resources Information Series, Washington, D.C., 194 pp.

Stanford, J.A., and G.C. Poole, 1996. A Protocol for Ecosystem Management. *Ecological Applications,* 6 (3), pp. 741-744.

Steele, J.H., and M. Schumacher, 2000. Ecosystem Structure Before Fishing. *Fisheries Research*, 44 (3), pp. 201-205.

Steele, J.H., 1998. Regime Shifts in Marine Ecosystems. *Ecological Applications*, 8 (1) Supplement, pp. S33-S36.

Sutinen, J. G., 1999. What Works Well and Why: Evidence From Fishery-Management Experiences in OECD Countries. *ICES Journal of Marine Science*, 56 (6), pp. 1051-1058.

Sutinen, J.G., and M. Soboil, 2003. The Performance of Fisheries Management Systems and the Ecosystem Challenge. In: *Responsible Fisheries in the Marine Environment*, M. Sinclair, and G. Valdimarsson (eds.), FAO and CABI Publishing, pp. 291-309.

Sutinen, J. G., and H. F. Upton, 2000. Economic Perspectives on New England Fisheries Management. *Northeastern Naturalist*, 7 (4), pp. 361-372.

Sutinen, J. G., (ed.) and 15 Others, 2000. *A Framework for Monitoring and Assessing Socioeconomics and Governance of Large Marine Ecosystems*. NOAA Technical Memorandum NMFS-NE-158, 32 pp.

Swallow, S. K., 1996. Economic Issues in Ecosystem Management: An Introduction and Overview. *Agricultural and Resources Economics Review*, 25 (2), pp. 83-100.

Talaue-McManus, L., S.V. Smith, and R.W. Buddemeier, 2003. Biophysical and Socio-economic Assessments of the Coastal Zone: The LOICZ Approach. *Ocean & Coastal Management*, 46 (5), pp. 323-333.

Thia-Eng, C., 1998. Lessons Learned from Practicing Integrated Coastal Management in Southeast Asia. *Ambio*, 27 (8), pp. 599-610.

Ukwe, C.N., C.A. Ibe, B.I. Alo, and K.K. Yumkella, 2003. Achieving a Paradigm Shift in Environmental and Living Resources Management in the Gulf of Guinea: The Large Marine Ecosystem Approach. *Marine Pollution Bulletin,* 47 (1-6), pp. 219-225.

U.N. General Assembly, (UNGA) 2002. Verbatim Records of the Plenary Meetings of the General Assembly, Fifty-Seventh Session, 71st Plenary Meeting, 10 December 2002, A/57/PV.71 & the 74th Plenary Meeting, 12 December 2002, A/57/PV.74. Online Available, November 10th, 2003 @ http://www.un.org/ga/57/pv.html .

U.N. General Assembly, (UNGA) 2003. Resolution(s) Adopted by the General Assembly, Fifty-Seventh Session. A/RES/57/141 Oceans and the Law of the Sea, & A/57/142 Large-scale Pelagic Drift-net Fishing, Unauthorized Fishing in Zones of National Jurisdiction and on the High Seas/Illegal, Unreported and Unregulated Fishing, Fisheries By-catch and Discards, and Other Developments, & A/RES/57/143 Agreement for the Implementation of the Provisions of UNCLOS of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, February, 2003. Online Available, November 10th, 2003 @ http://www.un.org/ga/57.

U.N. General Assembly, (UNGA) 2004. Fifty-Eighth Session, Agenda Item 52(b), Resolution 58/14, Sustainable Fisheries… and Related Instruments. Document A/RES/58/14 (A/58/L.18), January 21st 2004, Online Available February 9th, 2004 @ http://www.un.org/58.

U.S. EPA, 2001. National Coastal Condition Report, 2001. EPA Technical Report 620/R-01/005. Washington, D.C., 204 pp.

U.S. EPA, 2000. Toward Integrated Environmental Decision-Making. Science Advisory Board, Washington, D.C., August 2000, EPA-SAB-EC-00-011, 46 pp.

Vallega, A., 1999. Fundamentals of Integrated Coastal Management. *The Geojournal Library*, Vol. 49, Kluwer Academic Publishers, Boston, 264 pp.

Vandermeulen, H., 1998. The Development of Marine Indicators for Coastal Zone Management. *Ocean & Coastal Management*, 39 (1-2), pp. 63-71.

Verity, P.G., and V. Smetacek, and T.J. Smayda, 2002. Status, Trends and the Future of the Marine Pelagic Ecosystem. *Environmental Conservation*, 29 (2), pp. 207-237.

Villa, F., and H. McLeod, 2002. Environmental Vulnerabiloity Indicators for Environmental Planning and Decision-Making: Guidelines and Applications. *Environmental Management*, 29 (3), pp. 335-348.

Vitousek, P.M., H.A. Mooney, J. Lubchenco, and J.M. Melillo, 1997. Human Domination of Earth's Ecosystems. *Science*, 277 (5325), pp. 494-499.

von Bodungen, B., and R.K. Turner, 2001. Science and Integrated Management: An Introduction. In: *Science and Integrated Coastal Management,* von Bodungen, B., and R.K. Turner (eds.), Dahlem University Press, pp. 1-14.

Wagner, L. (ed.), 2001. Summary of the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem. *Sustainable Developments*, 61 (1), 11 pp.

Ward, T.J., 2000. Indicators for Assessing the Sustainability of Australia's Marine Ecosystems. *Marine and Freshwater Research*, 51 (5), pp. 435-446.

Watkins, J. D., 2004. Sustaining Our Oceans: A Public Resource, A Public Trust. *Oceanography*, 17 (1), pp. 102-106.

Watkins, J. D., 2002. U.S. Commission on Ocean Policy. *Oceanography*, 15 (4), pp. 4-6.

Watson, R., D. Pauly, V. Christensen, R. Froese, A. Longhurst, T. Platt, S. Sathyendramath, K. Sherman, J. O'Reilly, and P. Celone, 2003. Mapping Fisheries onto Marine Ecosystems for Regional, Oceanic and Global Integrations. In: *Large Marine Ecosystems of the World: Trends in Exploitation, Protection, and Research*, Hempel, G., and Sherman, K., (eds), Elsevier, Amsterdam, pp. 375-395.

West, M.B., 2003. Improving Science Applications to Coastal Management. *Marine Policy*, 27 (4), pp. 291-293.

West Group, 1996. Sustainable Fisheries Act, Public Law 104-297, Senate Report No. 104-276. *United States Code Congressional and Administrative News*, 104th Congress - Second Session. Volume 6, Legislative History, pp. 4073-4119.

Wilen, J.E., M.D. Smith, D. Lockwood, and L.W. Botsford, 2002. Avoiding Surprises: Incorporating Fisherman Behavior into Management Models. *Bulletin of Marine Science*, 70 (2), pp. 553-575.

Wilmsen, S., 2002. U.S. Judge Eases Rules on Fishing: Reverses Order That Sparked Intense Criticism. *The Boston Globe*, 261 (144), pp. 1 & A26.

Willmann, R., and D. Insull, 1993. Integrated Coastal Fisheries Management. *Ocean & Coastal Management*, 21 (1/3), pp. 285-302.

Witherell, D., C. Pautzke, and D. Fluharty, 2000. An Ecosystem-Based Approach for Alaska Groundfish Fisheries. *ICES Journal of Marine Science*, 57 (3), pp. 771-777.

Witherell, D, (Ed.), 2004. *Managing Our Nation's Fisheries, Past, Present and Future*. Proceedings of a Conference on Fisheries Management in the United States, Held in Washington, D.C., November 13-15, 2003, Published by the North Pacific Fishery Management Council, 254 pp.

Witherell, D., 1999. Incorporating Ecosystem Considerations into Management of Bering Sea Groundfish Fisheries. In: *Ecosystem Approaches for Fisheries Management*, Alaska Sea Grant College Program, AK-SG-99-01, Fairbanks, pp. 315-327.

Witherell, D., (ed.), 1998. Ecosystem Considerations for 1999. North Pacific Fishery Management Council, Anchorage, Alaska, November, 1998. Online Available, September 29th, 2003 @ http://www.fakr.noaa.gov/npfmc/ecosystem/ecobased.htm .

Witherell, D., and 11 Others, 1997. Ecosystem Considerations for 1998. North Pacific Fishery Management Council, Anchorage, Alaska, November, 1997. Online Available, September 29th, 2003 @ http://www.fakr.noaa.gov/npfmc/ecosystem/ecobased.htm .

Yaffee, S.L., 1996. Ecosystem Management in Practiice: The Importance of Human Institutions. *Ecological Appliications*, 6 (3), pp. 724-727.

Young, O. R., 2003. Taking Stock: Management Pitfalls in Fisheries Science. *Environment*, 45 (3), pp. 24-33.

Zabel, R.W., C.J. Harvey, S.L. Katz, T.P. Good, and P.S. Levin, 2003. Ecologically Sustainable Yield. *American Scientist*, 91 (2), pp. 150-157.

Table 1. An Ecosystem approach requires new thinking about how marine ecosystems are defined, and how problems and solutions are framed. (Adopted and modified from Fluharty, 2000; Holling, 1996; Gonzalez, 1996).

- Management scales are nested in a multiple spatial and temporal application of five module multi-sectoral suites of indicators ranging in scale from LME's for the ocean environment into watersheds.
- Ecosystem delineations must be scientifically defensible (e.g. best available science) and administratively practical.
- LME boundaries are based on ecological criteria such as ecosystem health, resilience, and stability.
- Ecosystem categories of threat, level of threat, and "distance" from desired restoration condition can be combined to rank ecosystems at risk. Ranks (should be based on a review of quantitative information by a scientific panel with stakeholder participation. Ranks (from e.g. comparative risk assessment(s)) can be employed to plan and prioritize management regulatory agency action for ecosystems at various levels of present and future risk.
- The United Nations Food and Agricultural Organization (FAO) provides a salient perspective definition of an "ecosystem approach to fisheries" that it "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" (see: http://www.fao.org/docrep/).
- Holling (1996) advocates that "at a minimum, the goal of ecosystem management is understanding to reduce uncertainties, action to maintain or restore resilience (i.e., the ability of a system to absorb change and variation without flipping into a different state where the variables and processes controlling structure and behavior suddenly change) as insurance for the unknown, and creation of incentives for maintaining sustainable systems".
- NOAA's strategic vision stated in *New Priorities for the 21st Century* places its first mission goal to "protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management." Its objectives under this mission goal are economically, scientifically and socially interdependent.
- Ecosystem-based Management: U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including humans and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries. Excerpt from April 2004 *U.S. Commission on Ocean Policy, Chapter 3: Setting the Nation's Sights,* at page 32.

Table 2. Key spatial and temporal scales and principal elements of a systems approach to the research and management of large marine ecosystems. (Source original adapted and modified from Sherman, 1994; Sherman and Duda, 1999 a&b; Watson et al., 2003.)

A. Spatial-temporal scales

Spatial	Temporal	Unit
→ Global (world ocean)	Millennia - decadal	Pelagic biogeochemical
→ Regional (exclusive economic zones)	Decadal- seasonal	Large marine ecosystems
→ Local	Seasonal- daily	Subsystems

B. Research elements

Spawning strategies
Feeding strategies
Productivity, trophodynamics
Stock fluctuations/recruitment/mortality
Natural variability (hydrography, currents, water masses, climate regime shifts)
Human perturbations:
(fishing effort, waste disposal, petrogenic hydrocarbon impacts, toxic runoff effects, aerosol contaminants, eutrophication effects, pollution effects, viral disease. vectors)

C. Management elements - Options and Advice - International, National, Local

Bioenvironmental and socioeconomic models
Adaptive management to optimize sustainable fisheries yields
Mitigation of pollution stress especially in near shore coastal areas from riverine runoff; improvement of ecosystem 'health'

D. Feedback loop

Evaluation of ecosystem 'health'
Evaluation of fisheries status and trends
Evaluation of management for "best practices", in addition: every ecosystem management effort regardless of its specific definition, should include eight principles (adapted from Christensen et al; 1996; Hennessey, 1998):

1. long-term sustainability as fundamental value and objective
2. clear, operational goals
3. sound ecological models and understanding
4. understanding complexity and interconnectedness
5. recognition of the dynamic character of ecosystems
6. attention to context and scale
7. acknowledgment of humans as ecosystem components
8. commitment to adaptability and accountability

From EPA (2001) measurement indicators at spatial and temporal scales include:

1. Measures of community and ecosystem structure and function
    - productivity
    - abundances and distributions of plants and animals
    - diversity
    - important attributes of nutrient and chemical cycling
2. Environmental stressors
    - primary stressors of coastal ecosystems (including anthropogenic sources)
    - habitat variables (measures required to interpret natural variability in rapidly changing coastal environments)
3. National sampling tier would be stratified by environmental issue, with a monitoring program associated with each stratum
    - Habitat degradation
    - Fisheries declines
    - Harmful algal blooms
    - Hypoxia

According to Ward (2000) "to ensure ecological relevance, each indicator represents, or relates directly to, one or more of five important attributes of marine ecosystems-diversity, stability, yields, productivity and resilience".

Table 3. In terms of sustainability, the assessment of the performance of LME-oriented fisheries management systems can be guided by the "Principals of Sustainable Development Performance Measurements" established by the Bellagio Conference (1996, Italy) and reported by the Federal Planning Bureau of Belgium (1997, Annex 3). Briefly, these principles (adapted and modified from Garcia and Staples, 2000) include the need for, inter alia:

- "a guiding vision and clear goals;
- a holistic perspective;
- consideration of essential elements such as intra- and inter-generational equity, resource use and over-consumption, poverty, rights, ecological conditions, as well as human well-being;
- adequate scope, with long enough time scales and wide enough spatial scales, analyzing historical patterns and projecting into the future;
- practical focus, using an organizing framework, a limited number of key issues and standardized indicators, comparing targets, reference values, ranges, and thresholds;
- openness and transparency;
- effective communication with a broad and diversified audience, reaching policy and decision-makers,
- using simple information and clear language;
- broad participation by key grass-root professional and technical groups as well as decision makers;
- ongoing assessment of progress towards sustainability, improved capacity, with continuous adjustments of the framework, promoting adaptive learning and feedback; and
- institutional capacity improving the data collection and analysis as well as decision making processes, assigning responsibilities, empowering local communities."

Present in and supported by the FAO Code of Conduct for Responsible Fisheries and its process of implementation, these principals ought to be reflected in any "guidelines" prepared for LME-oriented fisheries.

Table 4. National Standards to provide for the conservation and management of the fisheries from the Sustainable Fisheries Act of 1996, Public Law 104-297 October 11th.

1. Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.
2. Conservation and management measures shall be based on the best scientific information available.
3. To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.
4. Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be
    - (a) fair and equitable to all such fishermen;
    - (b) reasonably calculated to promote conservation; and
    - (c) carried out in such manner that no particular individual, corporation or other entity acquires an excessive share of such privileges.
5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.
6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.
7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.
8. Conservation measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to
    - (a) provide for the sustained participation of such communities, and
    - (b)to the extent practicable, minimize adverse economic impacts on such communities.
9. Conservation and management measures shall, to the extent practicable
    - (a) minimize by-catch and
    - (b) to the extent by-catch cannot be avoided, minimize the mortality of such by-catch.
10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

Note: National Standards 8-10 were added in October 1996 via Public Law 104-297. National Standards 1-4 were inserted via Public Law 98-623, which were amendments to the initial Magnuson-Stevens Fishery Conservation and Management Act (Public Law 94-265). It is also important to mention that via Public Law 97-453, section 301(b) Guidelines-the Secretary of Commerce "shall establish advisory guidelines (which shall not have the force and effect of law), based on the national standards, to assist in the development of fishery management plans." Adapted and modified from Darcy and Matlock, (1999) and information from http://www.nefsc.noaa.gov/magact/mag3.html).

Table 5. Selected prospective stages in the policy orientation process in an ecosystem-oriented LME fisheries (management) module. Adapted and modified after, e.g., Jones (1984); Burroughs (1996); Clark (1992); Olsen et al. (1998); Pielke et al. (1999); Thia-Eng (1998); Hennessey (1994); Juda and Burroughs (1990); Sorensen and McCreary (1990). The **bold** highlighted stages below indicate "significant scientific input for this activity" (Burroughs, 1996). *Prediction* as a process in fostering sound decision making from scientific research comes from Pielke et al. (1999) and Steele (1998). It too would contain significant scientific input.

- **Definition of problems in society (problem definition)**
- Initiation/invention may include preliminary investigation of management concepts
- Aggregation of concerned individuals, e.g., stakeholders, also public awareness
- Organization or initiation, e.g., stakeholders consensus building
- Representation, access to decision makers maintained
- **Agenda setting**
- **Formulation of proposals (by government)**
- Legitimation of program by government
- Preparation of a program may include pilot projects as a potential pre-test
- Estimation may include a more thorough assessment of management concepts
- Selection may provide benefits by reducing uncertainty about various options
- ***Prediction*** of policy decisions in planning and managing natural resources
- Budgeting for government program and (formal adoption of program)
- Adoption of organizational and legal mechanisms
- **Implementation of government program by key actors**
- **Evaluation of program**
- Refining and consolidating, including, e.g., program monitoring
- Adjustment and/or termination, including how adjustments come about

Table 6. A proactive precautionary fisheries management policy orientation may combine a variety of approaches and regulatory tools (adapted and modified from Garcia, 1994; Olsen, 1999) as follows:

- Adopting the sustainable development principle;
- Adopting the principle of precautionary management, with the degree of ‘precaution’ negotiated on a case-by-case basis;
- Using the best available science as evidence;
- Adopting a broader range of management benchmarks and reference points more directly related to (recruitment) reproduction capacity (safe biological limits, minimum spawning biomass, etc.);
- Developing a set of criteria;
- Taking a risk-averse policy position (e.g. requiring an environmental impact assessment (EIA) before authorizing any increase of fishing intensity beyond maximum rates of exploitation);
- Agreeing on acceptable levels of impacts (and risk) (e.g. negotiations between stakeholder interest groups, and within an appropriate institutional and legislative framework will be necessary);
- Basing management decisions on combined stresses on resources and environment (e.g. insert fisheries in the context of coastal zone/areas integrated management, for the U.S., within the scope and parameters of ‘federal consistency’ of the Coastal Zone Management Act of 1972 as amended);
- Improving management response time (e.g. adaptive management techniques, reproductive capacity, risk level);
- Improving participation of ‘non-fishery users’ in fisheries management bodies for more ‘transparency’ in fisheries management decision-making;
- Improving decision-making procedures (e.g. voting procedures and public comment periods);
- Introducing prior consultation procedures comparable to an EIA report for constituency comments;
- Strengthening enforcement monitoring, control and surveillance and raising penalties to deterrent levels.

Table 7. Existing proactive precautionary approaches for fisheries management (adapted and modified from Garcia, 1994; Rosenberg, 2002; Hennessey & Healey, 2000; Sissenwine & Mace, 2003) including:

- Step-wise development with effort monitoring and with accompanying research and trawl surveys;
- Early effort limitations instead of laissez-faire investment strategies which lead to overfishing;
- Design of institutional or financial 'brakes' to avoid 'explosive' redevelopment (e.g. Ludwig's Ratchet) together with possible prior-authorization for ordering new vessels or borrowing money for them (before proceeding into a fishery);
- Precautionary quotas for species for which proper reliable scientific assessments are not available, that is, give priority to conserving productive capacity of the resource when there is <u>considerable</u> uncertainty;
- Using 'pessimistic models' for stocks where low resilience is suspected or established establish an institutional (policy orientation) framework for management action under the "rule-of-law";
- Recommendations for 'experimental adaptive management' to pre-test systems response in multispecies assessments;
- Recommendations of catch targets below the Maximum Sustainable Yield (MSY) e.g. $F_{0\text{-}1}$, $F_{2/3}$, $F_{MSY,}$ and ensure that resource use be regularly reviewed for management adjustments;
- Adoption of the concept of 'safe biological limits', as ecosystem considerations;
- Agreement on cautious management thresholds (e.g. minimum spawning biomass) and course of action before crisis occurs and initiate corrective measures with little delay.

Despite their general availability, the above measures and variations thereof have not been adopted widely or successfully implemented in most delineated LME's.

Table 8. Selected proactive precautionary ecosystem management criteria. (Adapted and modified from Garcia, 1994; Garcia, 2000)

From an ecosystem point of view, minimize by-catch or using extremely selective gears might not be necessarily the best solution (with the proviso that discards be limited to a strict minimum). In multi-species management, a reasonable strategy would be to exploit all species proportionally to their abundance in order to maintain the overall structure. New criteria are required for species sustainability, for example, minimum reproductive biomass, safe biological limits, optimum recruitment levels, maximum statistical probability of ecological or economical collapse, especially for particularly low resilience species. New criteria are also needed for precautionary ecosystem management. Some principles and objectives can be operationalized to:

- minimize anthropogenic conversion of critical ecosystems to ‘lower’ trophic conditions;
- balance habitat conversion with restoration (a no net loss approach);
- maintain food web ecological relationships;
- maintain populations at optimal net annual recruitment increment;
- provide restoration ecology programs for depleted populations;
- minimize risk of irreversible change in the large marine ecosystem, etc.

Widely applied precautionary approach related indicators (after Garcia, 2000) include, inter alia:

- adopting target and limit reference points;
- study and take into account uncertainties and risk by arranging for pre-agreed (temporary) emergency management measures in case of threat or unintended, unforeseen consequences;
- consideration for social and economic impacts of regulatory decisions;
- conducting, for new gear or fisheries development, prior impact assessments (the Orange Roughy lessons learned approach).

Table 9. "It is increasingly realized that the predictability requirement cannot be fulfilled even within the limited scope of single stock management without ecosystem considerations". Ecosystem based management implementation proposal, taken from Degnbol (2002), suggests that the ecological aspects of a marine ecosystem-based management approach (EBM) would be implemented using the following steps in a typical fishery:

- Identify the stakeholders: the interested parties;
- Prepare a chart of the ecoregions: species, habitats and oceanographic features;
- Identify the partners and their interests: stakeholders directly interested or affected by the fishery;
- Establish the ecosystem values: habitats, species and uses;
- Determine the main potential hazards of the fishery to the ecosystem values;
- Conduct an ecological risk assessment: determine the actual risks of the fishery;
- Establish the objectives and targets: agreed goals for the ecosystem and the fish stock;
- Establish strategies for achieving targets;
- Design the information system: includes monitoring of stock and ecological indicators;
- Establish information needs and research priorities;
- Design performance assessment and review process;
- Design and Implement an EBM training and education package for fishers and managers.

Table 10. Criteria, reference values and indicators used in international LME fisheries from Garcia and Staples, 2000; Garcia, 2000.

Criteria(Issue)	Reference values	Indicators
	Fishery-related indicators	
Catch	Maximum Sustainable Yield (MSY); Maximum Constant Yield (MCY), Maximum Long-Term Average Yield (LTAY); Optimum Yield (undefined).	Catch.C/MSY.C/MCY.C/LTAY. (MSY - Yield)/MSY. Similar ratios using MCY, or LTAY. Similar ratios using 2/3 MSY.
Fishing mortality (*F*) Fishing effort (*f*) Fishing intensity (*f/area*) Fleet capacity (GRT)	F_{MSY}, F_{MCY}, F_{LTAY}, F_{MEY}, $F_{0.1}$, F_{OY} (undetermined), F_{MAX}, F_{low}, F_{med}, F_{high}, $2/3F_{MSY}$, $F_{30\%SPR}$, F_{crash}, F_{loss}, $F>=M$, $F<M$, Z_{bmp}. GRT_{MSY}, etc. Vessels in a targeted fishery (open access or permitted)	*f*.*f*/area.*F*.f/f_{MSY}, f/f_{LTAY}. F/F_{MSY}, F/F_{LTAY}, etc. Searching "steaming" time/fishing time (for schooling fish). Area fished/total species range. Fishing capacity (GRT). Ratio to optimal capacity.
Catch value or revenues (*R*) Rent	Maximum Sustainable Revenue (MSR). Maximum Economic Yield (MEY) = Max. Economic Rent (MER)	*R*.*R*/MSR, (MSR-*R*)/MSR Rent. Rent/MER.
	Technology indicators	
Environmental aspects: Selectivity. Discards	Ratios to best available (affordable) technology? "Zero Discards"? Prior Consent (PC) or Prior Authorization (PA) procedures. Lists of acceptable and/or banned gear. Gear regulations. Technologies addressing selectivity, by-catch of juveniles, and discards (Grid systems, protected nursery areas).	Lc_{50}. Tc_{50}. Total discards. Discards/By-catch. Discards/Catch.
	Social indicators	
Employment (EMP) Age (*A*) Social cohesion Community resiliency Community independence	Maximum Sustainable Employment (MSE)? ? Minimum social unrest. Maximum compliance	EMP. EMP/MSE Age (fisheries) or Age (rural sector) Non-compliance ratio. Index of diversity in employment %of economic activity based locally
On-board conditions Wealth indicator?	Minimum rate of accident? Maximum rate of insurance ?	Number of accidents/trip? Cost of insurance? % ensured. Fisheries over comparable wages in other job categories?
	Institutional / Governance Indicators	
Management capacity	A fisheries with Management plan (MP)	% of fisheries covered by MP
Decision-support capacity	Appropriate research / monitoring capacity	Research staff and budget. GIS capacity. Record of scientific advice to decision making and to assessment of management performance degree of participation (in information collection, option analysis, decision making, enforcement). Number and role of NGOs. Duration and severity of conflicts (?).
Legislation	In line with international agreements and conventions. Also national domestic laws and regulations.	Rate of adoption of aspects found in the FAO Code of Conduct for Responsible Fisheries?
Partnership / Participation	Degree of participation (from 0+No participation to 1=participation in decision and enforcement)	% of Fisheries with partnership mechanism.
MCS	Effective MCS system operational. Complies with duties of Flag and Port State	Rate of compliance. Number of penalties / Number of infractions

Table 10 Continued

Criteria(Issue)	Reference values	Indicators
	Institutional / Governance Indicators Continued	
Oversight	Independent oversight mechanism available	% Fisheries covered by Oversight Committees
Effectiveness of sector policy		
Research		Linkage between research and decision-making (research involved, utilized, published, publically available, scientific cooperation, independent advice) policy orientation
	Target resource indicators	
Resource biomass (B)	B=50% B(virgin). SB>MBAL. SB>0.3B(Virgin). B_{MSY}, B_{MCY}, $B_{50\%R}$, $B_{90\%R}$.	B.B/B(virgin). B/B_{MSY}, B/B_{MCY}, $B/B_{50\%R}$, $B/B_{90\%R}$
Spawning biomass (SB)		Biomass of target and non-target species. Catch per unit of effort (cpue) is a proxy indicators for B. In some cases, changes in distribution area could be used as a proxy to changes in biomass (small pelagic)
Resource structure: Length. Age. L_{c50}, L_{m50}, , $L_{F=0}$ tc_{50}, tm_{50}		Length or age composition and average length or age; ratio of average length or age to length or age at first maturity (Lm_{50} and tm_{50}). Ratio of present average length ( ) to pristine average length or age ($L_{F=0}$) eventually simulated with $F = 0$, Sex-ratio where relevant (e.g. marine mammals also sea turtles). School size where relevant (e.g., small pelagic resources). Index of fat content (e.g., in small pelagic fish used for reduction also used for Blue Fin Tuna).
	Ecosystem indicators	
Biological diversity	Minimum possible species loss. Minimum loss of genetic diversity	Existence of Marine Protected Areas (MPA). % littoral area protected, totally, partially. Existence of germplasm conservation scheme. Biodiversity index.
Water quality Pollution	'Pristine' conditions or conditions at an agreed reference point in time Conventional standards established by international environmental treaties and conventions, International Maritime Organization (IMO) etc.	Pollution index; transparency (Secchi values); satellite coastal zone color scanner (CZCS) indications; algae index; release of nitrogen components and phosphorates;other global pollution indicators; population density (average and seasonal peaks); absolute values or ratios to historical levels. % of change.
Critical habitats	Minimum % of area of seagrass beds, mangroves, mudflats, coral reefs, 'Pristine' habitat area (or, area at an agreed reference point in time), to be conserved. % of area which is formally protected; statute. Dead restrictions	Ratio between residual (hinterland) area and 'Pristine' or reference area, area of live and dead coral, grass density, species diversity indexes, other indexes of condition; protected areas (biosphere reserves)
	Environmental economics indicators (to be developed)	
Value of environmental assets		Compliance, extension education, subsidies and deterence theory

This page is intentionally blank.

Figure 1. Sketch map of the Northeast United States Continental Shelf Large Marine Ecosystem (LME) and Watershed.

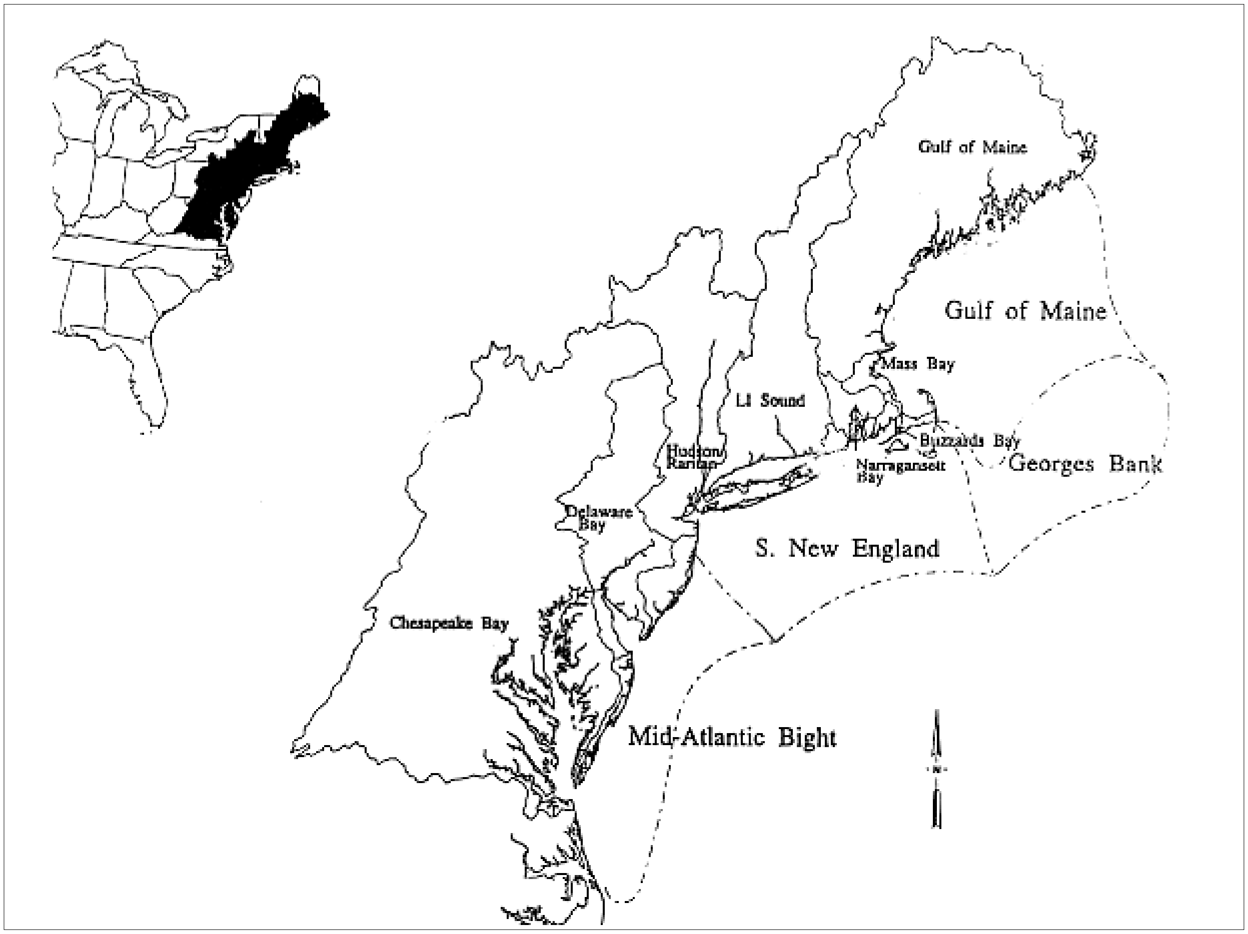


Figure 2. A five module LME strategy developed for assessing and analyzing ecosystem-wide changes in support of improved adaptive management decision practices (adapted from Sherman, 2000; Gable, 2003).

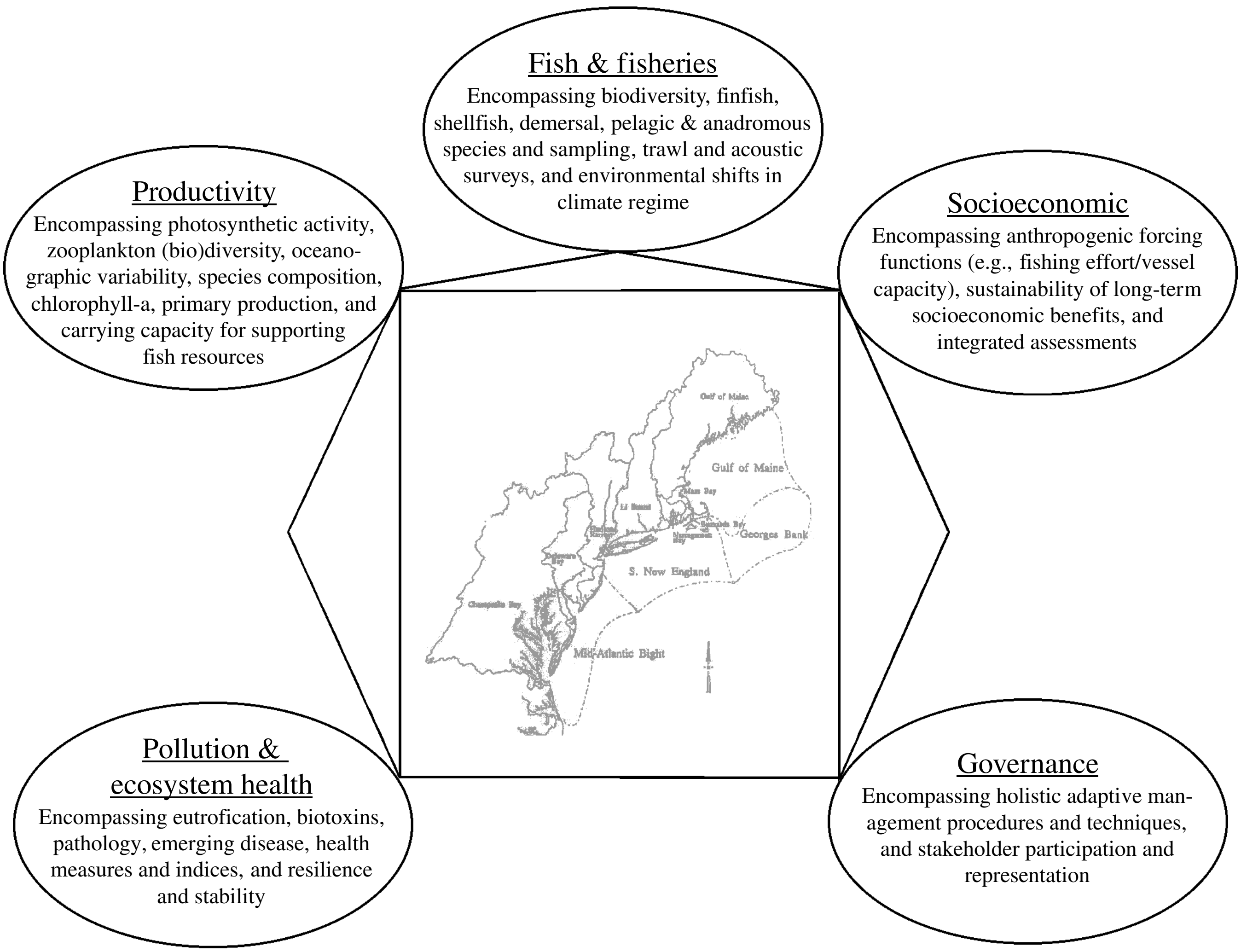


Figure 3. Ecosystem Considerations in Fisheries Management: Linking Ecosystem Research to Ecosystem Science Policy and Management Goals. (Adapted and modified from the North Pacific Fisheries Management Councils' "Ecosystem Considerations" Reports and the NOAA/NMFS Alaska Fisheries Science Center in Seattle).

There is a need to discuss and define the ecosystem-oriented management goals of the regulatory organization and the tools available to managers to attain those goals. Ecosystem research including GLOBEC (see; www.usglobec.org) and GLOBEC-like research efforts, habitat research, ongoing trophic interactions work, and long-term monitoring of commercial and non-commercial species already can serve as indicators of ecosystem status and trends. These marine science-based indicators can provide and early warning system for managers, signalling human or climate induced changes that may necessitate management action. Ecosystem considerations that can accompany the traditional stock assessment approach include ecosystem status and trend information and link management actions with ecosystem observations. The New England Fishery Management Council (and the Mid-Atlantic Fishery Management Council) as regulatory agencies within the Northeast United States Continental Shelf LME ought to commence preparation of a program for science policy ecosystem considerations to facilitate movement towards ecosystem-oriented fisheries management while utilizing a precautionary approach.

ECOSYSTEM-ORIENTED MANAGEMENT GOALS AND OBJECTIVES

- Maintain living marine resource(s) biodiversity for both targeted and non-targeted species
- Maintain and restore essential fish habitats
- Maintain system sustainability (human consumption sustainable yields and non-extractive uses while utilizing a "precautionary approach")
- Maintain the concept that humans are component parts of the marine ecosystem by changes denoted in fishing power and fleet composition and number and efficacy of limited entry, license or Individual Transferable Quota (ITQ) systems, if any.
- In order to derive standards to measure and track the success of ecosystem-oriented management efforts, management goals (and objectives) with regard to the jurisdictional ecosystem must be explicitly stated.

ECOSYSTEM MANAGEMENT INDICATORS

In order to measure performance towards meeting the stated goals and objectives, program monitoring should take into accord:

- Bycatch/discard amounts (e.g. specified and non-specified species)
- Area closed to bottom trawling (e.g. marine protected areas and amount time/area closures)
- Trophic level and total amount of catch (e.g. landings)
- Effort levels and controls (e.g. days-at-sea; net mesh size restrictions; gear types; vessel design and crew size, and fishery observers; and,exploitation rates by specific time/area units for fisheries with time/area quotas)

Thus, these indicators may provide evidence of direct human efforts on ecosystem components in combination with in-place fishery management actions and the efficacy of such policies.

MARINE ECOSYSTEM STATUS INDICATORS

In order to measure and evaluate marine ecosystem status and trends and make management adjustments if warranted, program monitoring should take into account:

- Status and trend indicators of:
  - Physical abiotic environment (NAO, "regime shift(s)," etc.)
  - Habitat (pollutant/contaminant amounts in the benthic sediments and groundfish, for example, benthos composition)
  - Living marine resources (abundance trends of phytoplankton-harmful algal blooms, zooplankton, forage fish-herring and mackerel, invertebrates, non-target fish species, marine mammals-right whales,seabirds e.g. bycatch/discard amounts)
  - Community or ecosystem level (diversity of fishery guilds sampled by bottom trawl surveys, trophic level, size diversity and model results)

Thus, these indicators can be utilized to potentially assess the possible role that both climate and humans may have on ecosystem variability and provide linkages between ecosystem research and "best practices" sustainable fishery management programs.

Figure 4. North Atlantic Ecosystem considerations, measures and influences provide feedback for adaptive management of resources. (Source: adapted and modified from information available from the North Pacific Fishery Management Council see: http://www.fakr.noaa.gov/npfmc/ and the Alaska Fisheries Science Center, Seattle WA).

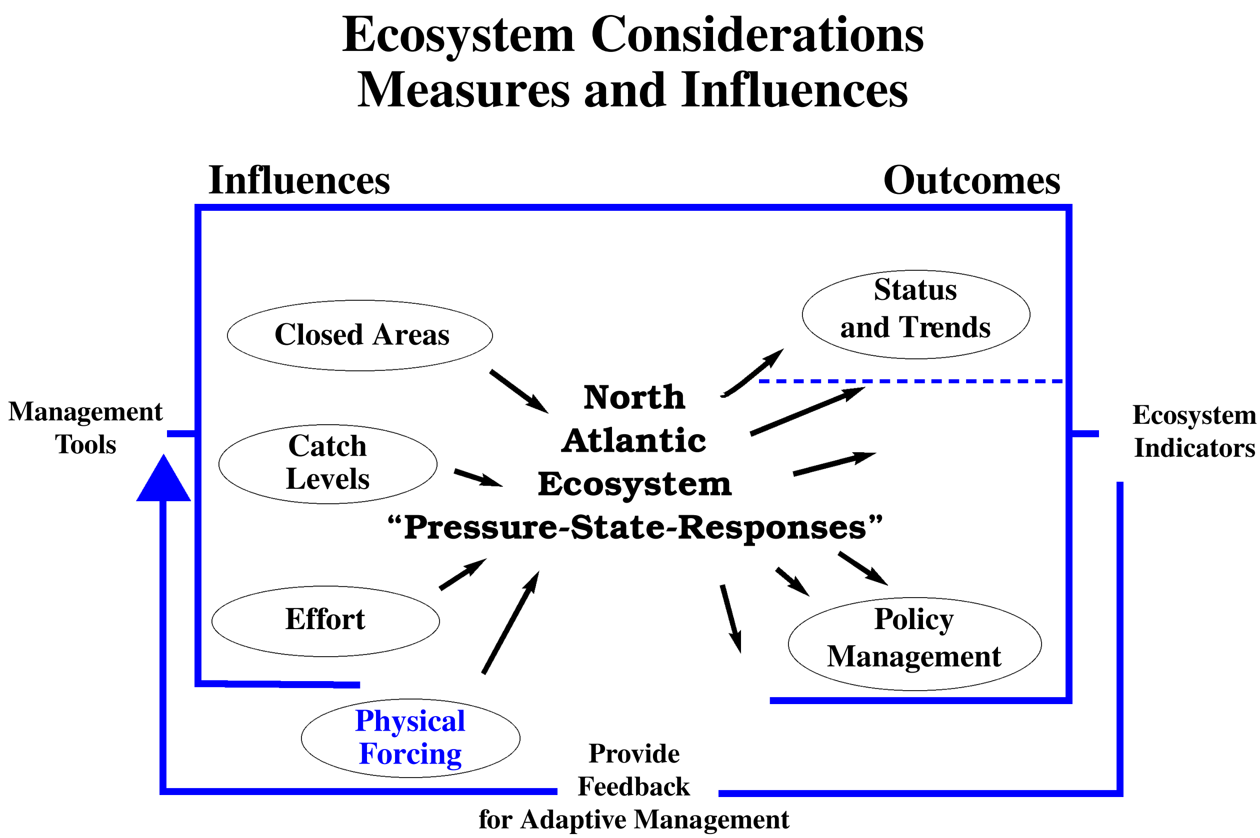


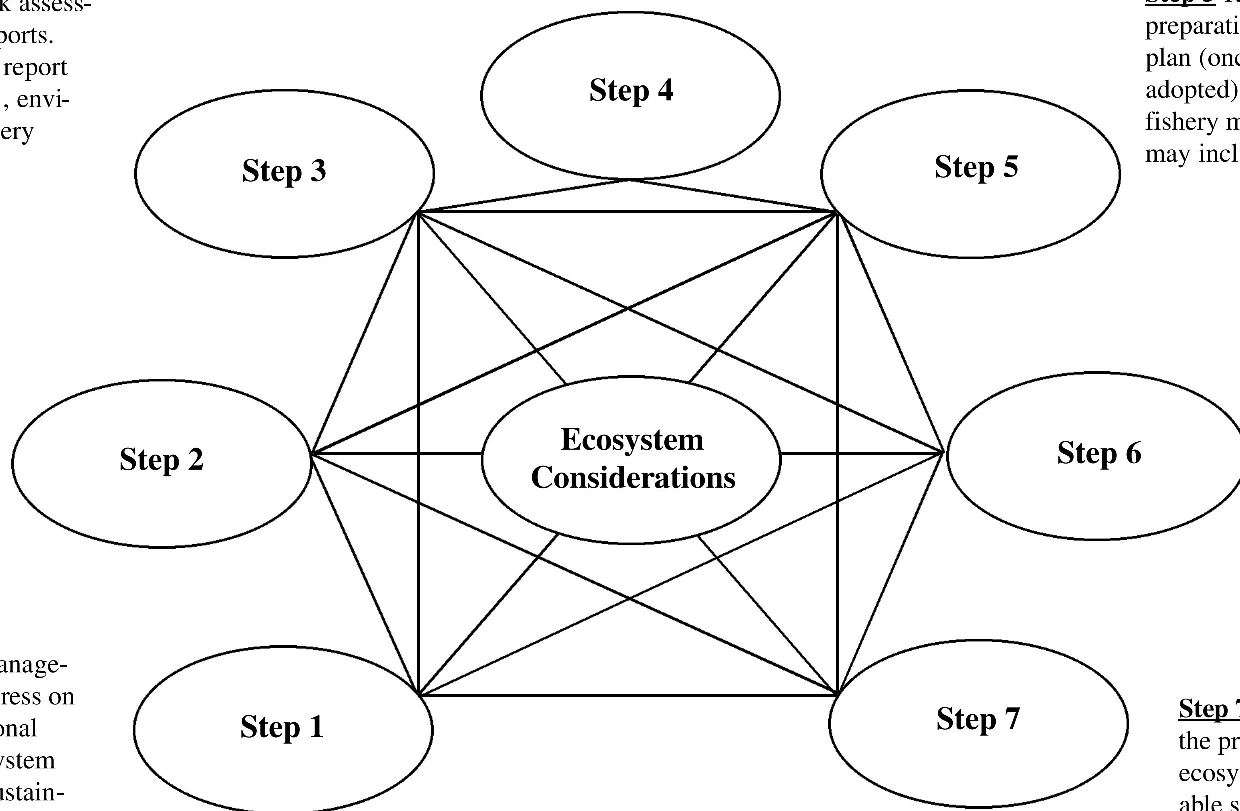
Figure 5. Recommendations for a potential U.S. LME “best practices” approach to implement regional fishery ecosystem-oriented management.

Step 4 Require NOAA/NMFS Fisheries to develop technical guidelines (not regulations) to assist Councils with preparing fishery ecosystem plans, which include clear goals and objectives.

Step 3 Require NOAA/NMFS Fisheries to prepare an annual “status of the ecosystem” report for each region, similar to the requirement for stock assessment and fishery evaluation reports. This “status of the ecosystem” report should contain socio-economic, environmental, ecological, and fishery ecosystem indicators.

Step 5 Require that each Council begin preparation of a draft fishery ecosystem plan (once the guidelines have been adopted) to serve as a foundation for all fishery management plans in the region, may include pilot projects as a pretest.

Step 2 Suggest that each Council establish an Ecosystem Committee to provide a forum for information exchange on ecosystem research and ecosystem-oriented “best practices” management.



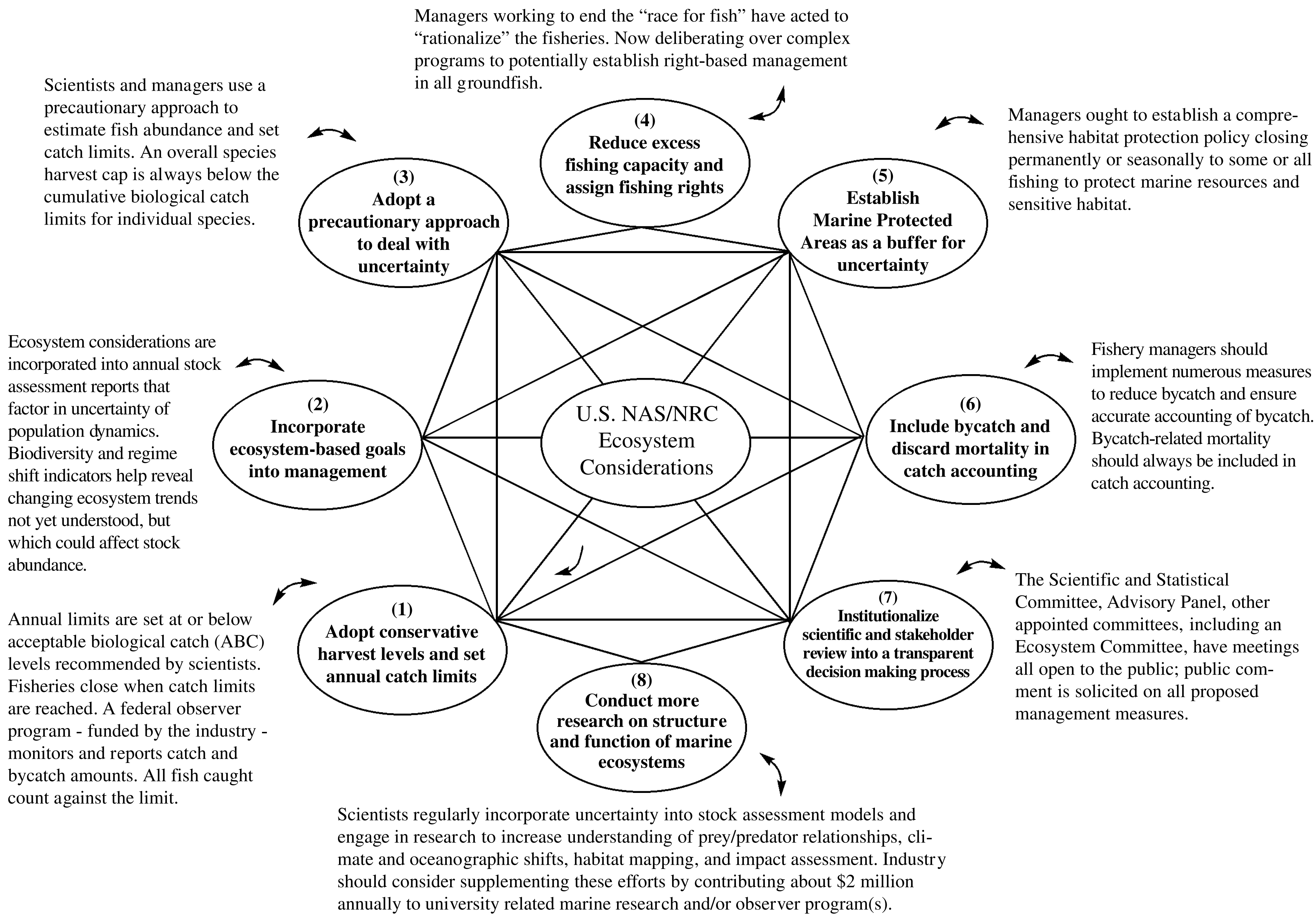
Step 6 Require NOAA/NMFS Fisheries to identify, within fishery ecosystem plans, the research priorities needed for full implementation of an ecosystem approach.

Step 1 Require each fishery management council to report to Congress on how they are meeting the National Research Council’s eight ecosystem recommendations to achieve sustainable fisheries. This serves as a self evaluation for Councils to determine where changes should be made.

Step 7 Fund research identified in the previous step, and modify fishery ecosystem plans as new “best available science” information becomes available.

(Adapted and modified from North Pacific Fishery Management Council, November 2003; http://www.fakr.noaa.gov/npfmc/).

Figure 6. Suggested "best practice" strategies for implementation of the National Academy of Science National Research Council ecosystem considerations.



(Adapted and modified from North Pacific Fishery Management Council, November 2003; http:www.fakr.noaa.gov/npfmc/).

Figure 7. Ecosystem-oriented management principals modeled on U.S. National Environment Policy Act (NEPA) of 1969 goals, that are germane for U.S. LME policy. Adapted and modified from Phillips and Randolph (2000).

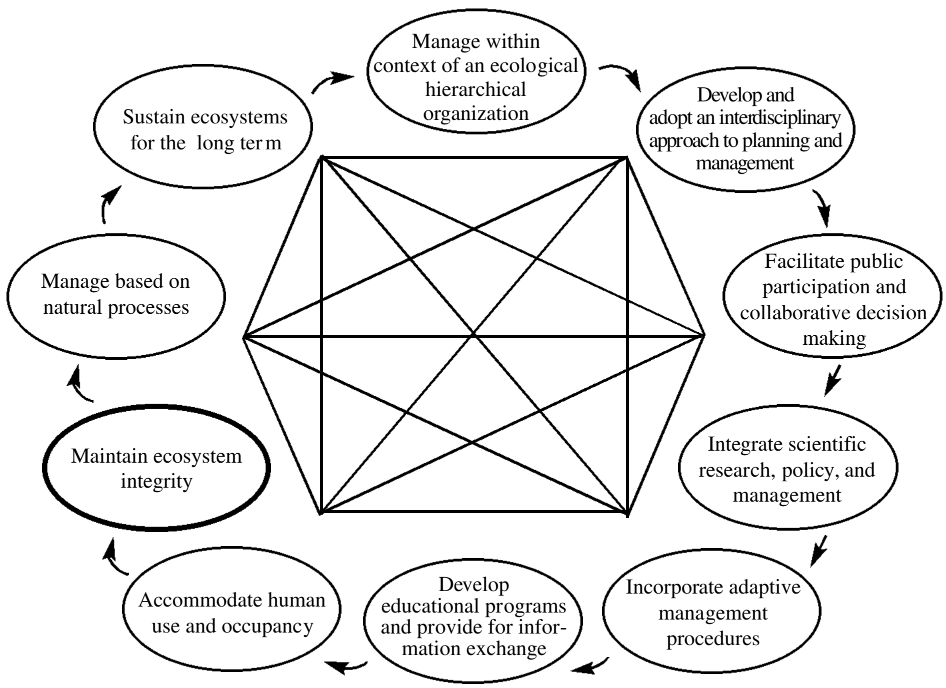


Figure 8. Draft key elements of an ecosystem-oriented fisheries management approach for the Northeast United States Continental Shelf Large Marine Ecosystem (LME) as a representative example.

Definition(s)	Ecosystem-oriented fishery management is "a strategy to regulate human activity towards maintaining long-term system sustainability (within the range of natural variability as we understand it", Fluharty, 2000) of the Northeast Shelf Ecosystem, covering the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight and their associated estuaries and watersheds. Protecting or restoring the function, structure, and species composition of the ecosystem, recognizing that all components are interrelated, and that safeguards the long-term ecological sustainability, natural diversity and productivity of the ecosystem, and considering the needs of people and environmental values. Highlighting the positive correlation between economic prosperity and environmental well-being, it is a goal-driven approach to restoring and sustaining healthy ecosystems and their functions and values using the best science available. (adapted and modified from Haeuber (1996) from select U.S. federal agency definitions). Ecosystem-based management "is based on large areas that are diverse ecologically, economically, and socially, and complexly connected and interacting. It entails scientific, descriptive components as well as normative components" (Slocombe, 1998). Ecosystem management occurs over multiple scales ranging in scope from a focus on the local scale (local abundance, local disturbance) and immediate benefits to broader geographic scales at the immediate coast and long-term benefits. (Schramm & Hubert, 1996).
Objective	The basic ecosystem consideration is a precautionary approach to extraction of fish resources to provide and ensure the intergenerational sustainability of ecosystem goods, services and socioeconomic benefits by establishing appropriate reference points and/or sustainability indicators for restoring and maintaining the fish and fisheries produced by this ecosystem based on the best scientific evidence available.
Goals	One "goal of the ecosystem approach is to restore, enhance, and protect ecosystem integrity. Ecosystem integrity entails the alleviation of physical stresses and the restoration of a healthy ecosystem structure and function. For those who support the ecosystem approach to integrated marine resources management, the goal is to institutionalize the concept within elected government" (MacKenzie 1997). 1. Maintain ecosystem productivity and biodiversity consistent with multiple spatial scales natural evolutionary and ecological processes, including dynamic change and variability. 2. Maintain and restore habitats essential for fish and their prey, that is, "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity" (e.g. see Fluharty, 2000). 3. Maintain system sustainability and sustainable yields of fisheries resources for human consumption including halting overfishing, that is, "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis "(e.g. see Fluharty, 2000). 4. Maintain the concept that humans are integral components of the ecosystem.
Guidelines	1. Integrate ecosystem-oriented management through interactive partnerships among the states and regulatory agencies, stakeholders, (public), regional and international organizations (e.g. NAFO). 2. Utilize peer-review ecological models as an aid in understanding the structure, function, and dynamics of the Northeast Shelf ecosystem. 3. Utilize best available science research and monitoring to validate a "best practices" ecosystem -oriented approach, for sustainable use of fishery resources. 4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.
Assumptions	1. Ecosystem-oriented management is an adaptive process which requires periodic evaluation preferably on an annual basis for refining and incorporating updated scientific information as it becomes available. 2. Ecosystem-oriented management requires temporal scales that transcend human generations. 3. Fish has become one of the most internationally traded food items, as some 37% (by volume) of all fish for human consumption is traded across borders (Sinclair and Valdimarsson, 2003).
Understanding	1. "The ecosystem is considered to be a unit of biological organization made up of all of the organisms in a given area interacting with the physical environment so that a flow of energy leads to characteristic trophic structure and material cycles within the system" (Odum, 1969). 2. Science policy management measures that are consistent with an ecosystem-oriented strategy include precautionary-conservative catch (allocation) limits, comprehensive monitoring and enforcement, bycatch controls including adaptable retention and utilization policies, gear restrictions, closed season/closed area/time marine protected areas (MPA's), and additional ecosystem considerations that are based on scientific research and advice (Witherell, et al., 2000).

(Adapted and modified from Sinclair and Validimarsson, 2003; Witherell, et al., 2000; Fluharty, 2000; Sherman and Duda, 1999 a&b; Witherell, 1999; Slocombe, 1998; MacKenzie, 1997; Haeuber, 1996; Schramm and Hubert, 1996; Odum, 1969)

Figure 9. Draft ecosystem-oriented fisheries management science policy for the Northeast United States Continental Shelf Large Marine Ecosystem (LME) as a representative example.

Definition(s)	Ecosystem-oriented fishery management is "a strategy to regulate human activity towards maintaining long-term system substainability (within the range of natural variability as we understand it", Fluharty, 2000). The area under consideration is the U.S. Northeast Shelf ecosystem and its four sub-areas - the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight.
Objective	"The basic ecosystem consideration is a precautionary approach to extraction of fish resources" to provide and ensure the intergenerational sustainability of ecosystem goals and services by establishing appropriate reference points and/or sustainability indicators based on the best scientific evidence available.
Goals	1. Maintain biodiversity consistent with multiple spatial scales natural evolutionary and ecological processes, including dynamic change and variability. 2. Maintain and restore habitats essential for fish and their prey, that is, "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity" (e.g. see Fluharty, 2000). 3. Maintain system sustainability and sustainable yields of resources for human consumption and non-extractive uses, including halting overfishing, that is, "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis "(e.g. see Fluharty, 2000). 4. Maintain the concept that humans are integral components of the ecosystem.
Guidelines	1. Integrate ecosystem-oriented management through interactive partnerships between and among regulatory agencies, stakeholders, (public), and international regional organizations (e.g. NAFO). 2. Utilize peer-review ecological models as an aid in understanding the structure, function, and dynamics of the North Atlantic ecosystem. 3. Utilize best available science research and monitoring to test and validate a "best practices" ecosystem approach. 4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.
Assumptions	1. Ecosystem-oriented management is an experimental adaptive process which requires periodic evaluation, refining and consolidation to incorporate updated scientific information as it becomes available. 2. Ecosystem-oriented management requires temporal scales that transcend human generations. 3. Fish has become the most internationally traded food, as some 37% (by volume) of all fish for human consumption is traded across borders (Sinclair and Valdimarsson, 2003).
Understanding	1. The ecosystem is considered to be a unit of biological organization made up of all the organisms in a given area (that is a "community") interacting with the physical environment so that a flow of energy leads to characteristic trophic structure and material cycles within the system (Odum, 1969). 2. Science policy management measures that are consistent with an ecosystem-oriented strategy include, among others, precautionary-conservative catch (allocation) limits, comprehensive monitoring and enforcement, by-catch controls including adaptable retention and utilization policies, gear restrictions, closed season/closed area/time marine protected areas (MPA's), and additional ecosystem considerations that include relying on scientific research and advice, etc.(Witherell, et al., 2000)

(Adapted and modified from Sinclair and Validimarsson, 2003; Witherell, et al., 2000; Fluharty, 2000; Sherman and Duda, 1999 a&b; Witherell, 1999; Odum, 1969)

Figure 10. According to Restrepo et al. (1999), the scope of the precautionary approach to fisheries management applies at all levels of LME fisheries systems. After completion of the FAO Code of Conduct for Responsible Fisheries and the technical guidelines on the Precautionary Approach by FAO, the facts or key elements of the Precautionary Approach that have received the most attention according to Restrepo et al. (1999) are:

- definitions of overfishing incorpor ating target and limit reference points;
- formulation of decision (control) rules that stipulate in advance what actions will be taken to prevent overfishing and promote tar get stock rebuilding;
- incorporation of uncertainty by using a risk-averse approach to calculate targets, constrain fishing mortality, and rebuild stock biomass.

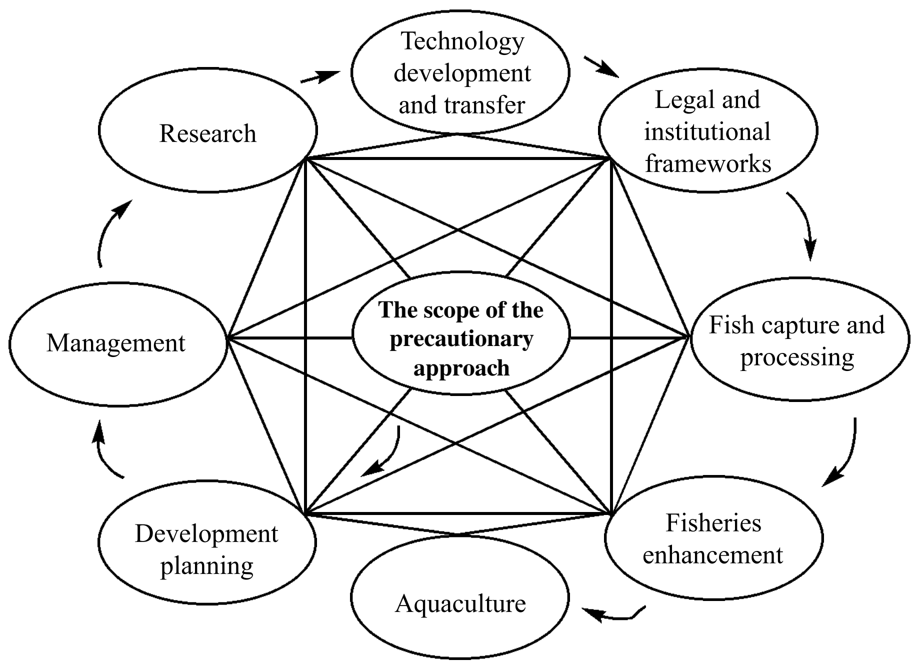


Figure 11. According to Restrepo et al. (1999), key elements of a precautionary approach sustainable LME fisheries management strategy would encompass the above ecosystem considerations.

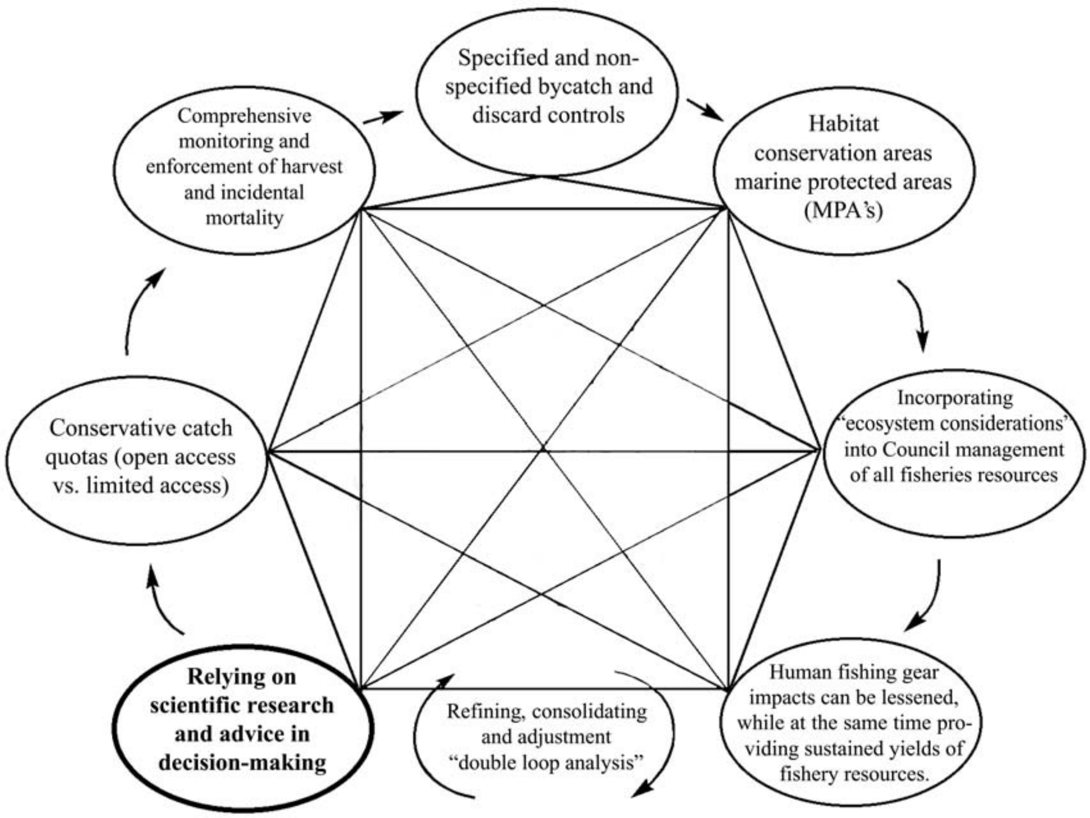


Figure 12. Generalized spatial and temporal effects on Northeast United States Continental Shelf LME Living Marine Resources (fisheries). Includes aperiodic incursion of Gulf Stream and Labrador current ocean water. Adapted and modified from Fluharty et al. (1999) and Fluharty (2000).

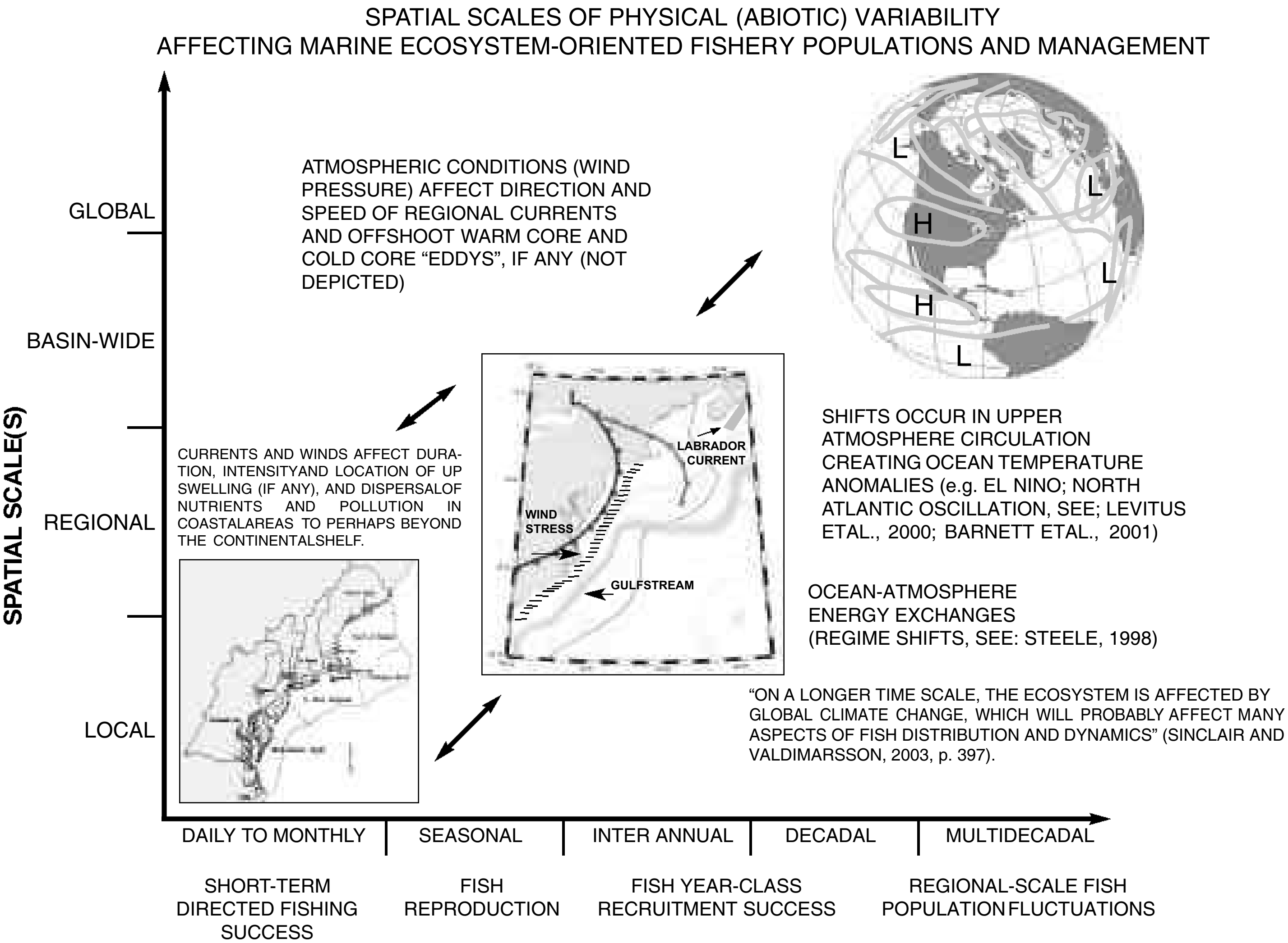


Figure 13. Fishery Management Measures practiced in "OECD" countries. It's been suggested that IFQs are perhaps most effective at resource sustainability and that TAC's might be the least. Adapted and modified from Sutinen, 1999.

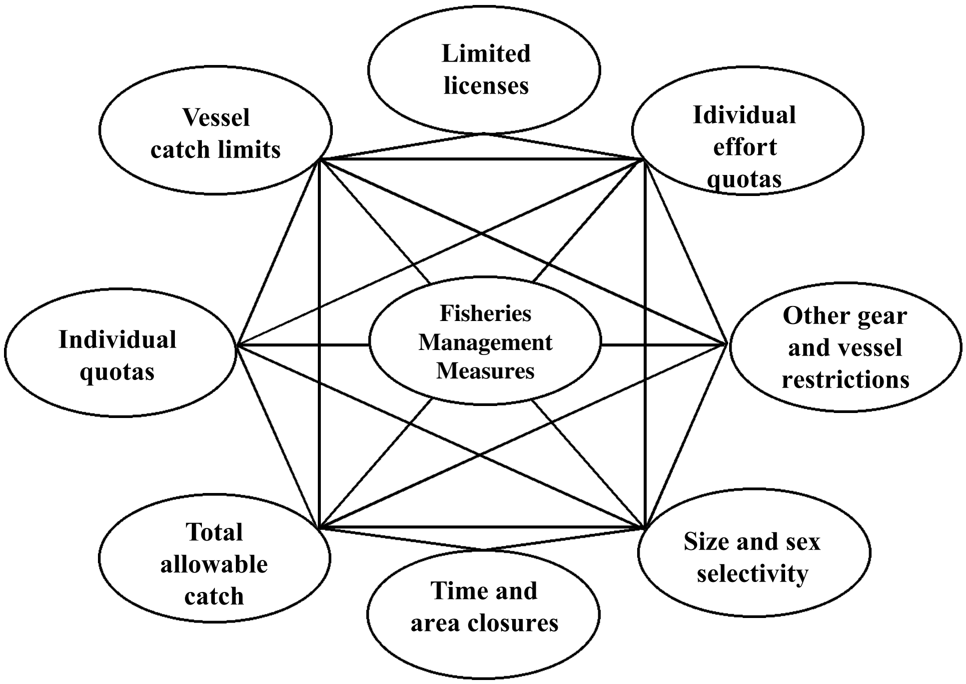


Figure 14. Five key barriers to the use of an experimental approach to planning. Adapted and modified from McLain & Lee (1996).

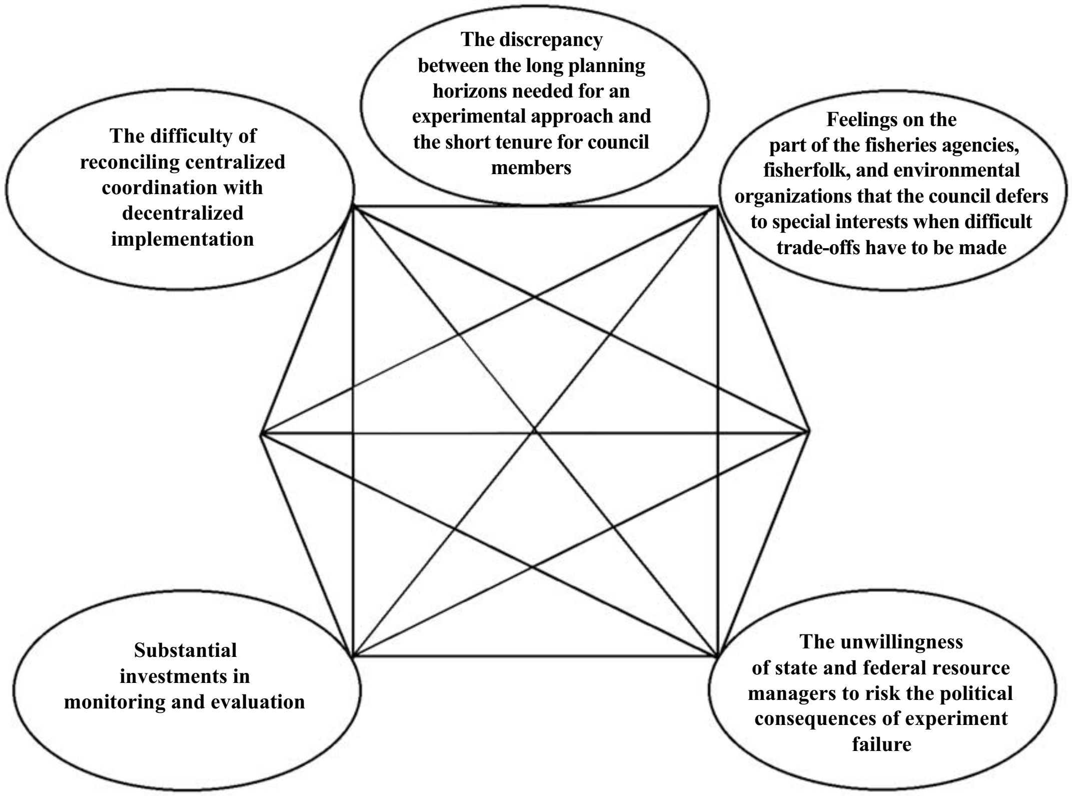


Figure 15. “Rubic’s Cube” diagram for a fusion of an integrated LME and Coastal Area Management system for the Northeast United States Continental Shelf as an illustrative locale. (Adapted and modified from Vallega, 1999 and references cited therein).

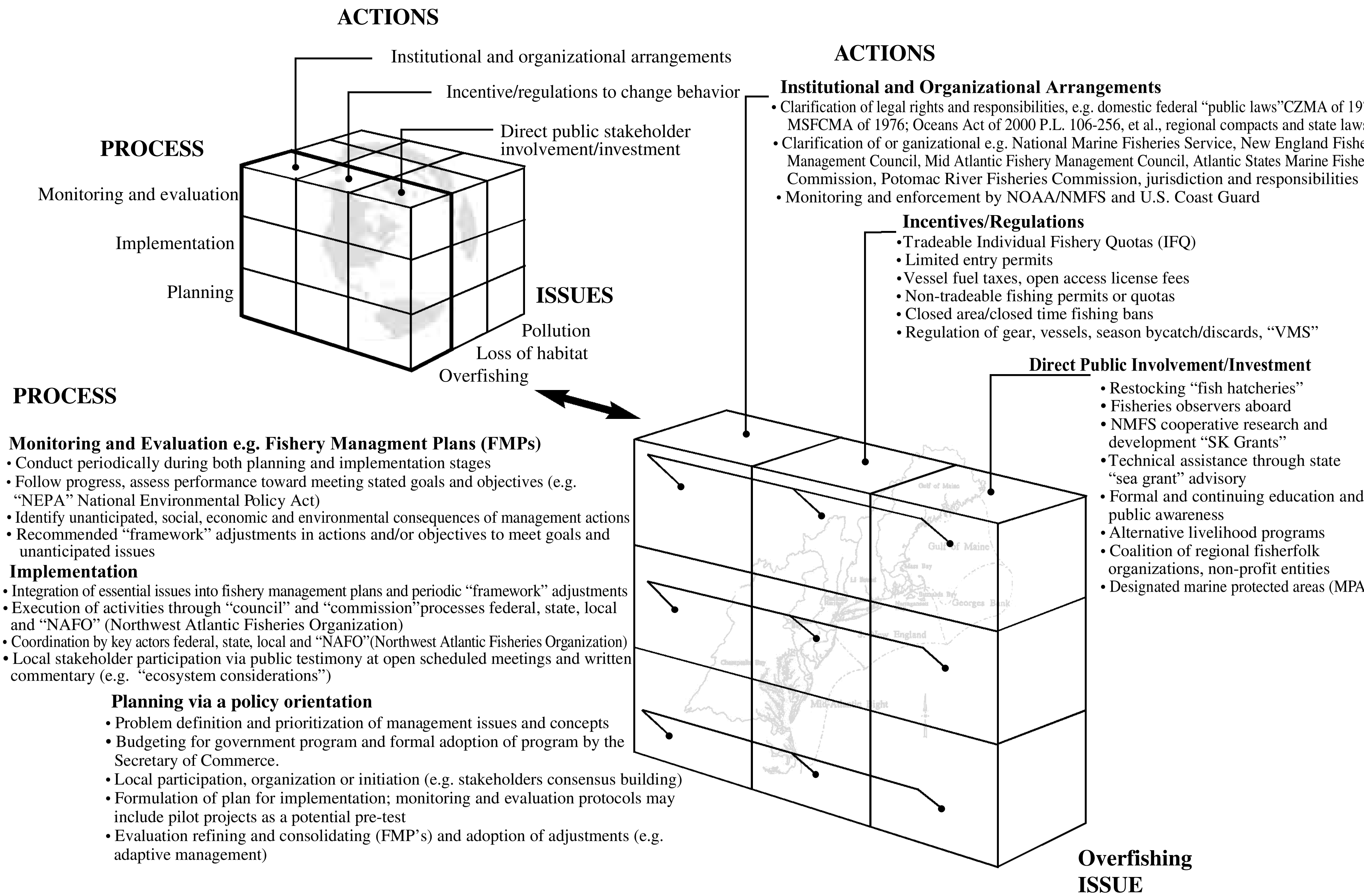


Figure 16. Principles of sustainable oceans governance utilizing an integrated adaptive management approach whereby uncertainty is acknowledged in policy-making. The major problems facing the oceans include: climate change, destruction of coastal ecosystems, land-based contamination, ocean disposal and spills, andoverfishing. Adapted and modified from Costanza et al. (1998).

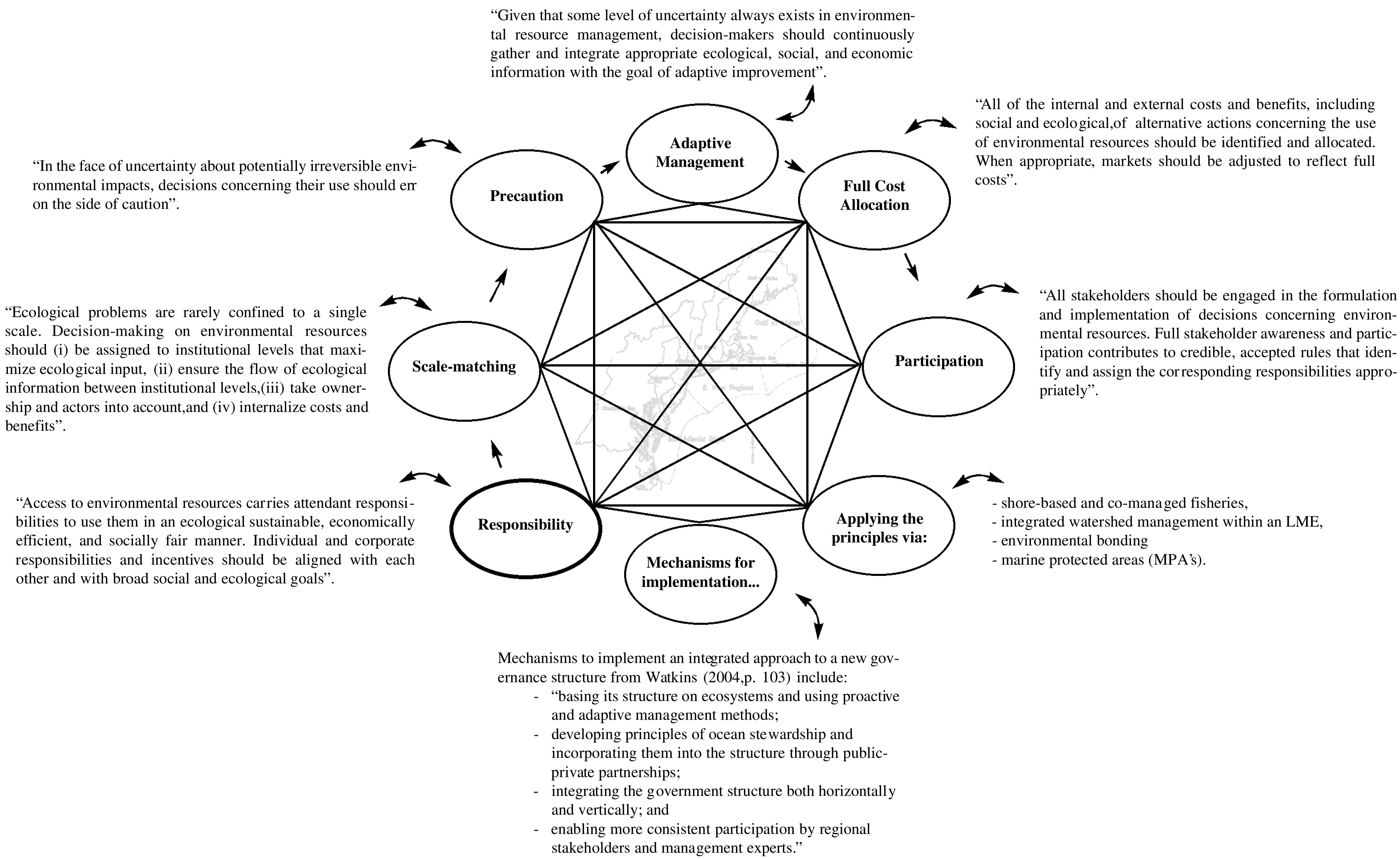


Figure 17. Based on the scientific literature, and the experiences of Sissenwine and Mace (2003), an ecosystem approach to a responsible fisheries management system ought to encompass the above listed parameters. An ecosystem approach also needs to take into account environmental variability upon fisheries resources. Six of the seven parameters of the fisheries ecosystem management system are also employed for single-species fisheries management (Sissenwine and Mace, 2003). The similarity between single-species fisheries management and an ecosystem approach should not be a surprise.

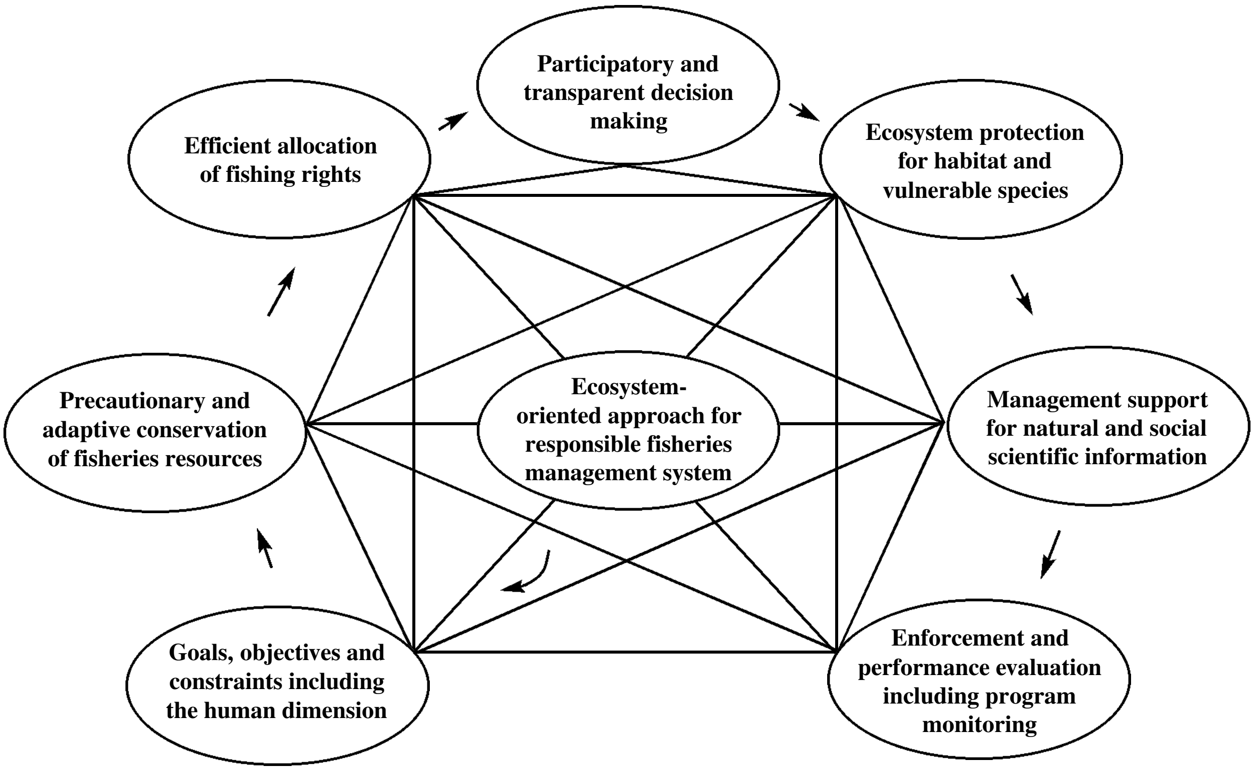
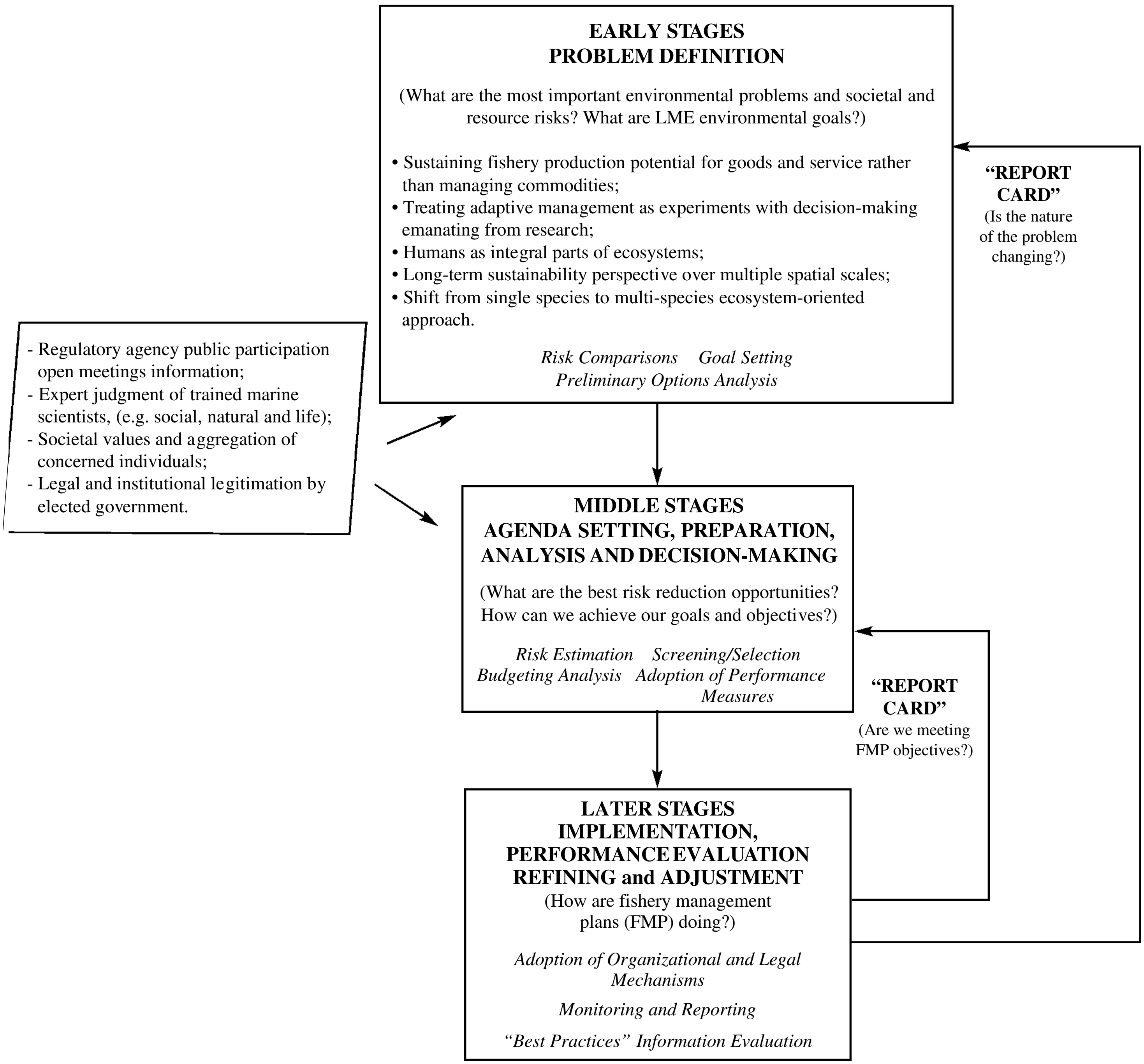


Figure 18. Adaptive Management Framework for Integrated Large Marine Ecosystem Environmental Science Policy Decision-making. (Adapted and modified from EPA, 2000; Sherman and Duda, 1999 a&b; see also Gable, 2003, Gable, 2000)



Risk Comparisons, in which sets of risks-including risks to ecological health systems, human health, productivity carrying capacity and/or quality of life-are ranked or rated, and a set of risks selected for detailed ecosystem consideration in the middle stages;

Goal Setting, in which the participating stakeholders concur on goals and objectives relating to the risks of concern and measures that will be used to evaluate progress towards those goals; and

Preliminary Options Analysis, in which an initial range of risk-to-the-resource reduction options is identified and considered in terms of the estimated total reduction of risk in the long-term and likely benefit-cost of each experimental decision while taking into accord a precautionary approach.

Figure 19. Selected representative pathways for a policy orientation process for mulation, implementation and refinement. (Adapted and modified from Brown and Mumme, 2000; Garcia & Staples, 2000.)

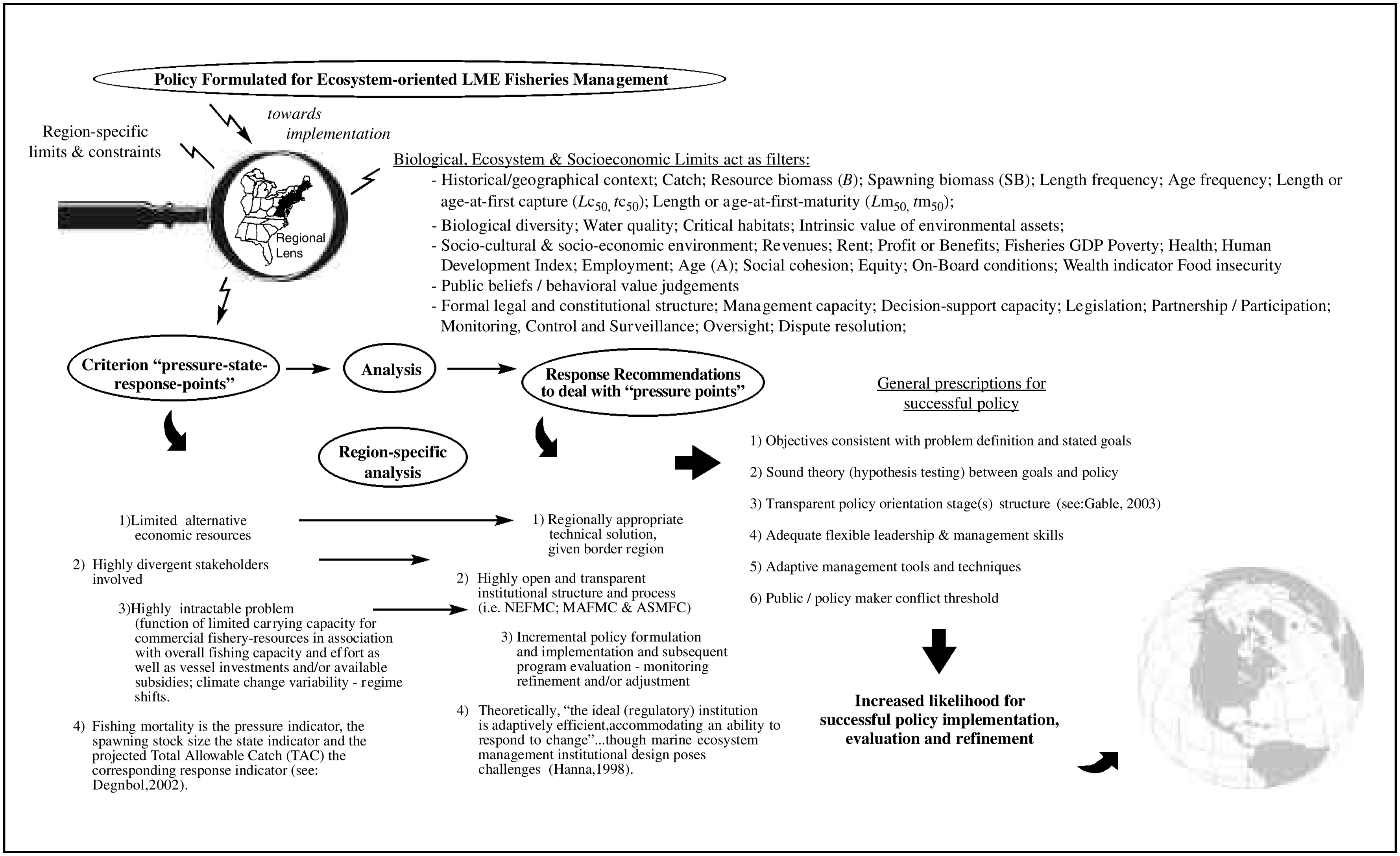
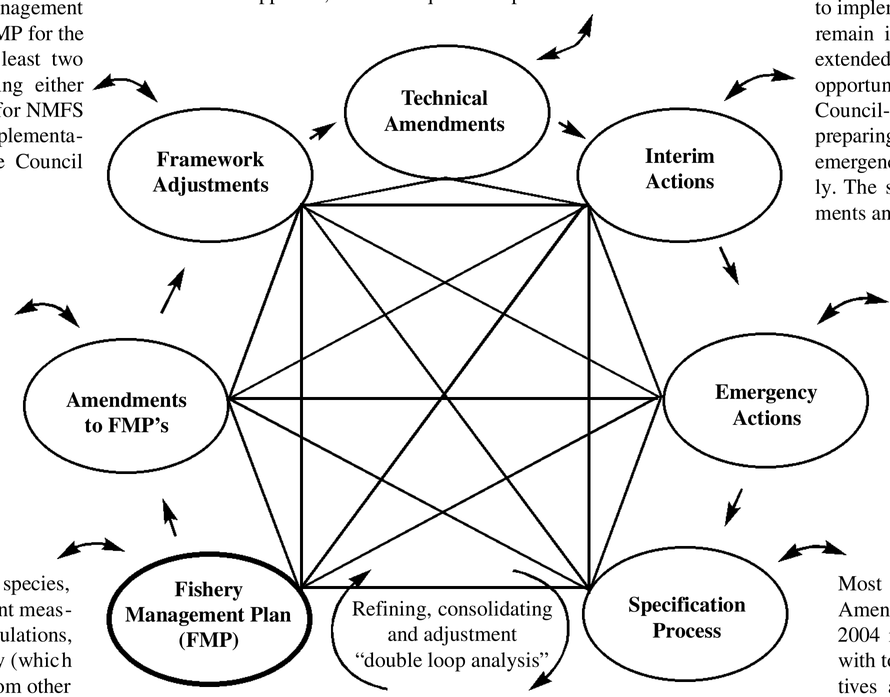


Figure 20. The New England Fishery Management Council (NEFMC) has several types of representative governance actions that are related to large marine ecosystems (LME) management. Most Council actions are related in one way or another. Unless a species is regulated within a fisheries management plan (FMP), the catch of the species is not managed directly, however, a species may be indirectly restricted via closed areas or gear requirement(s) regulations or other interim measures. An FMP must conform to related federal laws as amended such as, the National Environmental Policy Act (NEPA), the Coastal Zone Management Act (CZMA), the Regulatory Flexibility Act (RFA), and the Marine Mammals Protection Act, etc. Adapted and modified from www.nefmc.org especially the document "Types of Council Actions" dated July 17, 2000 and distributed January 27-29, 2004 at the Newport, Rhode Island Council Meeting.



An abbreviated rule-making process when there are no significant impacts on the human or physical environment, that integrates the public comment period and the development phases into the same Council meeting schedule, with the ability to publish the adjustment as a final rule, thereby eliminating a second public comment period. The scope of the action must fall within the existing goals and objectives of the management plan and types of measures already approved in an FMP for the same fishery. The framework process requires at least two Council meetings. The public may comment during either meeting. There is no mandatory timetable or "clock" for NMFS approval of a framework adjustment, thus overall implementation can be typically about one year including the Council development phase.

Utilized traditionally to clarify or correct regulations when changes are needed for the regulation to achieve its original intent. For illustration, if a fishing vessel develops a device for constricting the gear minimum mesh openings of a net, then a technical amendment may be used to prohibit that device in order to alleviate prohibited by-catch problems. These may be implemented with or without a public comment period. And, they may be implemented relatively quickly but there is no fixed time period within which NMFS must decide on approval, as a consequence implementation can be slow.

The interim action allows measures to be prevented to reduce overfishing while an FMP or other action is developed which can take a much longer time. If a Council finds that interim measures are needed to reduce overfishing for any fishery within its jurisdiction, whether or not a fishery management plan exists for such a fishery, it may ask the Secretary of Commerce to implement interim measures or emergency actions. Both will remain in effect for no more than 180 days. They may be extended for no more than 180 days, if the public has had an opportunity for comment on the measures. For extension of a Council-initiated interim action, the Council must be actively preparing an FMP, amendment or regulations to address the emergency or overfishing, (i.e. National Standard I permanently. The situation can result from uncertainty in stock assessments and the best available science at the time.

To develop and submit amendments usually takes one year to 18 months. It may or might not take at least another six months for approval implementation depending on the scope and complexity of the measures. It may or might not require an Environmental Impact Statement (EIS) or a Supplemental Environmental Impact Statement (SEIS) under NEPA. An EIS of SEIS requirement adds about 2 months to the amendment development process.

Emergency actions shorten the time it takes for implementation because an emergency situation is a justification for waiving prior public input. Emergency (and interim) actions must comply with the same laws that apply to FMPs and amendments, although, documents may be prepared after the action is implemented, if "circumstances" warrant.

An FMP basically identifies the management unit (the species, fish stocks, and geographical range of the management measures), the management goals, and the measures, regulations, and objectives needed to achieve the FMP. The fishery (which can be a group of stocks or species) is distinguished from other fisheries in terms of biology, area or method of catch. FMPs typically take 18 months to several years to develop and more than one year or more for NMFS review, approval and implementation. Can have two separate public comment periods prior to publication of final rule in the Federal Register. FMPs, and all subsequent regulatory adjustments must meet the National Standards and Required Provisions of the Magnuson-Stevens Fishery Management and Conservation Act as amended.

Most recently this was discussed under the NEFMC Amendment I to the Herring FMP presented March 23rd, 2004 in Gloucester, Massachusetts. There, it was associated with total allowable catch (TAC) and incidental catch alternatives and options as a "prelude" and simplification of the Herring FMP amendment (see earlier) process. It was described as being similar to the framework adjustment process with likely necessitating two Council meetings and at least one Plan Development Committee/Advisory Panel meeting. Thus, in general, a specification becomes a framework. It also should be noted that there are several jurisdictional pre-council meetings that employ individuals expertise, e.g., the Herring Committee and the Herring Advisory Panel as well as the "SSC",etc.

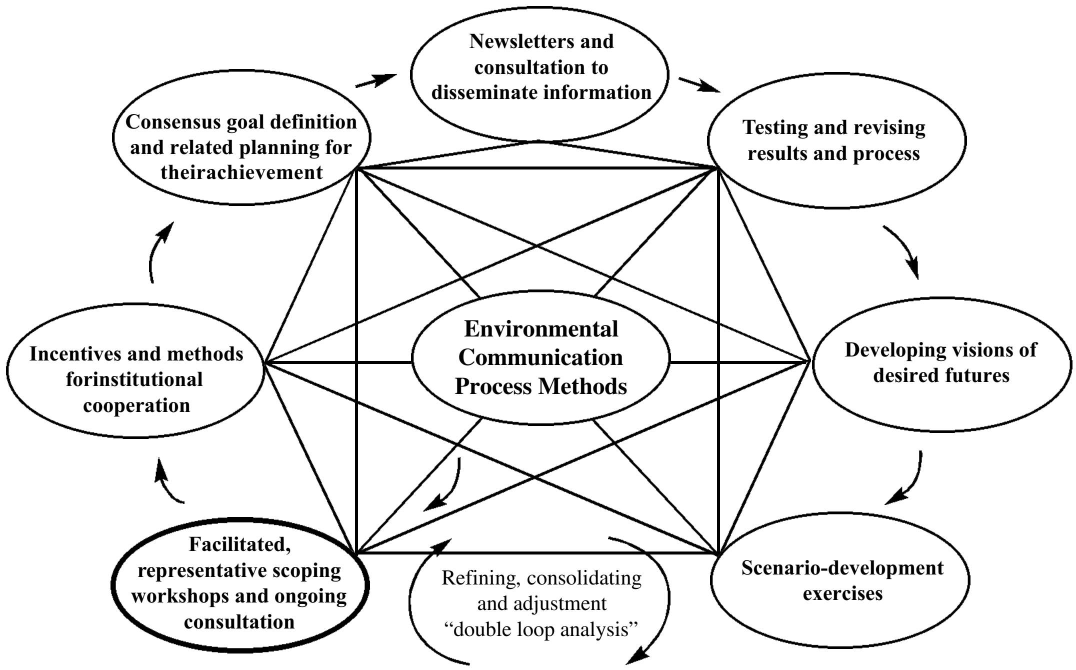
Figure 21. According to Sinclair and Valdimarsson (2003), adding "ecosystem considerations to present fishery management system methods can be done gradually, some changes are called for:

- "Instead of addressing a definite fish stock solely, the whole ecosystem and its components will have to be included in the consideration. This may well start with some factors only, reflecting the availability of data.
- Definition of management objectives will be broader, without losing sight of those of particular short-term interest to the fisheries sector.
- The number of reference points and indicators will increase, (e.g. size compositions or average trophic level of catch), and hence the need to widen the scientific base for management decisions.
- Monitoring, control and surveillance (MCS) systems will have to be strengthened, with inevitability higher costs.
- Institutional arrangements will have to be strengthened and broadened to include non-fishery stakeholders and allow consultations with all legitimate interested parties concerning management objectives as well as management measures, although those from the fishery sector, including the fisherfolk themselves, will continue to be the nucleus.
- Stakeholder engagement should be promoted through training and public awareness programs.
- A considerable extra effort in research will be required, not only for verifying indicators and reference points, but also on the economic and social implications of ecosystem-based fisheries management (EBFM), including factors such as the equitable sharing of costs and benefits between stakeholders (and by addressing any overcapacity and fishing effort problems).
- A visible leap ahead is needed to assisting developing countries to increase their capacity to introduce this wider fishery management concept into their fisheries."

Further, to achieve optimal management best practices an effort to reduce uncertainties is important to promote relevant research on ecosystem subjects such as:

- "considering improved methods for consultation and joint decision making so as to improve ecosystem governance;
- ensuring all critical habitats for the key species in the ecosystem are located and mapped, and identifying and addressing any threats;
- improving knowledge of the food webs, including prey and predator relationships, to facilitate consideration of possible ecosystem responses to different management actions;
- improving the monitoring of by-catch and discards in all fisheries to obtain a better knowledge of the amount of catch actually taken; and
- studying any threats to the marine ecosystems from human sources outside fisheries, whether land-based or marine, and investigating means to minimize these."

Figure 22. Environmental communication to elaborate an ecosystem-oriented approach in an LME. A facilitating framework of process methods (describing, planning, and managing ... while working with people and communities), and substantive methods (knowledge through description and analysis). Adapted and modified from Slocombe, 1998 & 1993.



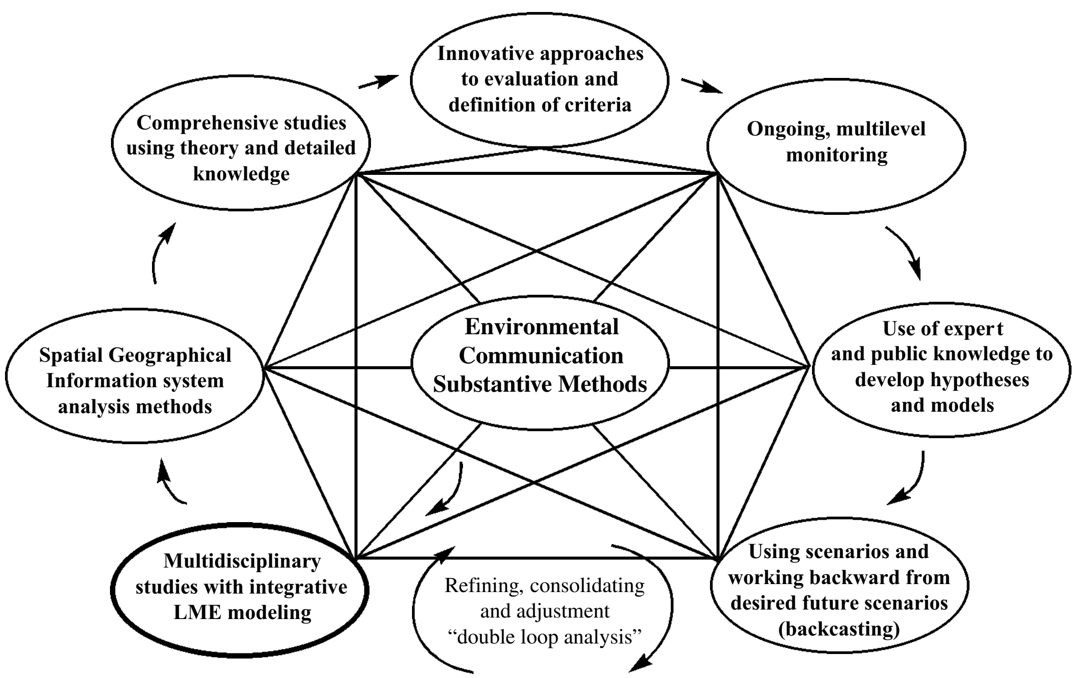


Figure 23. Goals comparison matrix for LME ecosystem-based management (adapted and modified from Slocombe, 1998).

	Goals									
	Normative	Principled	Integrative	Complex	Dynamic	Trans-disciplinary	Applicable	Participatory	Under-standable	Adaptive
Flows,amounts, areas	O	—	—	—	✔	O	✔	O	✔	O
Biodiversity	✔	✔	O	O	O	O	✔	O	✔	O
Health	✔	O	✔	✔	✔	✔	O	O	✔	✔
Sustainability	✔	✔	✔	✔	✔	✔	✔	✔	O	✔
Integrity	O	O	✔	✔	✔	✔	✔	—	—	O
Quality of life	—	O	✔	✔	O	✔	✔	O	O	✔
Developing consensus	—	✔	✔	✔	✔	O	✔	✔	O	✔
Developing understanding	O	O	✔	✔	✔	✔	O	O	O	✔
Planning and management	✔	✔	✔	—	✔	O	O	✔	O	✔
Doing things	—	O	—	✔	✔	O	✔	✔	✔	✔

A ✔ sign indicates strong consistency; a O sign, moderate consistency, and a minus sign (—), not consistent.

Figure 24. Suggested benefits to identifying common goals and objectives for ecosystem-oriented management, adapted and modified from Stanford and Poole, 1996.

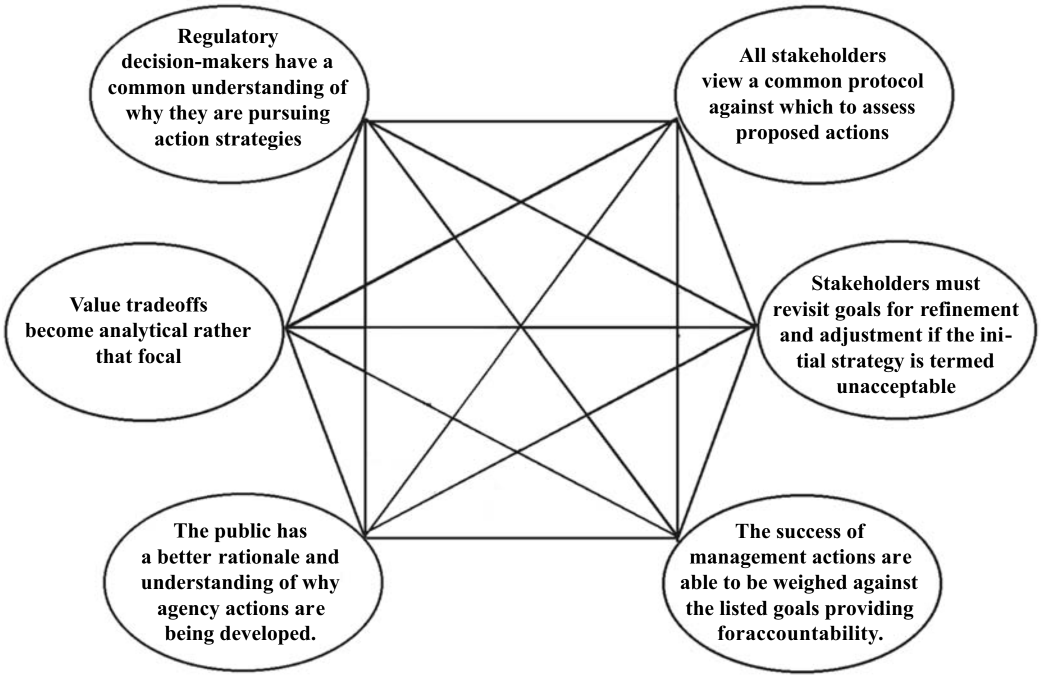


Figure 25. For the precautionary approach to be embedded in fisheries management decision-making, risk analysis approaches, and procedures for involving interested (though sometimes disenfranchised) groups needs to be taken into "consideration". Adapted and modified from McGlade, 2001.

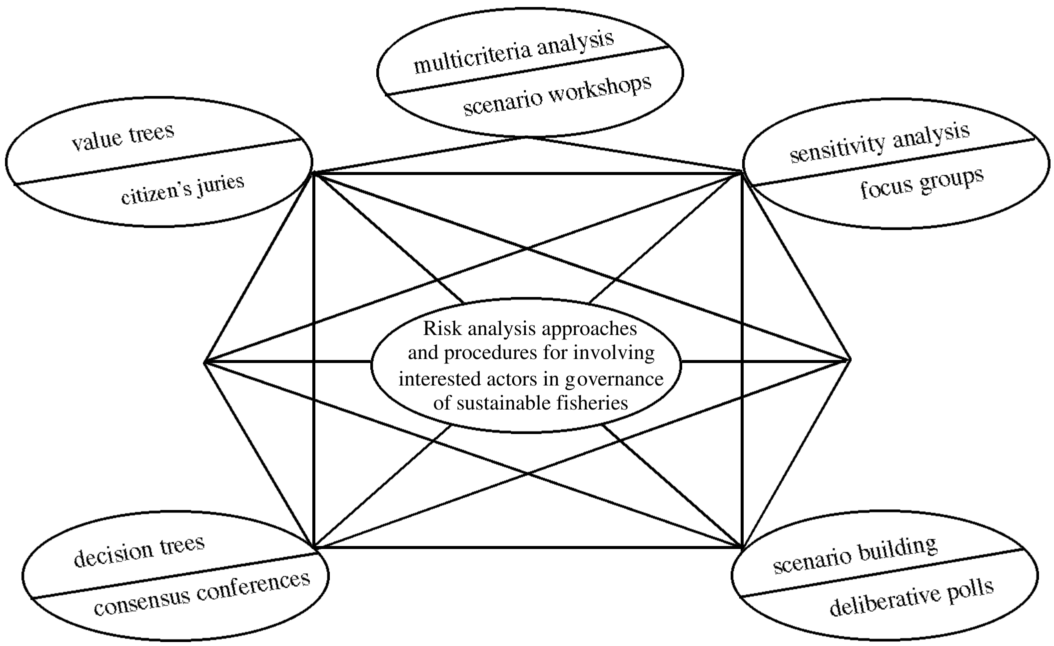


Figure 26. Prospective interconnected LME Governance systems capable of responding to fisheries/coastal change, adapted and modified from (Olsen 2001; Boesch, 1999).

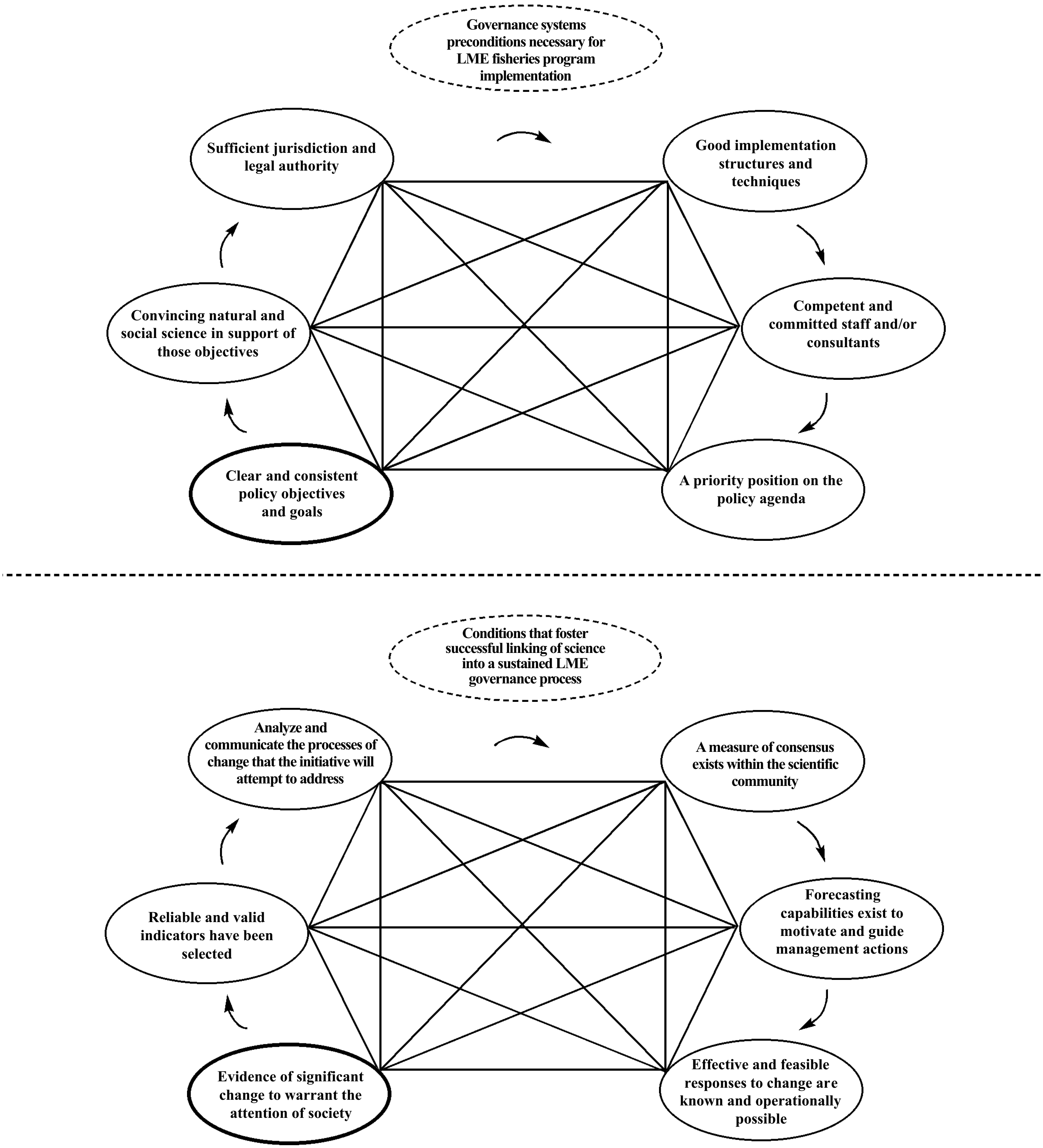


Figure 27. Iterative protocol for fusing basic/applied scientific research and synthesis and public opinionin adaptive large marine ecosystem LME management. (Adapted and modified from Stanford and Poole , 1996).

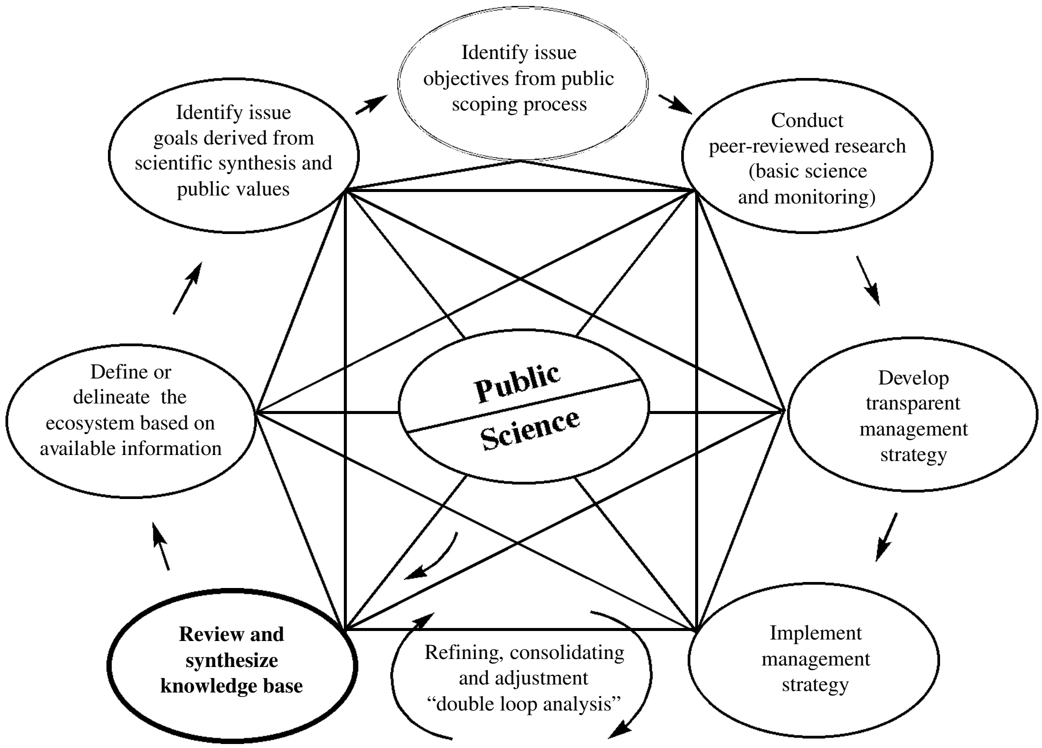


Figure 28. Relationships among science, management, and stakeholder participation in the provision of scientific advice for the precautionary approach to management of fisheries in a large marine ecosystem context. Arrows and the labels between the arrows indicate the direction of flow for eac h type of information. (Adapted and modified from Perry et al., 1999).

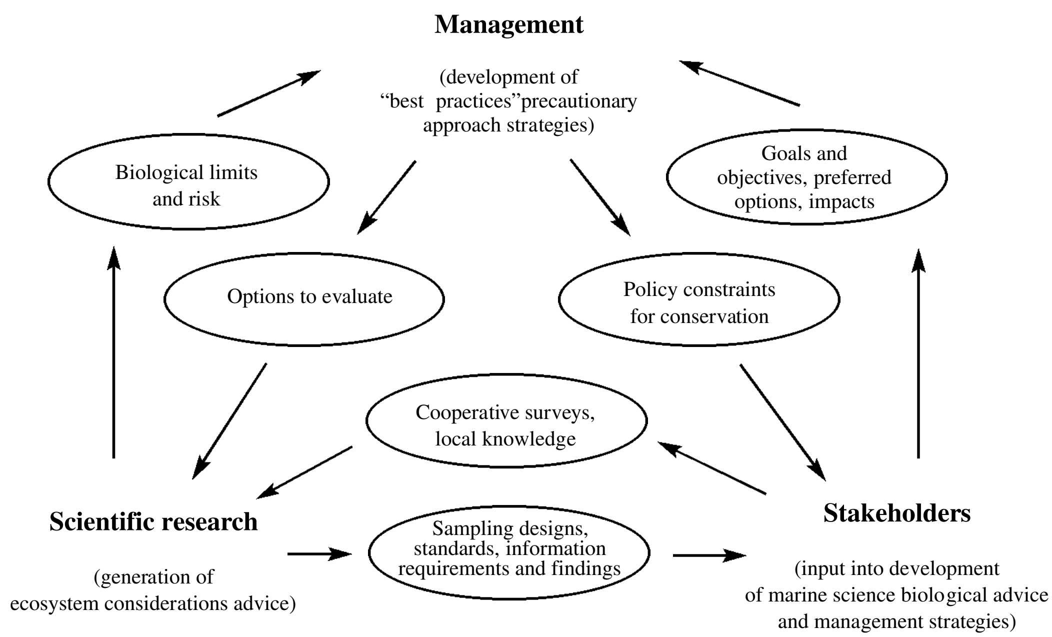
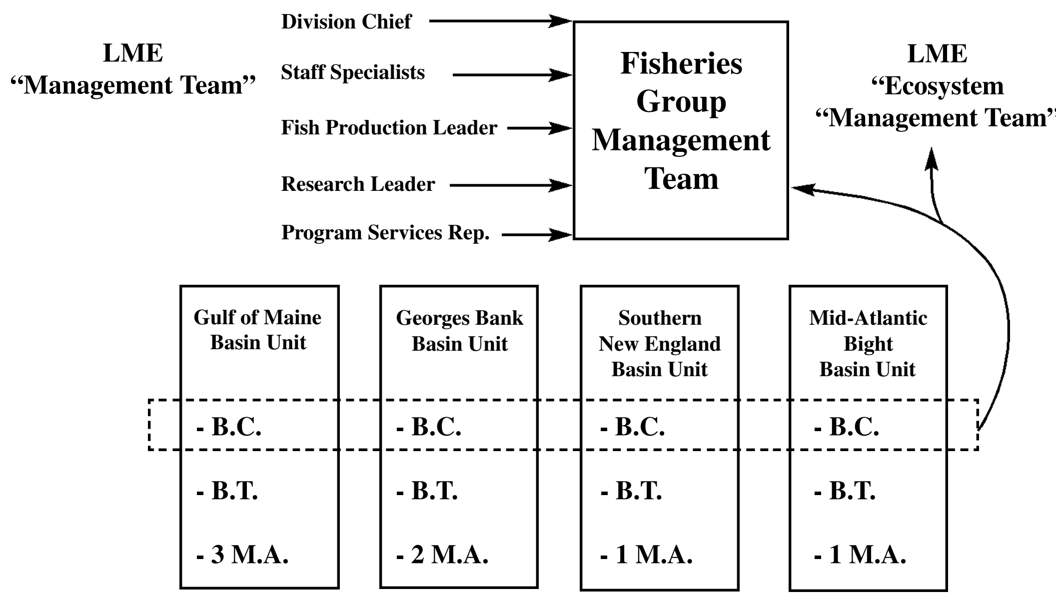


Figure 29. Draft concept for organization of the Northeast U.S. Continental Shelf LME Fisheries Governance. There would be an interplay among several existing regulatory-oriented agencies, including the New England Fisheries Management Council, the Mid-Atlantic Fisheries Management Council and the Atlantic States Marine Fisheries Commission as well as NOAA/NMFS and the U.S., Coast Guard, as well as state and local jurisdictional entities etc. (Adapted and modified from Lynch et al., 1999.)



- B.C. = Basin Coordinator (e.g. Northeast United States Continental Shelf)
- B.T. = Basin Team
- 3 M.A. = Management Area

Figure 30. Select ecosystem management principles for LME environmental policy. Adapted and modified from Haeuber (1996) and references cited therein.

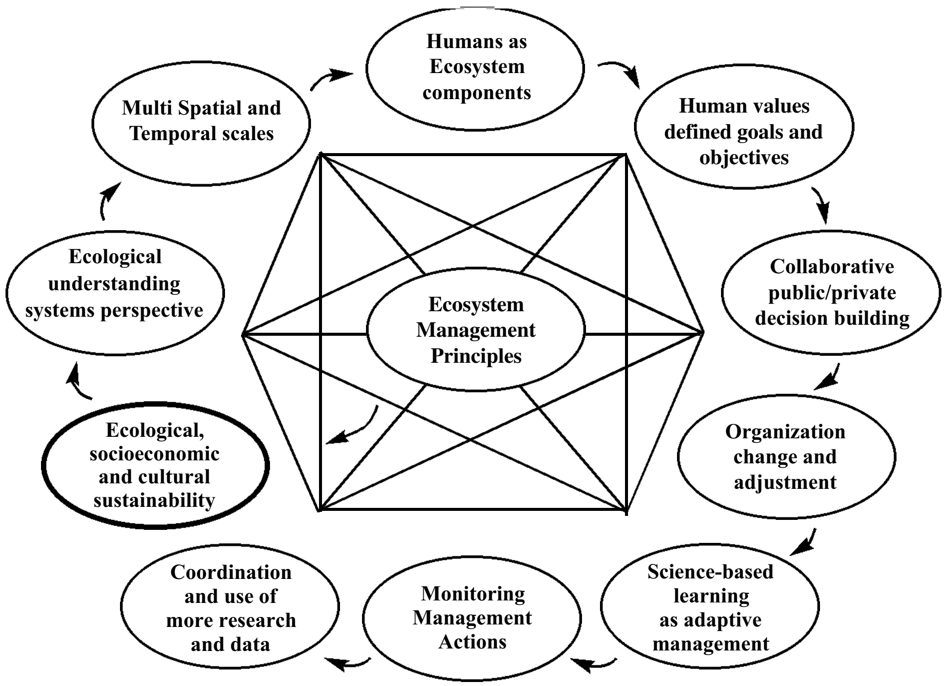
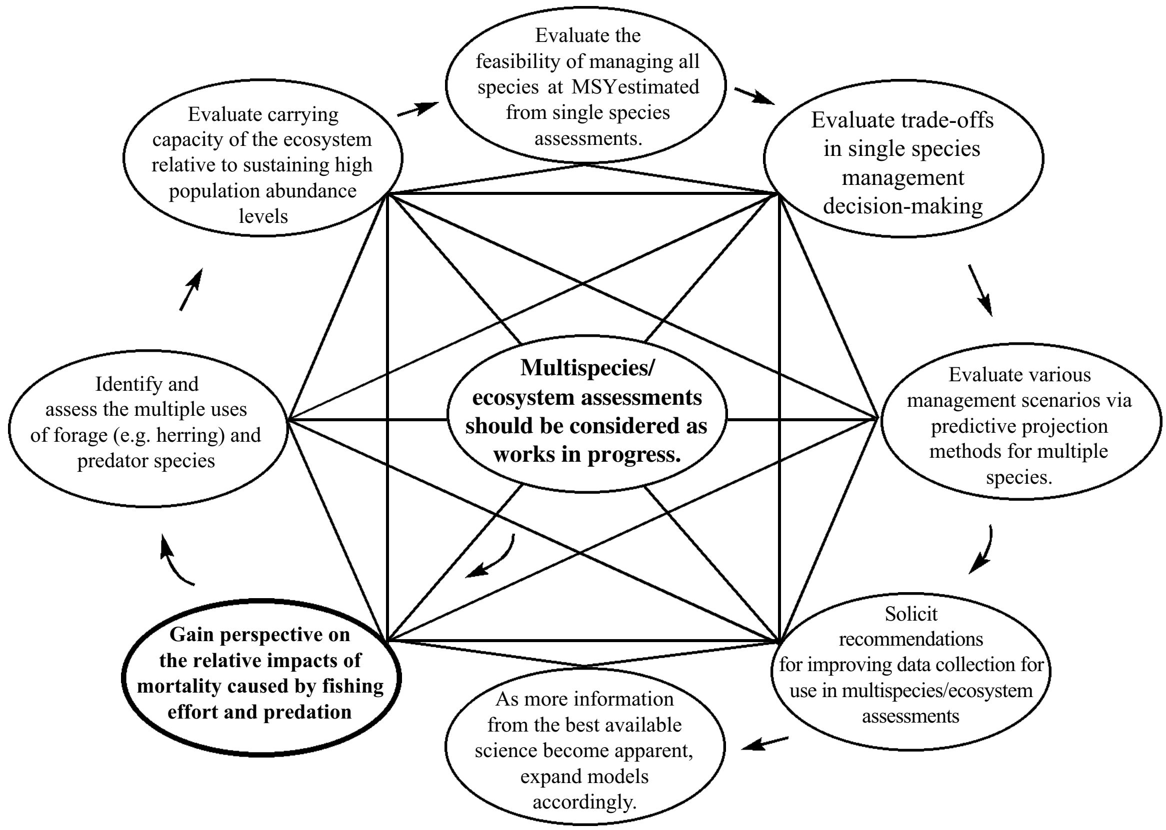


Figure 31. Multispecies assessments can enhance and improve single species fishery management decision-making over the long-term. Adapted and modified from ASMFC Fisheries Focus 12(2), April 2003, pp. 7 & 8; see also Hollowed et al., 2000; Link, 2002a.



Single species assessments according to Hollowed et al., (2000) traditionally include:

- An assessment of historical reconstruction of a stock to establish key parameters & relationships in describing present stock status.
- Short-term forecasting to move a stock towards a desired status through specific actions (e.g. TAC).
- Long-term forecasting predictions under various management scenarios of the likely future status of the stock.
- Instituting a precautionary approach while advising on the robustness of management procedures.

Link (2002a) suggests that single species approaches generally don't consider:

- species interactions;
- allocation of biomass;
- changes in ecosystem structure or function;
- non-fishing ecosystem services;
- non-target species;
- rare or protected species and biodiversity;
- ecosystem effects of discarding unwanted bycatch; and
- gear impacts on habitat.

Figure 32. Suggested analyses needed in the process of establishing a management system for an international LME setting. Each stage could be disrupted by political and governance concerns and/or budgetary constraints. (Adapted and modified after Larkin, 1996).

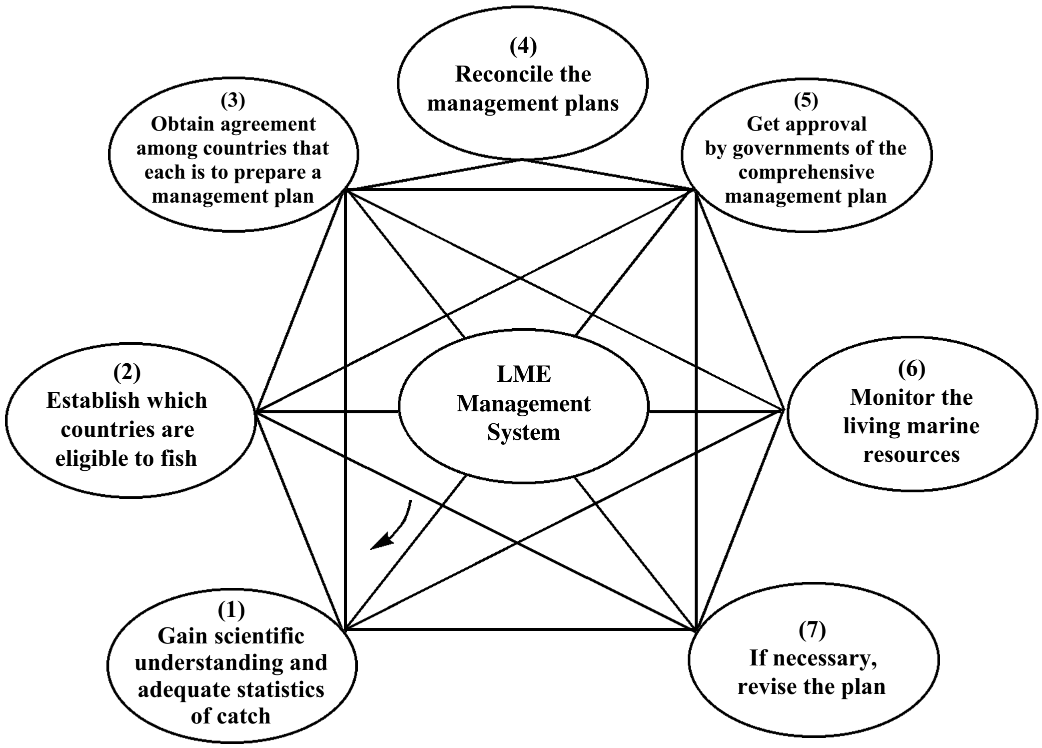


Figure 33. Challenges to the ecosystem approach, including generic program implementation, along with broader issues include the parameters below (adapted and modified from MacKenzie, 1997).

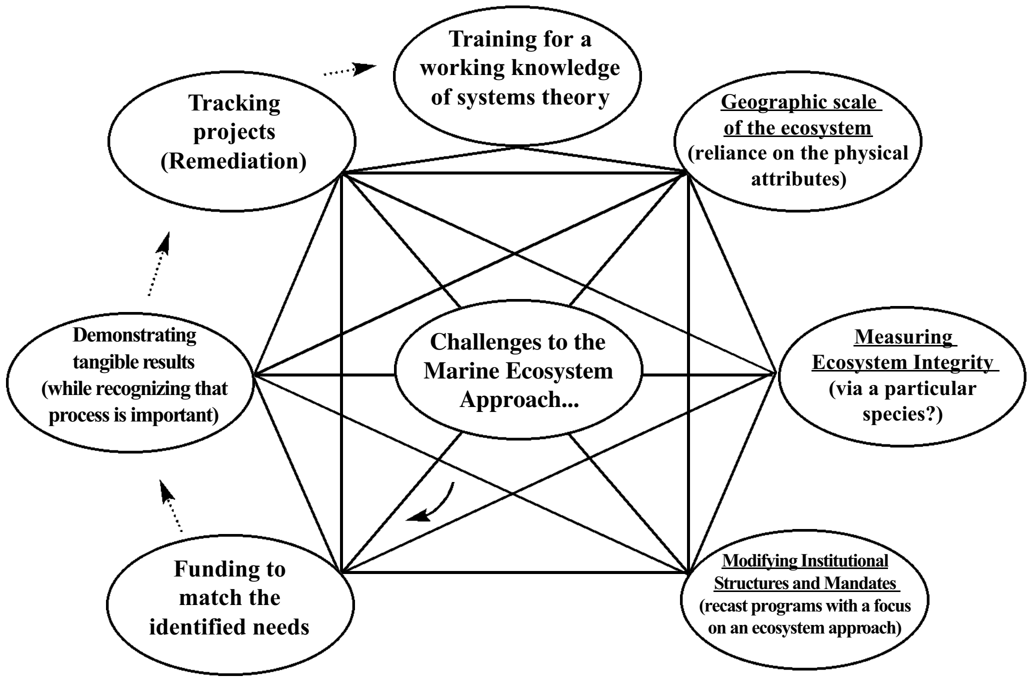


Figure 34. The Role of Scientists in an LME Approach. (Adapted and modified from Francis and Schotten, 1997; see also Slocombe, 1998; Barber and Taylor, 1990). The role of the policy decision maker is to specify the goals and objectives of the fishery management plan, while working in association with the scientists, to evaluate results while weighing the goals and objectives as well as take and disseminate the decision.

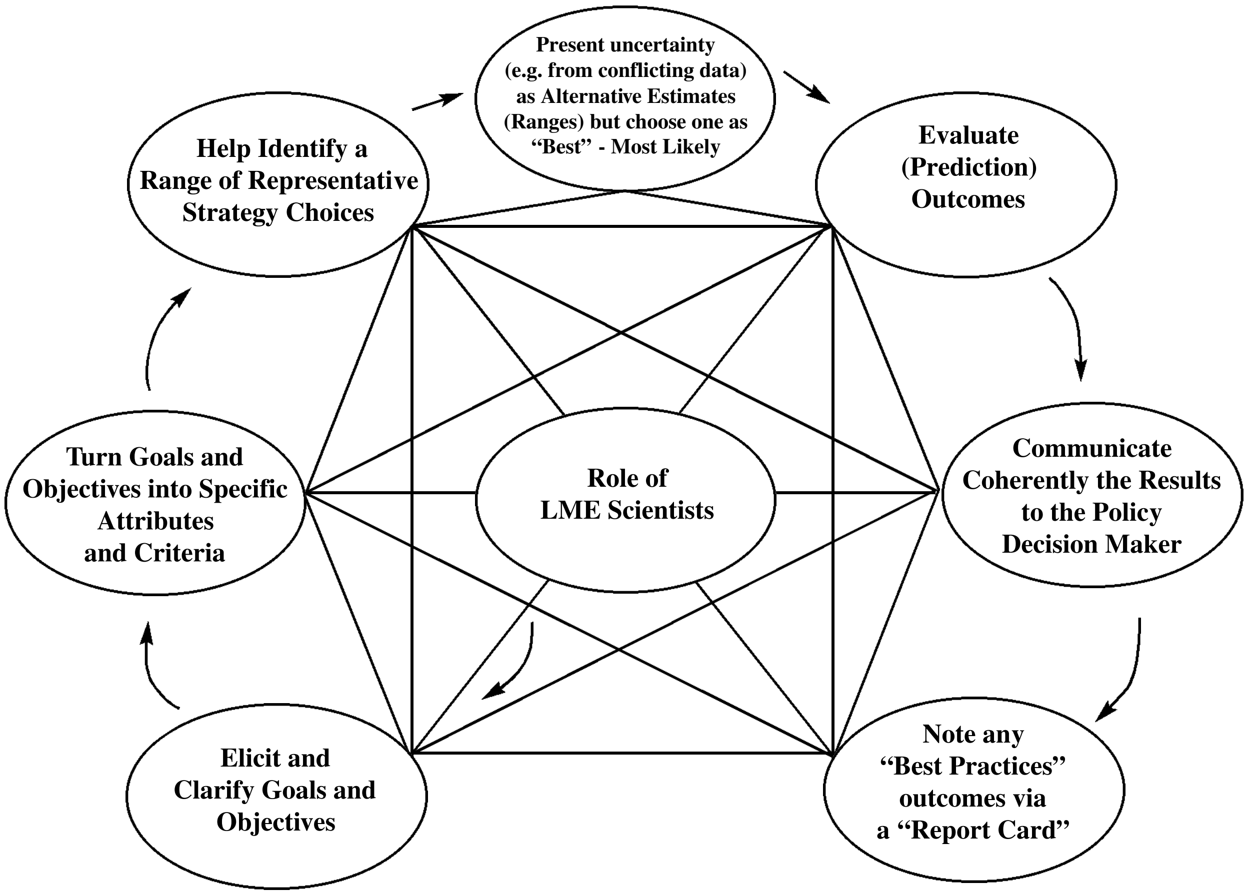


Figure 35. The characteristics of regulatory institutions that have successfully restricted common pool resources such as marine capture fisheries suggests that these elements are quite important. (Adapted and modified from Perrings, 2000; see also Imperial, 1999). Berkes et al.(2000) suggest that the Maine Lobster fishery provides a contemporary members only application of a "club" or "limited partnership".

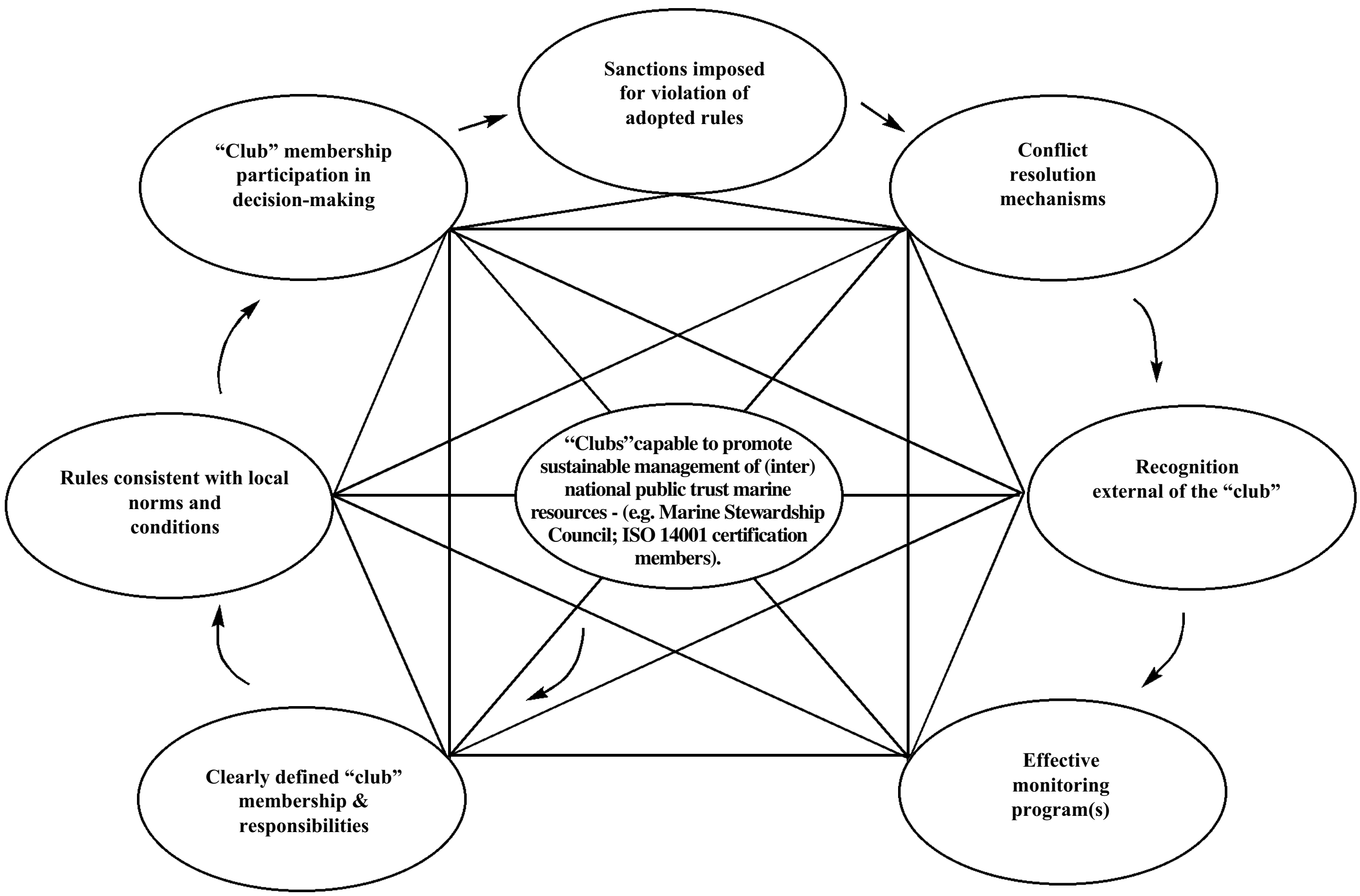


Figure 36. A future LME integrated coastal management (ICM) process ought to include the parameters below according to von Budungen and Turner (2001, with modifications). Thus, any related LME-ICM process should aim to unify all stakeholders including government, scientists, managers, as well as sectoral and public/private interests.

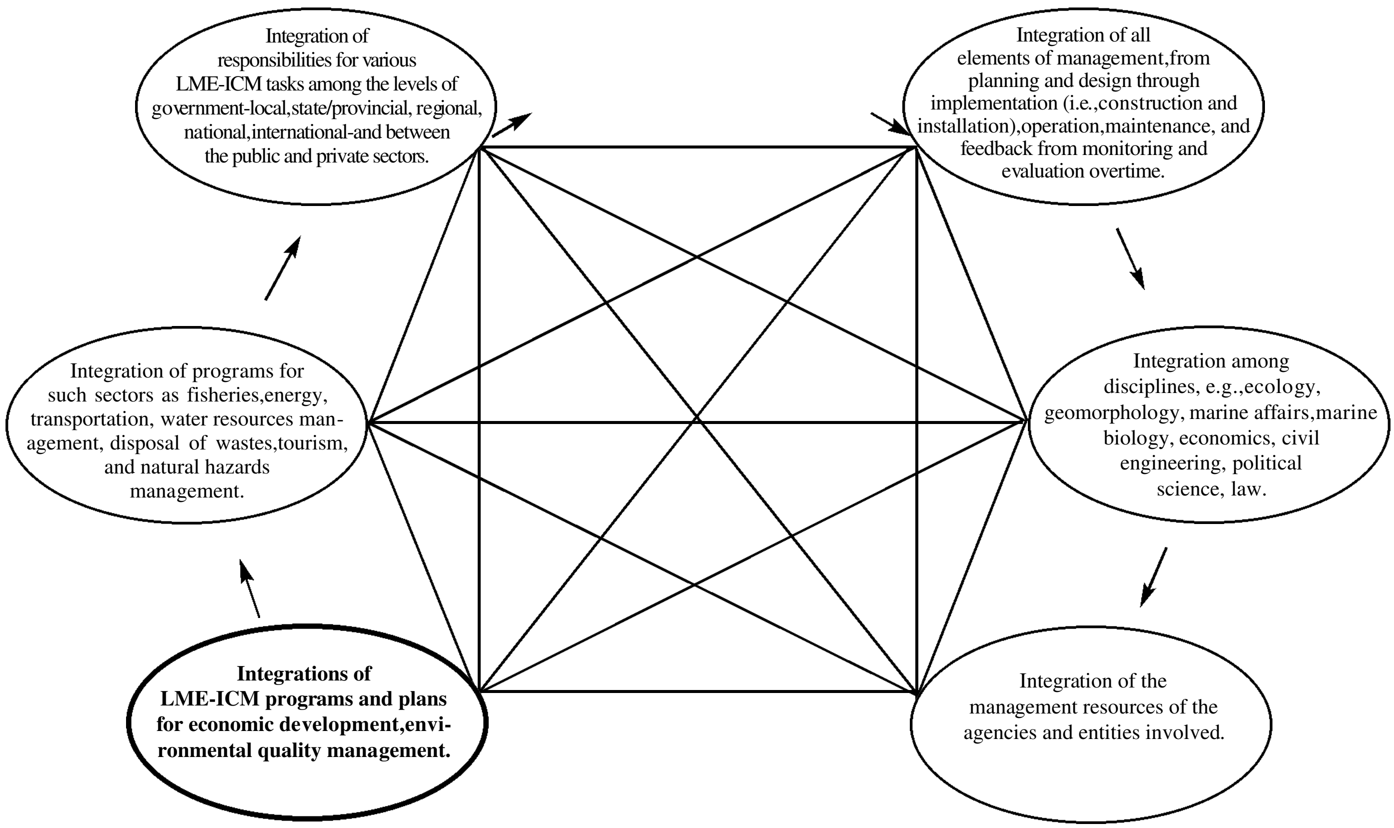


Figure 37. Select recommendations for mulated on the use of "indicators" for integrated LME-ICM efforts (adapted and modified from Belfiore, 2003).

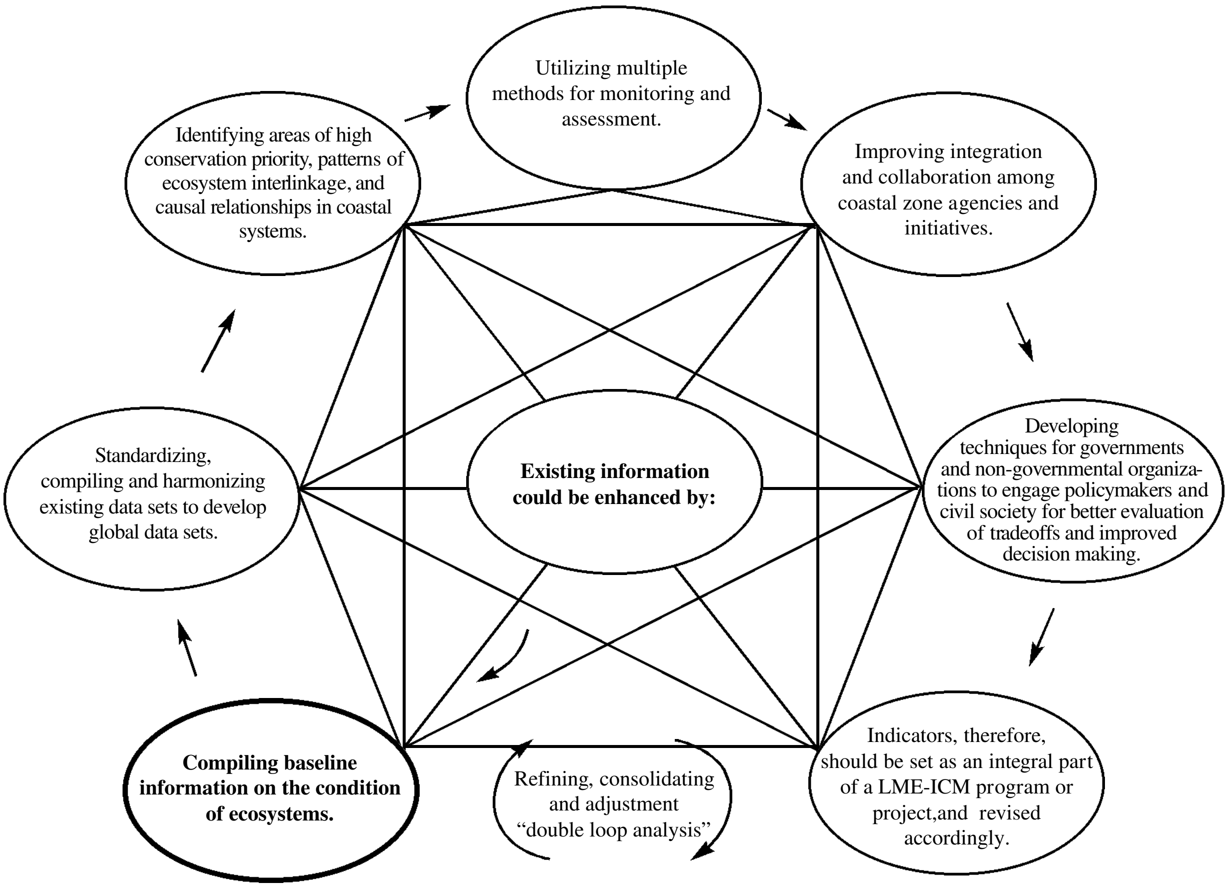
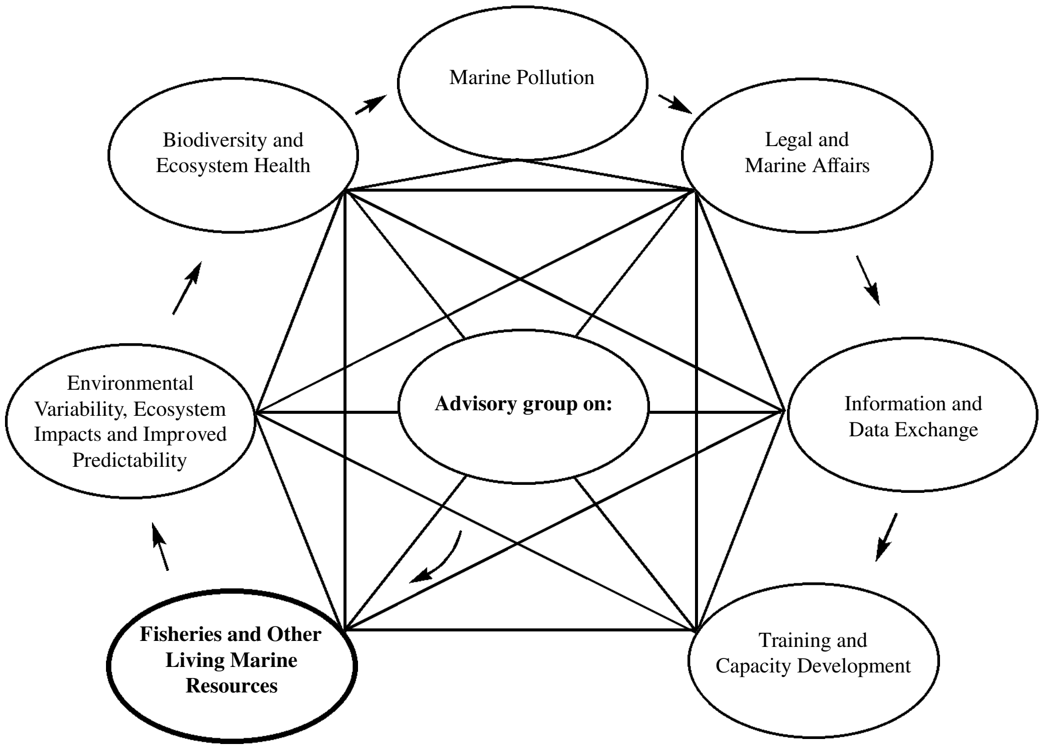


Figure 38. Select institutional arrangements established to aid LME strategic action(s) and management. These types of advisory groups could be employed in any LME organizational setting. Adapted and modified from O'Toole (2002).



Publishing in *NOAA Technical Memorandum NMFS-NE*

Manuscript Qualification

This series represents a secondary level of scientific publishing in the National Marine Fisheries Service (NMFS). For all issues, the series employs thorough internal scientific review, but not necessarily external scientific review. For most issues, the series employs rigorous technical and copy editing. Manuscripts that may warrant a primary level of scientific publishing should be initially submitted to one of NMFS's primary series (*i.e., Fishery Bulletin, NOAA Technical Report NMFS,* or *Marine Fisheries Review*).

Identical, or fundamentally identical, manuscripts should not be concurrently submitted to this and any other publication series. Manuscripts which have been rejected by any primary series strictly because of geographic or temporal limitations may be submitted to this series.

Manuscripts by Northeast Fisheries Science Center (NEFSC) authors will be published in this series upon approval by the NEFSC's Deputy Science & Research Director. Manuscripts by non-NEFSC authors may be published in this series if: 1) the manuscript serves the NEFSC's mission; 2) the manuscript meets the Deputy Science & Research Director's approval; and 3) the author arranges for the printing and binding funds to be transferred to the NEFSC's Research Communications Unit account from another federal account. For all manuscripts submitted by non-NEFSC authors and published in this series, the NEFSC will disavow all responsibility for the manuscripts' contents; authors must accept such responsibility.

The ethics of scientific research and scientific publishing are a serious matter. All manuscripts submitted to this series are expected to adhere -- at a minimum -- to the ethical guidelines contained in Chapter 1 ("Ethical Conduct in Authorship and Publication") of the *CBE Style Manual*, fifth edition (Chicago, IL: Council of Biology Editors). Copies of the manual are available at virtually all scientific libraries.

Manuscript Preparation

Organization: Manuscripts must have an abstract, table of contents, and -- if applicable -- lists of tables, figures, and acronyms. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area," "Methods & Materials," "Results," "Discussion" and/or "Conclusions," "Acknowledgments," and "References Cited."

Style: All NEFSC publication and report series are obligated to conform to the style contained in the most recent edition of the *United States Government Printing Office Style Manual*. That style manual is silent on many aspects of scientific manuscripts. NEFSC publication and report series rely more on the *CBE Style Manual,* fifth edition.

For in-text citations, use the name-date system. A special effort should be made to ensure that the list of cited works contains all necessary bibliographic information. For abbreviating serial titles in such lists, use the guidance of the International Standards Organization; such guidance is easily accessed through the various Cambridge Scientific Abstracts' serials source lists (see *http://www.public.iastate.edu/~CYBERSTACKS/JAS.htm*). Personal communications must include date of contact and full name and mailing address of source.

For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 20 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

Typing text, tables, and figure captions: Text, tables, and figure captions should be converted to WordPerfect. In general, keep text simple (*e.g.*, don't switch fonts and type sizes, don't use hard returns within paragraphs, don't indent except to begin paragraphs). Also, don't use an automatic footnoting function; all notes should be indicated in the text by simple numerical superscripts, and listed together in an "Endnotes" section prior to the "References Cited" section. Especially, don't use a graphics function for embedding tables and figures in text.

Tables should be prepared with a table formatting function. Each figure should be supplied both on paper and on disk, unless there is no digital file of a given figure. Except under extraordinary circumstances, color will not be used in illustrations.

Manuscript Submission

Authors must submit one paper copy of the double-spaced manuscript, one disk copy, and original figures (if applicable). NEFSC authors must include a completely signed-off "NEFSC Manuscript/Abstract/Webpage Review Form." Non-NEFSC authors who are not federal employees will be required to sign a "Release of Copyright" form.

Send all materials and address all correspondence to: Jon A. Gibson (Biological Sciences Editor), NMFS Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543-1026.

Northeast Fisheries Science Center
Operations, Management & Information Services Staff
Research Communications Branch
Editorial Office

Research Communications Branch
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

**MEDIA
MAIL**

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Resource Survey Report (formerly *Fishermen's Report*) -- This information report is a quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Resource Survey Report*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).