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A Framework for Monitoring and Assessing Socioeconomics and Governance of Large Marine Ecosystems

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Acronyms

CZMA	=	Coastal Zone Management Act
ESA	=	Ecological Society of America
EU	=	European Union
GEF	=	Global Environment Facility
GOM	=	Gulf of Maine
ICGP	=	Interorganizational Committee on Guidelines and Principles
LME	=	large marine ecosystem
NAFO	=	Northwest Atlantic Fisheries Organization
NGO	=	nongovernmental organization
NMFS	=	NOAA National Marine Fisheries Service
NRC	=	natural resource community
NRDA	=	natural resource damage assessment
NRR	=	natural resource region
VTIS	=	vessel traffic information service

Preface

In September 1997, NOAA awarded a contract (*i.e.*, #40 ENN F7 00378) to researchers at the University of Rhode Island to develop the conceptual framework for the analysis and monitoring of the large marine ecosystem (LME) modules for socioeconomic activity and governance of LMEs. This report provides a framework for linking the socioeconomic and governance modules with the natural resource science-based LME modules (productivity, fish and fisheries, and pollution and ecosystem health). This report fulfills the terms of the 12-mo contract.

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INTRODUCTION

The ecosystem paradigm is emerging as the dominant approach to managing natural resources in the United States as well as internationally. The shift away from the management of individual resources to the broader perspective of ecosystems has not been confined to academia and think tanks where it first began; it also is beginning to take root in government policy and programs. Since the late 1980s, many federal agency officials, scientists, and policy analysts have advocated a new, broader approach to managing the nation's natural resources. The approach recognizes that plant and animal communities are interdependent and interact with their physical environment to form distinct ecological units called ecosystems. These systems contribute to the production of fish, marine birds, and marine mammals that cross existing jurisdictional boundaries. The approach also recognizes that many human actions and their consequences, including marine pollution, extend across jurisdictional boundaries.

Emergence of this paradigm is a response to the failure of the single sector/single species approach to achieve sustainable development of interdependent natural resources and effective protection of the natural environment. There is now a pronounced trend toward more integrated ecosystem management. U.S. administration and legislation are increasingly requiring an ecosystem approach to natural resource research and management. The September 1993 "Report of The National Review: Creating a Government That Works Better and Costs Less" recommended that the President issue an executive order establishing ecosystem management policies across the federal government.[1]

To implement an ecosystem approach for environmental management, the White House Office of Environmental Policy established an Interagency Ecosystem Task Force to implement an ecosystem approach to environmental management. To date, the movement toward ecosystem management is reflected in, for example, the Magnuson-Stevens Fishery Conservation and Management Act (as amended through October 11, 1996), NOAA's Marine Sanctuaries Program, the National Estuary Program, the National Estuarine Research Reserves System, the 1990 Amendments to the Coastal Zone Management Act, and also in the actions of federal agencies with resource management responsibilities.[2] Further, NOAA's 1997 strategic plan is based, in large part, on the ecosystem approach to living marine resource management.

Ecosystem management is defined as a system "driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem structure and function" (Christensen *et al.* 1996). Ecosystem management necessitates intergovernmental and intersectoral management. This is why federal agencies will have to identify barriers to interagency coordination and why they must develop alliances and partnerships with nonfederal agencies and private sector stakeholders (Hennessey 1997). Ecosystems management must be able to cope with the uncertainty associated with the complexity of ecosystems as natural systems, and the organizational and institutional complexity of the implementation environment (Hennessey 1997; Acheson 1994).

The fit between the spatial and temporal scales of government jurisdictions on the one hand and ecosystems on the other requires investigation of ways to connect "nested" ecosystems through "networked institutions" at federal, state, local, and nongovernmental organization (NGO) levels (Hennessey 1997). How these institutions must adapt to deal with the complexity of the ecosystem and the complexity of the governance system in order to achieve an optimal mix of benefits and costs is a fundamental issue (Creed and McCay 1996).

The need for improved management of living marine resources is critical. The livelihood of coastal populations and national economies have depended, for many decades, on coastal and marine resources. As indicated in NOAA's strategic plan, "over half of the [U.S.] population now lives on the coast. Between one-third and one-half of [U.S.] jobs are located in coastal areas. About one-third of the nation's GNP [gross national product] is produced there through fishing, transportation, recreation and other industries dependent on healthy coastal ecosystems for growth and development. Rapid population growth and increasing demand for recreation and economic development in many coastal areas have degraded natural resources and led to declines in both environmental integrity and general productivity. Coastal areas provide essential habitats for the majority of commercially valuable marine species. But habitat loss, pollution[,] and overfishing have reduced populations of coastal fish and other species to historically low levels of abundance and diversity. Maintaining coastal ecosystems['] health and biodiversity is essential to the sustainable development of coastal resources and economies, and to the future welfare of the Nation."

The complex interplay of socioeconomic, ecological, political, and legislative processes underscores the need for an integrated approach to the management of drainage basins, coastal areas, and linked continental shelves and dominant current systems. In this report, we develop an integrated approach to these problems based on the LME concept.

The concept of LMEs is a science-based method for dividing the world's oceans, developed 15 yr ago by Kenneth Sherman and Lewis Alexander. LMEs are geographic areas of oceans that have distinct bathymetry, hydrography, productivity, and trophically dependent populations. The geographic limits of most LMEs are defined by the extent of continental margins and the seaward extent of coastal currents. Among these are the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Alaska, Gulf of Mexico, Eastern Bering Sea, and California Current. Some LMEs are semi-enclosed seas, such as the Caribbean, Mediterranean, and Black Seas. LMEs can be further divided into subsystems such as the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight in the case of the Northeast U.S. Continental Shelf (Sherman *et al.* 1988). Approximately 95% of all fish and other living marine resources produced are taken from the world's 49 LMEs. Unfortunately, many LMEs are currently stressed from overexploitation of marine resources, habitat degradation, and pollution.

The LME management approach links the management of drainage basins and coastal areas with continental shelves and dominant coastal currents. The approach: 1) addresses the many-faceted problem of sustainable development of marine resources; 2) provides a framework for research monitoring, assessment, and modeling to allow for prediction and better management decisions; and 3) aids in focusing marine assessments and management on sustaining productivity and conserving the integrity of ecosystems.

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 these marine systems..." (World Bank 1995).

The World Bank's operational guidelines for LME research require social science as well as natural science investigations, since many of the problems of the marine environment are human induced. The GEF's LME initiative has five modules: productivity, fish resources and fisheries, pollution and ecosystem health, socioeconomics, and governance.

The first three modules are natural resource science-based and well developed. During the past 15 yr, extensive scientific work has resulted in methods for monitoring and assessing the productivity, fish resources and fisheries, and pollution and ecosystem health of LMEs. Sustained, accurate, and efficient assessments of changing ecosystem states are now feasible because of the advent of advanced technologies applied to coastal ocean observation and prediction systems. Such systems can now measure ocean productivity, changes in fish stocks, and changes in water and sediment quality and general health of the coastal ocean.

Consideration of the socioeconomic and governance modules has been more limited,[3] despite the fact that work on these modules is essential to achieving effective ecosystem management. Management of LMEs requires not only knowledge of changing states of the system, but also the effects of change on socioeconomic benefits to be derived from using the LME resources. To provide sustainable, optimal use of marine resources, the services they provide must be identified and valued, the sources of market failure must be understood, and policy instruments to correct market failures and move toward sustainability must be adopted.

This report presents a methodology for determining what is known of the socioeconomic and governance aspects -- the human dimensions -- of LME management. The following sections describe a basic framework for identifying the salient socioeconomic and governance elements and processes of an LME. Methods for monitoring and assessing the various elements and processes are also discussed.

HUMAN DIMENSIONS OF LMES

Monitoring and assessment are prerequisites to effective management of LMEs threatened by pollution, overexploitation and other misuses of these important resources. Furthermore, management involves altering human behavior, especially behavior that threatens, directly or indirectly, the sustainability of LME resources. Therefore, we need to understand the human system and its relationship to the sustainability of LME resources and their services.

Human and ecological systems are both composed of complex webs of interrelated components and processes. Interactions occur both within each respective system and between systems. We view the natural environment and related human dimensions as a set of interrelated components and processes rather than isolated elements that act independently.

Ecological components of an LME can be viewed as, among other things, biophysical capital (*i.e.*, stocks of valuable natural resources). The various forms of the biophysical capital generate flows of goods and services, many of which are directly or indirectly used by humans (*e.g.*, in fishing and shipping activities). Some ecological goods and services are transformed into commodities that are cycled through the economy. These flows also include outputs of processes that are returned to the environment, sometimes as wastes.

Traditionally, property rights are poorly defined in the coastal zone and marine areas.[4] Externalities impact fishermen, recreation, and other activities that rely on the natural system for flows of commodities and opportunities from these capital assets.[5] Human activities that use or impact the biophysical capital of a typical LME may occur on land, in the coastal zone, or in offshore areas. High human population densities in the coastal regions and associated manufacturing, transportation, and extractive activities often result in environmental degradation and overexploitation. Municipal sewage and industrial waste disposal in coastal waters often overwhelm the assimilative capacity of marine areas. Nutrient pollution may result in large increases in phytoplankton production and microbial activity -- eutrophication. Fish and shellfish

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4. Assess the level of LME-related activities
5. Assess interactions between LME-related activities and LME resources
6. Assess impacts of LME-related activities on other users
7. Assess the interactions between governance mechanisms and resource use
8. Assess the socioeconomic importance of LME-related activities and economic and sociocultural value of key uses and LME resources
9. Identify the public's priorities and willingness to make tradeoffs to protect and restore key natural resources
10. Assess the cost of options to protect or restore key resources
11. Compare the benefits with the costs of protection and restoration options
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populations that are dependent on estuaries as essential habitat may be harmed, displaced, or rendered unfit for human consumption. In virtually all of these examples, the five LME modules are interdependent -- a change in one module will have impacts on other modules.

MONITORING AND ASSESSMENT

We anticipate several steps in the process of monitoring and assessing the human dimensions of an LME and the use of its resources. These steps are summarized in Table 1.

These steps provide information to management authorities, especially with regards to the efficacy of management policies. Most of these steps should be repeated periodically to update the information on the status of the LME. This information is an essential ingredient of the adaptive management approach, which requires frequent evaluation and feedback to take full advantage of experience and learning (Hennessey 1994; Lee 1993; Walters 1986).

STEP 1: IDENTIFY PRINCIPAL USES OF LME RESOURCES

The first step in the monitoring process involves identifying principal uses of LME resources. Management of LMEs requires comprehension of a variety of relationships within the natural and human environment and also of the effect of human uses on the environment. That is, policymakers need to be aware of, and sensitive to, the pattern of interaction resulting from their policy decisions if the sustainability of the environment, which supports human needs, is to be maintained.

Use is an important concept and requires careful definition. We define several types of use as follows:

- *Direct use* refers to the physical use of a resource on site or *in situ*. Common examples of direct use include commercial and recreational fishing, beach use, boating, and wildlife viewing. Most direct use is targeted by participants who visit a beach, fish at a particular location, and so forth. Direct use also may be *incidental*, for example, when a person traveling by boat unexpectedly sees whales or marine birds while en route to a destination (Freeman 1993).
- *Indirect use* occurs when, for example, wetlands or other LME habitats contribute to the abundance of wildlife or fish observed or caught elsewhere in the LME. In effect, the ecological services of the wetland or habitat help "produce" the wildlife or fish concerned, although the link between the direct use and the ecological services provided by the wetland or habitat may not be apparent to the recreational participant.
- *Nonuse (or "passive use")* refers to the enjoyment individuals may receive from knowing that the resources exist ("existence value") or from knowing that the resources will be available for use by one's children or grandchildren ("bequest value") or others even though the individuals themselves may not actually use the resources concerned.

Another useful distinction is between *consumptive* use and *nonconsumptive* use:

- *Consumptive use* occurs when one person's use of a resource prevents others from using it. For example, the shellfish, finfish, or waterfowl one person takes in the LME are unavailable for others to harvest. Hence, consumptive use of natural resources in this sense is like consumptive use of private goods exchanged on markets, such as a pizza or a pair of shoes.

- *Nonconsumptive use* refers to cases where one person's enjoyment does not prevent others from enjoying the same resource. For example, my viewing of marine mammals, other wildlife, or attractive views in the LME does not prevent you from enjoying the same resources.[6]

In this report, the uses include *direct* consumptive and nonconsumptive use, such as shipping, commercial and recreational fishing, mining, boating, beach use, and wildlife viewing. We emphasize that many activities, such as fishing and viewing of wildlife, rely upon the ecological productivity of LMEs; hence, these activities also involve the *indirect* use of these ecosystems.

STEP 2: IDENTIFY LME RESOURCE USERS AND THEIR ACTIVITIES

LME-related activities play a major role in the livelihood of coastal state residents who own, operate, or are employed by thousands of businesses in many sectors. These sectors engage in, or support, such activities as fisheries, marine transportation, and particularly tourism and recreation.

Determining use sectors that are LME-related is not always straightforward, and judgment necessarily plays an important role in making such decisions (*e.g.*, Rorholm *et al.* 1967; King and Story 1974; Grigalunas and Ascari 1982; Crawford 1984). Certain sectors are clearly LME-related, such as commercial fishing, marinas, ferries, and specialized retail stores such as bait and tackle shops. These are primary activities, which by their nature operate on or around the water; or they supply goods and services clearly related to consumptive and nonconsumptive uses of LME resources.

In a broad sense, however, much if not most activity along a coast is "LME-related," at least in part. For example, restaurants, hotels and motels, retail shops, real estate, and gasoline stations serve seasonal visitors to the coastal resources of the LME, as well as year-round residents and businesses.[7] Thus, these sectors are also LME-related to a large extent (although some activity in these sectors may also be dependent, in part, on the inland, terrestrial resources). Moreover, many residents may view the quality of the LME environment as an important factor attracting them to the area. In short, the dependence of human activity on LME resources and their quality is much broader (and more subtle) than might be suggested by first impressions.[8]

We recommend a pragmatic approach by defining two broad use sectors that are LME-related: directly-related and indirectly-related use sectors. Both sectors are involved with the consumptive or nonconsumptive uses of LME resources.

- *Directly-related use* sectors are relatively distinct and include primary activities or those that operate on or in the LME. These marine-related sectors are considered to be 100% LME-related. Examples include commercial fishing ports, marinas, and ferries that are physically located along, or that operate within, the LME.[9]
- *Indirectly-related use* sectors include tourism and recreation activities such as hotels, motels, restaurants, and sport facilities (*e.g.*, public golf courses and membership sports clubs) and retail sectors that service tourists and coastal residents, such as gas stations, bakeries, grocery stores, general merchandise stores, etc. Other indirectly-related sectors may include land-based agriculture, manufacture, and forestry, which may indirectly affect the health of the LME via pesticide runoff, wastewater discharge, or soil erosion upstream. These use sectors are considered not fully LME-related since the link between the LME and the level of these activities is weak or less clear.

STEP 3: IDENTIFY GOVERNANCE MECHANISMS INFLUENCING LME RESOURCE USE

As conflict of use and negative environmental consequences of human use become more obvious, collective responses at a variety of levels begin to emerge -- in short, governance efforts evolve. We recommend developing a "governance profile" for each LME (Juda and Hennessey 2001). It should be noted that in the case of most of the identified LMEs, governance involves governments and people of more than one state since political and LME boundaries typically do not coincide. This reality has significant implications and could provide either a rationale for interstate cooperation or, alternatively, an abandonment of national efforts, since if they are undercut by the actions of others they will be rendered ineffective.

Just as natural ecosystems vary from one another, so too do governance systems. Governance arrangements already exist in areas encompassed by LMEs; they are not, however, presently organized around the concept of LMEs. Institutional, sociocultural, and economic factors are of substantial significance in the use and management of the natural environment; like aspects of the natural environment, they are also "site specific." In seeking to move toward a governance system which is more appropriate for ecosystem-based management, it is necessary to understand how existing institutional and cultural systems operate, their implications for the natural environment and its resources, and how needed change may emerge, given societal structures and norms.

Why is governance important? The answer to this question lies in the fact that attempts to manage resources and the environment are really about managing human behavior and encouraging patterns of conduct that are in accord with the operation of the natural world. Governance af-

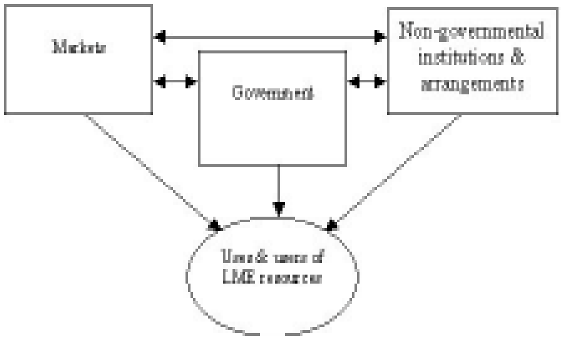

Figure 1. Governance mechanisms.

fects human uses of LME resources and may be conceived of as:

> *the formal and informal arrangements, institutions, and mores which determine how resources or an environment are utilized; how problems and opportunities are evaluated and analyzed, what behavior is deemed acceptable or forbidden, and what rules and sanctions are applied to affect the pattern of resource and environmental use.* (Juda 1999)

As suggested by this definition, the concept of governance is not equivalent to government but rather incorporates other mechanisms and institutions (both formal and informal) that serve to alter and influence human behavior in particular directions.

Reflecting the notion that governance is not the same as government, there are three key, general mechanisms of governance: markets, government, and nongovernmental institutions and arrangements. These mechanisms interact with one another in a pattern of dynamic interrelationships. Through the forces they generate, they individually and collectively impact use behaviors (Figure 1).

Markets generate prices, which structure the incentives faced by firms and households, affecting how environmental resources are utilized. Resources for which no markets exist in effect have zero prices (*e.g.*, fish in the sea), artificially deflating the cost of using such resources. That is, users do not face the full social and environmental cost of fishing, habitat destruction, waste disposal, etc., when these resources are not priced. Lower cost of use, in turn, tends to encourage excessive use and results in depleted LME fish stocks, too little essential habitat, and too much pollution.

Government regulations and requirements, whether at a local, regional, national, or international level, affect resource use. In general, government sets a wide array of rules and enforces them, recognizes and protects property rights, and produces goods and services. The rules regulate the use of environmental resources and affect the way goods and services are produced. The protective function of government is to maintain security and order by enforcing a set of rules within which people can interact peacefully with one another. These include rules against theft, fraud, and physical harm to person and property. Without protection, property rights are not secure and externalities arise. The government also produces goods and services that cannot be efficiently organized by the market. These activities and outputs include a system of jurisprudence (an example of a pure public good), fisheries and oceanographic research (quasi-public goods), fishing license and boat registries (regulatory services), guaranteed loans, and vessel buyback programs (transfer payments to users of the marine environment). These and other government activities tend to have a profound influence on how LME resources are used.

Social forces that are generated by nongovernmental institutions and arrangements also influence use patterns. These forces are shaped by norms, values, and beliefs that rationalize cognition of self and other members of society (ICGP 1993). They are dependent on the importance people attach to their community and neighborhoods, traditions, and long-standing social networks. Failure to heed the pressures from these factors may lead to sanctions that range from economic loss, to incarceration or monetary penalties, or to expulsion from the community.

The principal task of this step it to identify and describe the salient forces (markets, governmental, and nongovernmental institutions and arrangements) influencing users and theirs uses of LME resources. Practical, applied field methods will have to be developed to insure a complete inventory of such forces is compiled.

STEP 4: ASSESS THE LEVEL OF LME-RELATED ACTIVITIES

This step involves assessing the nature and extent of all LME-related activities identified in Step 2. The tasks include measuring the quantity and value[10] of the goods and services produced, the employment and income generated, use rates of LME resources, and other significant inputs used by these sectors.[11] These levels of LME-related activities should be calculated for the LME as a whole, and disaggregated by appropriate subregions and user/producer groups. Recent trends and patterns in these activities should be described in as much detail as the data allow. Historical uses should also be incorporated in order to provide a context with regard to present activities and arrangements.

STEP 5: ASSESS THE INTERACTIONS BETWEEN LME- RELATED ACTIVITIES AND LME RESOURCES

The notion that human use alters the natural environment is not new; what is relatively new is the degree to which that environment and its natural processes may be affected by human actions. If future sustainability is a matter of concern to decisionmakers, then it is necessary for them to consider the nature and character of the interactions between human activities and natural systems. That is, our monitoring and assessment framework must fully integrate the human and ecological systems related to an LME.

The need for human-ecological system integration is readily understandable due to the similarities and interaction between the two systems. This is reflected in many government and development agency policies, which advocate the use of ecological management and principles. However, the complexity with respect to the number of components and relationships makes this a difficult task. Most ecological studies have not fully integrated human activities, and most approaches have considered only one or a few sectors at a time. There is also a broad body of integrated environmental and ecological economics studies, but relatively few of these attempts have been successful (van den Bergh 1996).

Early attempts to integrate the two systems utilized input-output models to construct matrices of economic and ecological components and processes (Cumberland 1966; Daly 1968; Isard 1972; Victor 1972). Although the format of each attempt varied, the framework generally followed work by Isard (1972), depicting both ecological and economic processes. A variety of matrices also have been used by others in conjunction with generic coastal or ocean use (Couper 1983; Vallega 1992).

Input-output models have disadvantages that limit their usefulness. Input-output models are composed of a system of linear equations that are dependent on technical coefficients which symbolize the amount of an input required for each dollar of output. This assumes constant proportions with no substitution or economies or diseconomies of scale. Unfortunately, most socioeconomic and ecological systems involve component relationships which are neither static nor linear. Additional problems are related to the complexity of ecological systems. Most models of ecosystems consider the transfer of energy through the food chain. However, ecosystems resemble a web with multiple connections rather than a linear chain. Many species are generalists that change diet according to season, prey availability, or life history stage, while each prey item has a different energy transfer efficiency. Decomposers that utilize dead organisms and other unused organic matter also add another layer of complexity to the structure of food webs. In addition, there are other interactions within the system such as competitive and mutualistic relationships that are especially difficult to quantify. Given more realistic, albeit complex, modeling alternatives, input-output models may be too restrictive and simplistic for quantitative assessments of these systems. However, the input-output framework is a good foundation for our purposes, especially with respect to the inventory, organization, and exploration of the myriad relationships related to an LME.[12]

We believe it is important to organize data and information about the interplay of human activities with natural processes in such a manner as to illuminate interrelationships, with the hope that consideration of highlighted interactions will foster behavior appropriate to the goal of sustainability. The framework that follows seeks to promote understanding of relationships and to encourage the utilization of adaptive management approaches (Hennessey 1994; Lee 1993; Walters 1986) that take full advantage of experience and learning. For these purposes, this study proposes the use of interaction matrices which can serve as diagnostic tools and provide a framework for analysis and consideration of management problems and possibilities. These matrices have the capacity to inventory human uses of the LME and ecological processes that are related to the LME, to organize human activities, commodities, and processes within a framework, and to explore linkages and relationships among sectors. The interaction matrices can be modified to depict different geographic zones and different industrial or species groupings. The geographic designation of land and marine can be further broken down into economic and ecological subgroupings. Therefore, regions or ecological groups can be subdivided depending on the desired method of classification, the desired scale, and the functional relationships that are being investigated. Given the complexity and need for a comprehensive approach, interaction matrices can provide a description of the current situation and provide a basis for predicting the consequences of changes to the system. The matrices also are a useful education and communication tool for policymakers that readily shows relevant sectors and linkages.

The study of these systems relies on common descriptive characteristics such as scale, spatial and temporal distribution, linkages, thresholds, resiliency, and diversity. Ecosystems can be assessed on different levels that include the individual organism, population, community, and ecosystem. Human systems also include different levels such as the individual, household and family, community, business enterprise, use-sector, region, and society. Scale is essential to understanding both human and ecological systems. An ecosystem may range in scale from a cubic foot of soil to thousands of square miles. Human systems also range from the household to the national and global economy. Spatial and temporal factors are also important considerations for both systems. Many socioeconomic activities and ecological distributions may be seasonal, patchy, and migratory in nature. Ecosystems with greater diversity are likely to be the most stable (Caddy and Sharp 1986). This is also likely to be true of a regional economy with diverse economic sectors compared to one dependent on only one or a few commodities.

Perhaps the most important characteristics are the linkages and interdependencies between components within both systems. In both cases, a change in one element has repercussions for other elements within the sys-

			Land								Marine						
			Use Sectors				Ecological				Use Sectors				Ecological		
			Agriculture	Manufacturing	Services	Forestry	Productivity	Wildlife	Plants	Eco. Health	Aquaculture	Fishing	Transportation	Recreation	Productivity	Fish	Eco. Health
Land	Use Sectors	Agriculture															
		Manufacturing															
		Services															
		Forestry															
	Ecological	Productivity															
		Wildlife															
		Plants															
		Ecosystem Health															
Marine	Use Sectors	Aquaculture															
		Fishing															
		Transportation															
		Recreation															
	Ecological	Productivity															
		Fish															
		Ecosystem Health															

Figure 2. Interactions among LME-related activities and LME resources.

tem. Figure 2 illustrates a matrix that could be used to show the potential linkages among land-based and marine-based processes. For example, nutrients from agriculture can affect productivity in estuaries and nearshore areas. Land-based processes that affect marine-based processes potentially involve similar modules that may need to be taken into account. Figure 2 divides the processes in each region into ecological and use sectors, and provides a few examples of such processes (*e.g.*, fishing, aquaculture, marine transportation). The matrix contains cells wherein the relationships between, say, aquaculture and ecosystem health, are described in terms of the degree of compatibility and nature and extent of impact.

This and the other matrices illustrated in this report are recognized as being general and simplistic. Clearly, it is necessary that broad categories of activity be subdivided appropriately. In the case of fishing, operations are conducted in many different ways around the world and even among fishermen of a particular state. Commercial, industrial, artisanal, recreational, and subsistence fishing, and the use of different gear and techniques, while all coming under the general rubric of fishing, may have varying impacts on the biomass and the physical environment, and, accordingly must be differentially assessed.

Contained in the elements of the matrices is information on the interactions between human use activities and the LME environment and its resources. It may well be that the effects of human use are not well understood, or, fully documented, and a degree of precaution may be called for to avoid irreversible damage or long-term costs as decisions are made. Indeed, it would be useful for decisionmakers if some explicit assessment could be made as to data availability and the degree of understanding of natural processes, both of which could be factored into decisions about the application of precaution. Consideration of interplay based on experience may be suggestive of priorities for future study where data or understanding are deemed insufficient.

To a considerable extent, human use of, and effects on, the ocean/coastal natural environment have been generally described. For instance, water quality has been monitored and evaluated, wetland loss has been studied, the introduction of alien species has been noted, and coastal demographic changes have been documented. But in addition to studying changing conditions of the environment, greater consideration must be given to the consequences of those changes. The scientific community needs to highlight, in terms understandable to the lay person, the consequences of those changes for human well being, a step which goes beyond observing the relationships of the type noted in the interaction matrices.

The finding of depleted oxygen in coastal waters, for example, needs to be attached to the more practical consequences of fewer opportunities for commercial and recreational fishermen since it is such considerations which may serve to motivate public concern and appropriate actions. Accordingly, a subsidiary matrix which reflects the impact of ecosystem effects on outcomes of interest to stakeholders and the wider public is warranted. A more sophisticated version would provide for contemplation of impacts of human uses on the environment and its ecosystem resources.

A "vulnerability assessment" of specific environmental conditions is needed for coastal management (Lourens *et al.* 1997), since variance in a number of natural conditions may alter the significance of possible threats. Indeed, the process of International Maritime Organization special area designation as a result of the Protocol of 1978 of the 1973 International Convention for the Prevention of Pollution from Ships, the establishment of marine sanctuaries through the 1972 Marine Protection, Research, and Sanctuaries Act, the inclusion of the concept of essential fish habitat in the 1996 Sustainable Fisheries Act, and other special area zones such as those in the 1972 Coastal Zone Management Act 1972, indicate recognition of vulnerabilities of particular areas.

STEP 6: ASSESS THE IMPACTS OF LME-RELATED ACTIVITIES ON OTHER USERS

The lack of strong and complete property rights to all biotic and abiotic elements of an LME is the fundamental cause of externalities and threats to the sustainable use of an LME. (For more on this, see the later section on "Property Rights Entitlements and Regimes for LME Management.") The users of LME resources usually have free and open access to those resources (*e.g.*, transportation of goods, harvesting of food and industrial raw material, use for leisure activities). The resulting negative externalities tend to affect the marine ecosystem in injurious ways: overharvesting of wild species, destruction of habitat, pollution, etc. These effects are costs (harms) imposed on the environment and other users that are external to those causing the damage. The methods developed for assessing the damages to natural resources can be employed to estimate the external costs of pollution, habitat destruction, etc. We explain below (Example 1) how the monetary damages from oil spills and other transboundary marine pollution can be assessed.[13]

This step aims to assess the impacts that activities directly or indirectly have on others, especially the extent and nature of those impacts. The task is to identify and measure the benefit or harm imposed and the compatibility or incompatibility of particular uses in relation to other uses. Contained in the elements of an interaction matrix is information on the nature and extent of the interactions among the users of the LME environment and its resources. The information should characterize the interactions in terms of: 1) degree of impact, 2) compatibility, and 3) desirability.

Compatibility implies either that the uses do not interfere with one another, or, possibly, that they may serve to enhance one or both of the uses through positive externalities. Incompatibility indicates detrimental effects of one use on another or both on each other through negative externalities. The compatibility of particular uses in relation to other uses may be measured or described in terms such as compatible, conditionally compatible, or incompatible. The amount or frequency of activity (*e.g.*, high, moderate, or low) needs to be considered as it relates to compatibility. At low levels of use, uses may be compatible, while this might not be the case with high levels of an activity.

The concept of compatibility and conflict of use is basic to the fields of coastal zone management (Clark 1996) and land planning; as ocean uses increase and intensify, it has been recognized in sea or ocean use management (Vallega 1992). Some activities are mutually exclusive while others are compatible to varying degrees. Often incompatibility is demonstrated in practice as sectorally based decisions are implemented and negative externalities are generated. In the face of such experience, planners and coastal managers, accordingly, have resorted to devices such as zoning to keep apart activities which have significant incompatibilities.

Social conflict may take several forms both within specific sectors and between sectors. Allocation decisions that favor a specific sector may be economically efficient, but detrimental to a specific user group.[14] This may result in high social costs at the household or community level if alternatives are unavailable. Social costs may take the form of higher crime rates, poor diet, drug use, or the breakup of households and families. These effects include less easily quantified social considerations such as community stability, maintenance of social networks and traditions, and the distribution of benefits.

The normative characterization (*e.g.*, desirable or undesirable) of the interplay among users and uses is essential to management decisions. We note that normative characterizations are determined largely in a cultural context, a factor which once more underscores the need for a site-specific analysis of human interaction with the environment (Juda and Hennessey 2001).

How should these elements be measured, and what scale should be used? The characterizations suggested above require operationalization; that is, terms such as "compatible," "high," "substantial," and "desirable" need to be given definition. As suggested by McGlade (1995) "fuzzy logic" may be of assistance in this regard. But beyond the matter of assessing each of the four elements, the question remains as to how the data will be aggregated (Underdal 1980). Whatever device or procedure is used to organize and evaluate data, there can be no escape from a significant element of subjectivity. Moreover, values and preferences aside, the fact is that decisions will be made under conditions of imperfect knowledge and uncertainty.

STEP 7: ASSESS THE INTERACTIONS BETWEEN GOVERNANCE MECHANISMS AND RESOURCE USE

Traditionally, governance arrangements have developed along sectoral lines on an *ad hoc*, piecemeal basis. As noted in the classic report of the Stratton Commission (1969), in governmental contexts, a problem is brought to

		Governance Units										
		General Purpose Regional Intergovernmental		Single Purpose Regional Intergovernmental		Central Government		State/Provincial Governments		Local Authorities		NGOs
		International	National	International	National	United States	Canada	United States	Canada	United States	Canada	
		GOM Council	Canada Atlantic Action Plan	NAFO				Maine, Mass., N.H.	Nova Scotia, New Brunswick		Halifax Port Authority	Save Casco Bay
	Shipping/Ports											
	Fishing											
	Aquaculture											
	Industrial Siting											
	Military Uses											
	Recreation											
Use Sectors	Waste Disposal											
	Offshore/Gas											
	Mining											
	Housing											
	Agriculture											
	Mining											
	Forestry											

Figure 3. Governance-use matrix: Gulf of Maine example.

light one way or another and some department or agency is given the responsibility to address that particular problem. Over time, responsibilities for a host of activities and areas are spread among levels of government and among departments. Eventually, interactional problems become evident since decisions are being taken without due regard to externalities: the lack of coordination leads to mutual interference, inefficiencies, and uncoordinated management.

While substantial attention has been given to mapping ecosystems, the mapping of governance systems, too, deserves attention. The "mapping of LME governance" can be facilitated by filling in the cells of a matrix such as the Gulf of Maine example in Figure 3. There is no question but that the governance system affects the pattern of use of coastal/ocean areas. It is important to know who is responsible for what, and how the elements of governance, like those of ecosystems, interrelate and interact. They, too, are part of the "working environment" and must be taken into account as efforts are made to provide for effective use and protection of ecosystems.

As noted above, the concept of governance involves more than government and its dimensions include: 1) levels of governance (*e.g.*, international, national, regional, local); 2) sectoral areas (*e.g.*, fisheries, offshore mining, waste disposal, recreation); and 3) stakeholders (*e.g.*, fishermen, corporations, real estate interests, port authorities). As is the case with particular LMEs, governance arrangements have site-specific characteristics that need to be recognized and understood.

Relating to levels of governance, one issue which needs consideration is: At what level should a problem be addressed? The principle of subsidiarity suggests that authority belongs at the lowest level capable of effective action (von Moltke 1997). In fact, the European Union (EU), in its Integrated Coastal Zone Management Programme, has adopted this principle and calls for problems to be addressed in the order of local, regional, national, and EU levels (EU 1998). And, in its consideration of a needed framework for managing activities in the ocean and coastal areas of the United States, a recent report of the National Research Council, entitled "Striking a Balance: Improving Stewardship of Marine Areas," emphasizes the need for a federalist approach in which power is placed at the level appropriate to achieving desired objectives (National Academy of Sciences 1997). In this context, different levels of governance share responsibility, and coordination is provided at higher levels. The subsidiarity principle is suggestive, then, of another matrix, one which relates level of governance to issues, and ponders what is the appropriate level of governance to treat identified problems.

Governance Interactions

The manner of organization of governance arrangements can certainly affect resource use and ecosystem health (Costanza *et al.* 1992). As long noted by political scientists and office holders, bureaucratic arrangements can be instruments of delay, and introduce the element of "turf" into all decisions (Downs 1967). But, the interplay of different elements of government and governance can also play a positive role by widening perspectives and forcing consideration of externalities.

In looking to the future and considering how ecosystem-based management efforts may be improved, it is necessary to take the current governance system as a given and the point of departure. Changes will be needed in terms of institutions, mores, and values if there is to be a shift away from sectoral approaches to management of natural systems and their resources. Identification of incremental modifications would be desirable since such changes are easier to adopt and implement than more radical changes, and cumulatively may still have substantial effects.

Government Programs and Use Interactions

As the problems associated with sectoral approaches to problems become increasingly manifest, efforts are made to overcome them. One approach is through the adoption of legislation and the development of govern-

		Program		
		CZMA Section 6217	National Estuary Program	FCMA Habitat Provisions
Use Sector	Fisheries			
	Aquaculture			
	Shipping			
	Military Uses			
	Recreation			
	Industrial Siting			
	Housing			
	Agriculture			
	Forestry			
Governance	General Purpose Regional			
	Single Purpose Regional			
	Central Government			
	United States			
	Canada			
	State/Provincial Government			
	Local Authorities			
	NGOs			

Figure 4. Program-use and governance matrix.

mental programs which reach across sectoral divides, with crosscutting effects, and force consideration of externalities. The National Environmental Policy Act of 1969 provides one such legislative example (Juda 1993). The requirement for the use of an environmental impact statement, mandates attention to the subject of externalities.

In the United States, major federal, state, and local programs have the potential to impact LMEs. Such programs now encompass all of the coastal watersheds associated with areas of fisheries and marine habitat. Watershed management emerged through the passage of Section 6217 of the Coastal Zone Management Act (CZMA) Reauthorization Amendments of 1990 which mandate efforts to control nonpoint-source pollution in coastal waters. Coastal states are required to use a watershed planning and control approach to deal with sources of pollution from agriculture, forestry, urban development, marinas, recreational boating, and hydromodifications. Plans must address the preservation and restoration of wetlands and riparian areas. States are to develop enforceable management measures to treat these sources of pollution (Imperial and Hennessey 1993, 1996).

The National Estuary Program, established in 1987, complements the above efforts by providing funding to states to develop a comprehensive planning process to improve water quality and enhance living resources. There are currently 30 estuary programs in the United States, including four in the Gulf of Maine watershed (Imperial and Hennessey 1996).

Coastal habitat issues have recently come to the fore and have been addressed through the Sustainable Fisheries Act of 1996 which reauthorized and modified the Magnuson Fishery Conservation and Management Act (now the Magnuson-Stevens Fishery and Conservation and Management Act, FCMA), and required NMFS to specify "essential fish habitat" for all managed species and fisheries. Each regional fishery management council must amend its fishery management plans to: 1) identify and describe the essential fish habitat for each managed species, 2) identify the fishing- and nonfishing-related threats to the habitat, and 3) develop management and conservation alternatives for that habitat.

Exploring the legislative or programmatic mandates relevant to LME management is worthwhile for several reasons. First, it is important to understand the program interactions with different LME uses and interaction with existing governance structures. Second, management decisionmakers need to understand how they may alter traditional agency activities and how they may serve to contribute to more holistic management approaches. Figure 4 indicates selected programmatic initiatives in the United States that merit specific attention in this context. Many other programmatic examples are available which also merit evaluation.

STEP 8: ASSESS THE SOCIOECONOMIC IMPORTANCE OF LME-RELATED ACTIVITIES AND ECONOMIC AND SOCIOCULTURAL VALUE OF KEY USES AND LME RESOURCES

The coastal and marine natural resources of an LME are capital assets -- in effect representing wealth embodied in its marine natural resources. Capital assets -- natural or otherwise -- can provide valuable services ("interest") over time if maintained, much like savings in a bank provides a flow of interest income.

Underlying much of environmental economics is the notion of resource valuation (*i.e.*, valuing nature's services). Resource valuation involves the use of concepts and methods to estimate the economic value the public holds for natural resource services.[15] These services may be direct or indirect; and they may or may not be bought and sold in the marketplace.

Direct services include onsite use of marine parks, beaches, commercial fishing, exploitation of marine minerals, or harvesting of fish, shellfish, or wood from mangroves. Indirect services occur offsite, for example, when fish "produced" by a mangrove are harvested many miles away. Some natural resources services are exchanged in organized markets, such as commercial fisheries, oil and other minerals, some coastal property, or tourism. However, a central feature of many, if not most, marine resource issues is that the services provided are not traded on markets. The services provided, as for example, by mangroves, corals, and sea grasses, water quality, recreation, scenic amenities and biodiversity, are not bought and sold on markets -- and as a result, often are given inadequate attention in public policy.

Four types of value are associated with resource services. First, *use value* is the benefit received from onsite or physical use, such as harvesting of fish, exploitation of oil, or beach use. Second, *passive use value* is the enjoyment one gets from a resource above and beyond any direct use.[16] Passive use losses may arise if individuals feel worse off when they learn of the loss of an endangered species, closure of beaches, or other adverse impacts on other natural resources -- even if they do not use these resources themselves. People might be willing to pay to prevent such losses, much as they might pay to preserve, say, an historically or culturally significant building or site, even if they never actually visit it. Third, *total value* is the sum of use and passive use value. Fourth, individuals also may have an *option value* when supply (*e.g.*, threat of extinction, the outcome of a policy) or demand is uncertain. Option value may be thought of as what you would pay to keep the opportunity open to later use a site or resource.

Resource valuation usually is not an end in itself, except in the case of commodities such as oil or other minerals, or of fish, where the government might lease public resources to private businesses.[17] Instead, estimates of the value of particular resource services normally are more useful as contributions to policy for improving resource management. Most policy decisions involve specific proposals affecting resources and their services "at the margin"; hence, resource valuation most often will involve assessments of the marginal value of resource services rather than the aggregate value.

Social and cultural factors correspond to, and reinforce, the need for economic valuation, but their focus and the use of sociocultural analysis are also quite different. Indicators such as income, employment, and economic sector performance are elements of both types of investigation. However, sociocultural analysis takes a step away from strict enumeration of these elements and focuses on people's knowledge and views (norms and values) about their work, and how this affects their perceptions and actions toward LME resources (Brainerd *et al.* 1996). Although this is not easily measured on a monetary scale, these factors are considered significant by those involved in resource use. Sociocultural analysis has the capacity to contribute to management by considering the values of cultural and social elements of the community, and the potential costs associated with social and economic disruption and dislocation.

Social and cultural factors are closely linked to governance, users, and uses of LME resources. One way to account for these linkages is to view human action within the context of natural resource communities (NRCs) (Dyer *et al.* 1992). The interface between a regional system of extractive NRCs, their service flows, and the associated LME is here defined as a natural resource region (NRR).[18] Dyer *et al.* (1992) define NRCs as populations whose sustainability depends upon the utilization of renewable natural resources. By broadening the definition to include those dependent on nonrenewable aspects of the marine environment as well, they and their aggregations as NRRs represent the LME-dependent communities within a coastal region.

The NRR includes social, cultural, human, economic, and biophysical capital and their interactions within networks of LME-dependent communities (Dyer and Poggie 1998). These forms of capital are defined as follows:

- *Social capital* is the interactive network of humans that occurs within and between natural resource communities. Social capital is key to the flow of other forms of capital, as well as central to the dynamics of governance and resource utilization.
- *Cultural capital* is the behaviors, values, knowledge, and culturally transmitted behavior and ideas of a population, applied to the transformation and utilization of natural resources.
- *Human capital* is the human population and the knowledge and skills it acquires from formal and informal education associated with the occupational roles of natural resource extraction.
- *Manufactured capital* is long-lasting manufactured goods (*e.g.*, buildings, machines, tools, fishing vessels and gear) that enhance the ability to produce other goods and services.
- *Biophysical capital*, as explained above, is used to denote those natural resources of an LME that directly or indirectly generate flows of goods and services used by humans. The value of these natural resources is derived from the dynamic between human action and the natural environment. These include potential resources, identified but not actively utilized in extractive processes, or those having primary value in passive recreational activities (*e.g.*, the whale as resource to the whale watching industry).

Fishing is a good example of the interactions of some of these forms of capital. A fishing boat out at sea is a production-extraction unit of the NRR, relying directly on the productivity of the fish resources of the LME (the NRR biophysical asset). The fishing boat is thus an extension of the NRC from which it came, carrying with it social, cultural, human, and manufactured capital in its hunt for fish resources.

The conceptualization of capital interactions within an NRR network lends understanding to the occupational valuation placed on "way of life." For example, Doeringer *et al.* (1986) show how kinship support systems -- a form of social capital in our formulation -- allow fishermen to maintain labor linkages to the fishing industry in defiance of seemingly debilitating economic conditions, usually associated with declines in volume and value of fish catch, as well as severe management restrictions on fishing.

In the interface with LMEs, primary units of human-environment interaction -- individuals, families, households or communities -- are to be viewed as interconnected within regional networks held together by shared values and forms of capital. The NRC is a nodal form of human organizational structures and of regional and capital interactions, and provides for points of spatial reference by which to study the LME-NRR dynamic.

Networks of NRCs within NRRs act as conduits through which total capital is exchanged, shared, and transformed by human action. For example, we can consider the NRC[19] as a regional contributor to whatever commerce is stimulated by LME-related activities, and as a means of providing sustainable support to LME-related households and families as they contribute products and services to the region and nation in which they are embedded. While only a subset of the NRC interact directly with the marine environment and its resources (*e.g.*, fishermen, shipping vessel operators), these individuals are nevertheless connected to more differentiated communities and towns, contributing to the economic and food security of those communities and towns, and buffering coastal development in a way that contributes to social and economic diversity.

Social impact assessment variables point to measurable change in the human population, communities, and social relationships resulting from policy change (ICGP 1993). The Interorganizational Committee on Guidelines and Principles (ICGP) identified a list of social variables under the general headings of: 1) population characteristics, 2) community and institutional structures, 3) political and social resources, 4) individual, household, and family changes, and 5) community resources. Definitions of each heading considered by the ICGP are as follows:

- *Population characteristics* mean present population and expected change, ethnic and racial diversity, and influx and outflows of temporary residents as well as the arrival of seasonal or leisure residents.
- *Community and institutional structures* mean the size, structure, and level of organization of local government to include linkages to the larger political systems. They also include historical and present patterns of employment and industrial diversification, the size and level of activity of voluntary organizations and interest groups, and how these institutions relate to each other.
- *Political and social resources* refer to the distribution of power and authority, the identification of interested and affected parties, and the leadership capability and capacity within the community or region.
- *Individual, household, and family changes* refer to factors which influence the daily life of the individuals, households, and families, including attitudes, perceptions, family and household characteristics, and social networks. These changes range from attitudes toward the policy to an alteration in family and household relations and social networks to perceptions of risk, health, and safety.
- *Community resources* include patterns of natural resource and land use, notably, the availability of housing and of community services for health, police and fire protection, and sanitation. Key to the continuity and survival of human communities are their historical and archaeological cultural resources. Under this collection of variables, we also consider possible changes for indigenous, ethnic, and religious subcultures.

Sociocultural elements may also be assessed by performance indicators related to equity issues such as the distribution of benefits among stakeholders, the nature of access to LME resources, and the reliance of communities on LME resources (Patricia Clay, NMFS, per. comm., 1998). The distribution of income is a measure of equity within NRCs and between NRCs and wider society. Benefits distribution can take other forms such as the pattern of fish consumption and distribution, and allocation of, and/or access to, resources. The nature of access to LME resources considers property rights as well as the local involvement in resource management. Community reliance on LME resources may take several forms, including employment and other economic factors, food security, and cultural factors. The relative importance of different social variables will vary depending on the specific NRC and its relationship to the resource in question.
Dyer and Griffith (1996) isolated five variables that help identify fishing community dependence on an LME. It will become obvious that the five variables overlap somewhat; thus, they must be considered together. These are:

- Relative isolation or integration of LME resource users into alternative economic sectors. To what extent have users (*e.g.*, fishermen, processors) segmented themselves from other parts of the local political economy or other fisheries?
- User types and strategies of users within a port of access to LME resources. What impact does the mix of types (*e.g.*, fixed fishing gear -- weirs, fish corrals -- versus mobile fishing gear) across ports and states have on the long-term sustainability of LME resource stocks?
- Degree of regional specialization. To what extent have users from related areas and use-sectors moved into the region? Clearly, those users who would have difficulty moving into alternative use-sectors are more dependent on LME resources than those who have histories of moving among several sectors in an opportunistic fashion.
- Percentage of population involved in LME resource-related industries. Those communities where between 5 and 10% of the population are directly employed in LME resource-related industries are more dependent on the LME than those where fewer than 5% are so employed.
- Competition and conflict within the port, between different components of use sectors. Competition between smaller scale and industrial scale users can create conflict between users within the same port -- as well as between different actors in a use-sector (such as boat owners, captains, and processors). Dependence may have a strong perceptual dimension, with users perceiving the resources they are extracting to be scarce and that one user group's gain (*e.g.*, industrial trawling, purse seining) is another user group's loss (*e.g.*, gill netting).

These five variables can be adapted and broadened to cover the full range of LME-related activities. A fundamental assumption of the NRR model is that there is some degree of reliance on the *natural resources* (*i.e.*, biophysical capital) of an LME. In an LME-linked NRC, biophysical capital reliance manifests itself as learned social behaviors of LME-related activities. The combined social, cultural, and economic interactions arise from the conditions that increase or decrease access to the LME and its biophysical capital. Furthermore, dependence on natural resources limits the occupational roles of community members, and can intensify cultural assimilation for those immigrating into an NRC.

Disruption of LMEs is occurring more frequently as NRRs are stressed by human factors that push resources beyond their ability to renew themselves and permanently degrade physical structures such as bottom topography. Such resource degradation patterns in an NRR can be found in conditions of severe poverty, overpopulation, management which inadequately takes into account local or site-specific conditions, the practice of destructive extraction techniques (*e.g.*, blast fishing in Philippine reef systems), or the development of overcapacity in a fishery [*e.g.*, the groundfish fisheries of New England (Dyer and Griffith 1996)]. In an idealized condition, an effective state of environmental awareness is generated among NRC residents and NRR networks that allows for sustainable utilization of biophysical capital in an LME. Less idealized conditions -- most real world ecosystems and their human actors -- require some form of management appropriate to the political ecology and cultural and environmental history of the region in question. Thus, although a generic LME/NRR management framework for the Bay of Bengal and the Gulf of Maine may be conceptually similar, operationalizing the model cannot proceed without considering site-specific human-environmental dynamics.

The interdependence of economic, social, cultural, and governance elements is readily apparent. They overlap, complement, and conflict with one another in different situations. Their relative importance and tradeoffs between different sociocultural and economic values will depend on the interplay of the community, LME resources, and larger society.

STEP 9: IDENTIFY THE PUBLIC'S PRIORITIES AND WILLINGNESS TO MAKE TRADEOFFS TO PROTECT AND RESTORE KEY NATURAL RESOURCES

An implicit assumption underlying social science research in this document is that what people want -- that is, their preferences -- matters in public policy decisions concerning LMEs. In economies where markets work reasonably well, market prices are a good indicator of the marginal value individuals attach to incremental units of a good or service. However, widespread market failure in LMEs makes the connection between market prices and preferences tenuous or nonexistent for many major problems. An important issue in the absence of reliable market data, then, is how to obtain useful information on public priorities and preferences that can be used in decisionmaking for LME management.

One possibility is greater use of opinion polls and general attitude surveys on LME resource issues. However, most members of the public, when asked, will identify "the environment" as an important concern and will indicate that, at an abstract level, we should "do more" for the environment. Such general attitudes, however, are not very informative of actual values people hold for resources and their services. This is because value is indicated by what one is willing to give up to keep or get more of something, and general opinion polls do not confront respondents with the costs of their decisions. It is not surprising, for example, that when asked to assign priorities to management actions to improve coastal environments, survey respondents will recommend actions that impose little or no direct costs on themselves, but are less favorably disposed to measures that would require them to bear costs (Opaluch *et al.* 1999). Choices, by definition, imply tradeoffs and values. Real policy actions are not free, and opinion polls and general surveys that do not require respondents to recognize costs of actions are unlikely to provide useful information to LME decisionmakers about public preferences. For this purpose, more structured surveys are needed that specifically ask respondents to make tradeoffs.

Stated preference methods, such as contingent choice and contingent valuation, are potentially valuable frameworks for assessing public priorities, the willingness of the public to make tradeoffs, and the public's economic values. These methods involve the use of carefully developed surveys that are then administered to a random sample of the population of interest. Stated preference methods are one way to assess resource priorities for public goods and to potentially estimate passive use values for LME resources.

Ethnographic fieldwork can provide in-depth assessment of values and the degree to which they are strongly or weakly held. This type of research is more labor intensive, but can be especially important when dealing with site-specific decisions or where a decision must be made that may go against particular local values and thus require public education or remediation.

Hence, the development of socioeconomic and governance elements for LMEs may well draw heavily upon advances in the use of survey and other methods (*e.g.*, ethnographic interviews, focus groups, panels) for obtaining information on public preferences for resource management decisions, information that otherwise may be unavailable for decisionmakers to consider.

STEP 10: ASSESS THE COST OF OPTIONS TO PROTECT OR RESTORE KEY RESOURCES

Typically, many alternatives will be available for addressing any problem within an LME, and each can be accomplished at different scales. Consider nutrients, for example, a serious coastal water quality issue in many areas. This issue can be addressed in many ways, including: expanding or upgrading public wastewater treatment facilities, encouraging measures to reduce application of fertilizers in agriculture, using buffers for agricultural lands along water bodies to reduce runoff, introducing measures to control runoff of animal wastes from farms and roads into coastal waters, and investing in sewage lines to avoid use of septic systems for household residences. Pollution trading between sources (*e.g.*, wastewater facilities and farmers) also is possible.

Each of the above alternatives is technically feasible and will be effective in varying degrees. However, the investment and recurring costs of the alternatives will vary substantially. Selecting among them is not straightforward and requires information not only on costs over time, but also on their relative efficiency in reducing nutrient discharges -- that is, cost effectiveness. Cost effectiveness involves selecting the alternative(s) with lowest cost per unit treated. At one level, this can be viewed as a technical, engineering-economic problem. However, effective policy requires implementation, and thus it is critical that management mechanisms and institutional structures be in place that will allow alternatives to be considered with their cost-effectiveness used as an important criterion.

STEP 11: COMPARE THE BENEFITS WITH THE COSTS OF PROTECTION AND RESTORATION OPTIONS

As noted often, many technically feasible alternatives are available to address resource management problems. Cost effectiveness, outlined above, ensures activities will be done at least cost. However, cost effectiveness presumes that an activity is a worthwhile investment of society's scarce resources. In fact, there are many good potential societal investments that compete implicitly or explicitly for limited public resources. An important issue concerns whether a particular proposal is a good investment in the sense that the resulting benefits justify the costs (*i.e.*, what society must give up in other goods and services to realize the benefits).

Increasingly, international agencies and others require benefit-cost analysis be conducted to help decide whether, and to what extent, to undertake projects. In carrying out such analyses, agencies are concerned about considering not only narrow, commercial transactions, but environmental benefits and costs as well.

Benefit-cost analysis can be a valuable decision tool, for several reasons. First, it puts public investments on the same footing as private investments in that they must meet the same standard: the costs of a policy, program, or activity should be justified by the resulting benefits. Further, a well-done benefit-cost analysis makes all calculations and assumptions explicit, and by that, transparent for all stakeholders. This may help add legitimacy to a process, an important consideration in many situations.

Of course, benefit-cost analysis raises several issues, as well. One is whether all-important benefits and costs can be quantified. Many advances have been made in natural resource valuation, and the opportunities and limitations of resource valuation are becoming increasingly well understood. But it is also true that many difficulties remain, and data problems are always an issue, especially in developing countries. Furthermore, equity -- the distribution of the benefits and costs of a proposed policy action -- is an important issue influencing whether or not actions will be taken and the form they will take (*e.g.*, Zeckhauser 1981). However, distributional effects can always be included in an analysis. For example, different groups and/or regions can be assigned different weights, provided one knows the relative importance (weight) assigned to them; indeed evaluation of such issues is a strength of analytical methods commonly used in economics. Beyond this, even the best benefit-cost analysis is not a substitute for good policymaking; decisionmakers as a matter of course take into consideration the distribution of benefits and costs when deciding whether and how to implement a program or action. Looked at this way, to the extent good social science data are available on distributions and types of impacts (*e.g.*, through social and economic impact analyses based on the framework established here), the equity problem in practice is not as serious an issue for benefit-cost analysis as some may believe.

STEP 12: IDENTIFY FINANCING ALTERNATIVES FOR THE PREFERRED OPTIONS FOR PROTECTING/RESTORING KEY LME RESOURCES

The results of cost-effectiveness analysis, benefit-cost analysis, and social impact analysis can help select the preferred option from among several technically feasible alternatives. To implement the preferred option, however, sustainable financing must be available. Financing is often viewed as "merely" a distributional issue, but, in fact, sustainable financing has become an increasingly important issue not just to ensure that revenues cover costs, but also as a way to affect incentives that encourage favorable behavior and discourage unfavorable actions.

Many alternative financing approaches are available, depending upon the issue and area. Broad principles to be employed may include the user- or beneficiary-pays and polluter-pays principles. The user- or beneficiary-pays principle has strong appeal on fairness grounds in many if not most cases, but is less useful and may need modification for cases where a program is provided specifically to achieve an equity objective. The polluter-pays principle also has a strong basis in fairness, but additionally -- when effective -- provides incentives for operators to avoid pollution by internalizing costs. The polluter-pays principle also works to place at least some of the costs of such actions on the consumer of the polluting good. In sum, the polluter-pays principle ensures that operators and consumers face the full social costs of producing and using the good involved.

The user- or beneficiary-pays principle is especially challenging to invoke in practice for resources that have widely dispersed and significant nonuse benefits. For example, preservation of unique marine parks (*e.g.*, the Great Barrier Reef) or marine mammals (*e.g.*, sea manatees or whales) likely provide major benefits far beyond those who use these resources and may extend to the public nationally and internationally. A user pays or beneficiary pays principle obviously is difficult to invoke on nonusers in such cases. This suggests that for such unique, widely appreciated resources with strong nonuse value, international donations must play a critical role rather than reliance on access fees.[20]

Criteria for selecting the type of financing might include adequacy of revenues, transactions costs, distributional effects, political feasibility, effects on behavior, and conflicts with other objectives. Examples of the last criterion include actions by some countries to: 1) provide subsidies to fisheries while at the same time trying to limit catch, 2) impose taxes on imports of construction materials while trying to protect corals (which are mined in some countries as a source of construction materials), or 3) encourage agriculture while at the same time attempting to protect or restore water quality.

APPLICATIONS OF THE MONITORING AND ASSESSMENT FRAMEWORK[21]

EXAMPLE 1: ASSESSING MONETARY DAMAGES FROM OIL SPILLS AND OTHER TRANSBOUNDARY MARINE POLLUTION[22]

Oil spills and other transboundary pollution in an LME are important concerns due both to: 1) the risk of accidents, and (2) the many important resources, activities, and ecosystems that are vulnerable to injury from pollution. Managing the risk of spills raises two interrelated issues. One is the appropriate scale of measures to prevent and control spills. A second issue -- the focus of this section -- has to do with the institutional framework, methods, and standards that might be used to assess the monetary value of natural-resource-related damages when spills occur.

When oil spills or other pollution incidents occur, it is necessary to decide whether to assess damages, which losses can be compensated for, the best method(s) to be used to assess damages, and the institutional framework within which such assessments take place. This is where natural resource damage assessment (NRDA) becomes important.

NRDA is a method that applies legal, scientific, and economic principles to assess monetary damages caused to natural resources by pollution and other human actions. NRDA provides measures for sustainable financing in the form of compensating for injuries and lost natural resource services due, for example, to transboundary pollution. NRDA, as applied in the United States, consists of a formalized process and an institutional regime within which allowable losses from covered incidents can be quantified and collection of claims can be undertaken and enforced. NRDA is a relatively new area of research, and the concepts and approaches being used have been evolving relatively quickly.

The intended outcome of an NRDA is a claim against a responsible party. The scope of items included by governments as damages has grown, as has the size of settlements. As a result, NRDAs necessarily involve tensions and adversarial debate between government, which is responsible for implementing and enforcing NRDAs, and industry, which must respond to and pay legitimate claims. Critics of NRDA question the reliability and, in some cases, the appropriateness of NRDA assessments. Supporters of NRDA make comparisons with the many empirical challenges and imprecisions addressed as a matter of course when assessing damages such as the value of intellectual property rights, antitrust issues, and losses from personal injury in work-related accidents.

In spite of controversies surrounding NRDA throughout its evolution, establishing liability for damages due to oil and hazardous substance marine pollution is of increasing interest. This interest stems from its important role as a practical method based on economic incentives (*i.e.*, the polluter-pays principle) in environmental policy. Improvements in the understanding of the scientific, economic, and legal concepts used in NRDA facilitate its implementation. NRDA is of interest to many parties, because:

- Littoral states must decide the adequacy of NRDA measures for compensation for losses due to spills. Particularly important are losses to publicly controlled or managed resources, such as open-sea fisheries, wildlife, and ecosystems.
- Owners and operators of mariculture, fishing, tourism, and other coastal businesses at risk from spills are concerned about recovering lost earnings.
- Industry is concerned about the legitimacy of claims against them for losses, about transactions costs for legal and expert reports and proceedings, and about avoiding double counting of losses (paying twice -- or

more -- for the same loss). They are especially troubled about the potential for damage claims based on speculative losses or losses based on unreliable or "theoretical" methods. Of particular worry is the potential for major claims, if damages are expanded to include nonmarket and other, hard-to-quantify losses, especially passive use value[23], as they have in the United States, for example (*e.g.*, USDOC/NOAA 1993; Hanemann 1994).

- Insurance companies are concerned about the nature and size of claims they will face for response, cleanup, assessment, and damages. In many respects, their concerns are similar to those of industry.

Interest in NRDA by public bodies stems from the promise of NRDA in helping to achieve two important environmental policy goals. First, it provides an organized framework for pursuing compensation for the many costs that can result when natural resources, coastal activities, and property are adversely affected by oil and other marine pollution. Many types of pollution damages currently are not compensated for, and as a result, these costs are borne by coastal states. Second, polluter liability under NRDA requires the responsible party to bear the costs of marine pollution (*i.e.*, polluter-pays principle). Liability provides built-in incentives for polluters to avoid incidents, and by that, plays to their self interest as a matter of course (*e.g.*, Opaluch and Grigalunas 1984; Grigalunas and Opaluch 1988). This is consistent with worldwide trends toward the use of market mechanisms to address environmental issues as recommended, for example, in Agenda 21 of the 1992 Rio Convention. At the same time damage assessment raises several issues, including the:

- Nature of liability
- Scope of incidents covered
- Scope of impacts ("injuries") for which damages can be assessed
- Allowable damages
- Allowable methods for estimating damages
- Standards to apply in weighing the results of such methods
- Means for limiting transactions costs

A recent survey paper by Grigalunas *et al.* (1998) presents concepts and issues in NRDAs and summarizes several case studies to illustrate different types of losses and efforts to estimate these losses. Any attempt to develop an LME-wide approach for NRDA in an LME would need to address these (and other) issues in great detail.

EXAMPLE 2: ECONOMICS, SCIENCE, AND POLICY IN ESTUARY MANAGEMENT

This example is based on a series of economic studies for the Peconic (New York) Estuary System as part of the National Estuary Program in the United States. The estuary and surrounding watershed are very attractive and used intensively, particularly during the peak summer season. The estuary itself has generally good water quality. However, pollution exists and threatens some uses; for example, extensive shellfishing grounds have been lost due to pollution. Also, development has caused the loss of important habitats/ecosystems, and threatens the scenic amenities of the area. Thus, many market- and nonmarket-valued resource services are at issue in this case -- as is true in most other coastal and marine cases.

By close work among program mangers, scientists, and citizen advisory groups, a series of studies have been carried out, or are ongoing (Grigalunas and Diamantides 1996; Opaluch *et al.* 1999), to:

- Estimate the economic importance of estuary-related activities
- Identify coastal users, their activities, and concerns, using a carefully prepared survey
- Identify the public's priorities and willingness to make tradeoffs to protect and restore key natural resources using a second carefully developed survey
- Estimate the economic value (benefits) of key recreational uses and coastal amenities
- Assess wetland productivity and habitat services
- Assess the cost of options to preserve or restore key resources
- Compare the benefits with the costs of preservation and restoration options
- Help select financing alternatives for the *preferred* options for preserving/restoring key natural resources

Preliminary results indicate that estuarine-related activities play a major role in the livelihood of several thousand residents who own, operate, or are employed by more than 1,000 businesses in some 24 identified sectors. These sectors engage in, or support, such activities as fisheries, marine transportation, and particularly tourism and recreation.

It was also found that more than 100,000 people annually engage in millions of days of recreational activities, and preliminary estimates of the value of key recreational activities range from $8.59 per trip for beach use to $38 for a recreational fishing trip. The total annual value across the three recreation activities studied to date is more than $50 million per year, again based on preliminary results. These are economic benefits to users above the costs they incur (*i.e.*, "unpaid-for benefits").

An interesting and potentially very important part of this work is how users of coastal areas are affected by water quality. A link between objective water quality measures and subjective measures of quality, as perceived by recreationists, has been estimated. This allows joint work with scientists who estimate the changes in various measures of water quality due to policies being considered to control pollution. Given the cost of such control measures and of preservation and protection measures, the benefits will be able to be compared with the costs of these policies.

Preliminary survey results also suggest that the public holds strong values for preserving key area natural resources. These results are supported by preliminary results from a separate, housing value study. This study suggests that residents are willing to pay more for property located near coastal waters, parks, and open space.

A wetland productivity study of the value of eelgrass, intertidal salt marsh and mud flats yielded preliminary results for the marginal value (asset value) ranging from $12,700 per acre for eel grass to $4,400 per acre for mud flats. These estimates include the estimated market value of fish and shellfish "produced" by, and harvested from, these ecosystems, and the value of waterfowl hunted and birds viewed. The value estimates include only food web effects and habitat values, and hence are conservative in that such services as shoreline erosion protection and storm protection services provided by salt marshes, for example, were not considered. The estimates of economic value (benefits) of these three types of wetlands will be used in benefit-cost studies of management proposals for restoration of habitats.

As noted, ongoing work will examine the cost of options for preserving and restoring resources, compare the benefits with the costs for different options, and help select financing alternatives for the preferred options. Again, an important aspect of this work is the willingness and commitment among the program managers and participants to work together to link socioeconomics, natural resource science, and policy.

EXAMPLE 3: SUSTAINABLE FINANCING FOR POLLUTION PREVENTION AND CONTROL[24]

Environmental programs to prevent or control pollution may require major investments. Benefit-cost analyses of public projects often do not consider how projects will be financed, nor do they usually present the implications of different financing and institutional alternatives.[25] Yet, to be successfully implemented and maintained, attention must be given to financing, to important institutional measures, and to the distribution of benefits and costs in general. Financing in particular is important for several obvious and perhaps less apparent reasons:

- Inadequate funding will limit the implementation of effective pollution prevention measures.
- Mechanisms used to finance projects (*e.g.*, user fees versus general revenues, different formulae for cost-sharing) have important distributional effects which often are a major factor influencing how -- and even whether -- a policy is adopted (Zeckhauser 1981).
- Financing options can affect users' incentives, thus influencing behavior and the resulting size of benefits.
- Financing options may differ with respect to ease of administration (transactions costs), political feasibility, stability of revenues, or in other important respects, all of which influence whether and how measures are adopted, as well as their effectiveness.

For all of these reasons, sustainable financing of pollution management actions is a significant issue for LMEs.

Sustainable financing mechanisms include: 1) user fees and related, cooperative mechanisms, when available and appropriate (and allowed under the United Nations Convention on the Law of the Sea); 2) NRDA; 3) potentially attractive investments in private-public partnerships, including potential investments under the Buy-Transfer-Operate and related public-private programs; 4) international donors; and 5) international trusts.

User fees and, more generally, mechanisms employing incentive-based approaches, have considerable appeal. They are based on the user-pays and polluter-pays principles, and reflect commonly shared notions of fairness. They also can work to harness the power of the market to sustain pollution prevention and control measures, in an efficient manner, in effect using private interest to serve the broader public interest (Schultz 1975; Grigalunas and Opaluch 1988).

To be effective, however, markets must work, or appropriate institutional arrangements must exist to allow markets to function. Major problems may arise in devising mechanisms to prevent and control pollution, because of market failure and "institutional failure." For example, many navigational aids and safety measures are public goods; other safety measures (*e.g.*, use of pilots and vessel transit systems) may create important external benefits not captured in the market; and in still other cases, institutional problems prevent effective reliance on user fees. As a result, developing methods to promote greater reliance on user fees for sustainable financing of antipollution measures often is not a straightforward exercise.

Many measures are available to prevent or control sea-based transboundary pollution:

- Best management practices to control agricultural wastes
- Sewerage treatment facilities in critical areas
- Compulsory pilotage
- Salvage operation
- Vessel traffic information service (VTIS)
- Navigational aids/services
- Electronic charts ("marine electronic highway")
- Shore reception facilities
- Contingency planning and oil spill response

These measures are, or can be, taken by private parties (*e.g.*, vessel and cargo salvage, shore reception facilities, sewerage facilities), governments (*e.g.*, navigational aids), or a combination of the two (*e.g.*, VTIS), to prevent or control spills or promote port efficiency. The above list is not exhaustive and omits some measures (*e.g.*, efforts for further cooperation and training among the coast guards of littoral states).

Mechanisms currently used to finance programs in most areas rely primarily on national sources, but also include user fees, international donations, and other support through international organizations, notably the International Maritime Organization, in the case of pollution from shipping. Liability used to compensate for response, control, and cleanup of spills, as well as for payment for certain economic losses and for restoration actions, is another funding source for managing pollution by restoring the environment. Individual companies also spend considerable (but unknown) amounts on pollution prevention and response training, as well as on purchase of equipment to prevent and control spills and avoid other sources of marine pollution.

Financing *mechanisms* to prevent transboundary pollution include:

- Penalties, fines, and taxes
- Subsidies
- User fees
- Port dues
- Revolving funds
- Public-private partnerships
- Privatization
- NRDA

Briefly, the revolving fund is a source of money that the littoral countries can draw upon (*i.e.*, borrow from) to finance response and cleanup activities in the event of a spill. NRDA is a process to: 1) identify categories of costs and losses due to oil spills for which compensation would be paid, and 2) provide appropriate methods and standards to be used to quantify losses in monetary terms.[26] Port dues are self explanatory. Public-private partnerships involve various cooperative approaches the private and public sectors might take to jointly address pollution from shipping or other pollution.

Measures can be evaluated using several criteria or factors, such as administrative efficiency, effectiveness as a regionwide instrument, revenue-generating potential, behavioral change potential, fairness and equity among users and beneficiaries, and political acceptability among the littoral states.

PROPERTY RIGHTS ENTITLEMENTS AND REGIMES FOR LME MANAGEMENT

Marine resource management is fragmented in many coastal states by policies that pay little attention to environmental, institutional, social, and economic scale, or to interactions and tradeoffs. In fisheries in particular, the single-species (stock) approach to management does not adequately account for ecological interactions (Larkin 1996) or for what factors influence harvesting and investment decisions (Hanna 1998). Recent research on environmental management is attempting to integrate natural and human systems in order to sustain benefits that humans derive from fishery and other natural resources (Costanza *et al.* 1997; Larkin 1996; McGlade 1989; Sherman *et al.* 1996).

This section investigates the implications of ecology, technology, and what are known as transactions costs for the structure of property rights entitlements in LMEs; and it comments on the characteristics of concordant property rights regimes that structure human behavior vis-à-vìs an LME. This line of inquiry has received serious attention recently in the ecological economics literature (Costanza and Folke 1996; Hanna 1998; Hanna *et al.* 1996), but it was introduced mid-century by economist H. Scott Gordon who explained why the absence of property rights to fishing "grounds" caused fishery resources to be overfished and their value dissipated through investment in too much fishing capital. Although the subsequent literature developed around disaggregated fish stocks, by "grounds" Gordon (1954) actually referred to "shallow continental shelves" where upwelling waters support "marine-food chains" of resident demersal and migratory pelagic species. He emphasized that "it is necessary to treat the [collective] resource of the entire geographic region as one." In another, later seminal work, Steven N. Cheung (1970) asked: "What resource in marine fisheries is non-exclusive [accessible with little or no effective restriction] -- the ocean bed, the water, or the fish? The answer is that any productive resource is multi-dimensional, and the term 'fishing ground' is chosen to include all of them."

Related anthropological literature on common property regimes (*e.g.*, McCay and Acheson 1987) and territorial use rights fisheries, or "TURFs" [*e.g.*, Pollnac (1984)] describes the frequency of geographically based folk management [*e.g.*, McGoodwin (1990)] and the applicability of such approaches to modern management [*e.g.*, Cordell (1984), Dyer and McGoodwin (1994)], as well as discusses the implications and benefits of property held under group versus individual tenure [*e.g.*, Hunt (1997)].

Although shrouded by confusion, bias, and emotion, property rights and their institutional context are the foundation of economic activity and are therefore essential to sustainable management of the goods and services supplied by marine ecosystems. LME management will be improved by scientific research, but we risk repeating the mistakes of single-species fishery management in particular if humans continue to be regarded as exogenous agents of regulatory regimes. Ecosystem management also requires structures of property rights that reflect environmental and economic principles, and it requires governance institutions that reflect the goals and values of a society.

THE STRUCTURE OF PROPERTY RIGHTS ENTITLEMENTS IN AN LME

Property Rights

In his book on the evolution of property rights in natural resource sectors, Gary Libecap explained that "[b]y defining the parameters for the use of scarce resources and assigning the associated rewards and costs, the prevailing system of property rights establishes incentives and time horizons for investment, production and exchange" (Libecap 1989). Different property rights structures lead to different rewards (or penalties) and thereby create incentives that influence how people use the natural environment. For clarity's sake, we adopt the definitions of property and property rights used by Bromley (1992):

> *Property is a benefit (or income) stream, and a property right is a claim to the benefit stream that some higher body -- usually a government -- will agree to protect through the assignment of duty to others who may covet, or somehow interfere with, the benefit stream.*

It is useful to identify five dimensions of property rights which affect the size and duration of benefits that owners can expect to receive from economic resources: 1) entitlements, 2) divisibility, 3) exclusion, 4) right to transfer entitlements, and 5) enforceability.

Entitlements are the ways that owners -- government, commons, or private entities -- are allowed to use and derive benefits from assets, including attributes of the environment. For example, the U.S. federal and state governments own marine resources on behalf of the public. In contrast, fishermen own vessels and fishing permits, energy companies own leases to outer continental shelf lands above pools of petroleum and natural gas, and shipping companies own access rights to shipping lanes, to name a few. Virtually all entitlements are attenuated, however. Thus, it is against the law for fishermen to use their vessels to smuggle contraband into the United States, and their fishing activities tend to be regulated by a host of gear restrictions and time and area closures.

Divisibility involves the richness of entitlements to complex resources with multiple attributes. The scope of this property right is suggested in a quote from Alchian (1977) who wrote about partitioning land: "[A]t the same time several people may each possess some portion of the rights to use the land. A may possess the right to grow wheat on it. B may possess the right to walk across it. C may possess the right to dump ashes and smoke on it. D may possess the right to fly an airplane over it. E may have the right to subject it to vibrations consequent to the use of some neighboring equipment." We can obviously substitute fishing ground or a marine environment such as Georges Bank or the Gulf of Maine in the Northeast U.S. Shelf Ecosystem for "land" and illustrate with separate entitlements to harvest (or preserve) populations of Atlantic cod, sea scallop, and American lobster, to extract minerals such as sand, gravel, and petroleum from the seabed, to sail a boat or to ride a personal watercraft, to transport cargo in shipping corridors, to patrol using military craft, to conduct scientific research on benthic communities and habitat requirements, to dump sewage, and so on. The ecology and economics of divisibility will be a major consideration in designing property rights structures for multi-attribute LMEs as discussed later.

The remaining three dimensions of property rights are mentioned here, but they are most relevant to the discussion of regimes in the next section. *Exclusion* concerns whether others are prevented from using or damaging your entitlements. In the papers by Gordon and Cheung that were quoted earlier, nonexclusiveness, or even extreme attenuation of this right, shortens time horizons, giving rise to short-term profit motives. In fisheries, harvesters invest in technologies that facilitate rapid catches of target species independent of the technologies' impacts on discards or habitat. Sustainability is further undermined by the absence of investment in resource productivity, including the enhancing of the survival of prey and the controlling of predator populations.

The *right to transfer* entitlements to other entities increases the time horizon beyond the owner's lifetime or generation. Transfer increases property value by making it available to others who value it more highly, and by implicitly including demands of future generations.

Finally, without *enforcement*, the other rights have no practical value. In addition to being a property right, enforcement must also be affordable, otherwise it won't be practiced. Enforcement is the bane of fisheries management by governments, and it is infeasible for resource claimants when resources are nonexclusive.

Virtually all property rights are attenuated by private contracts, laws, or government regulations that protect public safety and social values. For example, you are entitled to drive your car to work if you are licensed and your car is registered; however, you may not exceed speed limits or violate other motor vehicle laws. Likewise, fishermen are entitled to use their vessels to harvest fish stocks, but their landings might be restricted in terms of overall weight or fish size, or time or area closures might be imposed to protect marine mammals and endangered species, or their gear might be restricted to configurations that reduce discarding of uneconomic species. Attenuations reduce the value of a property right to the owner, but they are justified to protect public welfare.

Bundled Entitlements

The remainder of this section attempts an objective analysis of the implications of ecology, technology, and transactions costs for partitioning LME resources into bundles of entitlements. Transactions costs are a collection of costs involved with gathering information on, and otherwise delineating, a resource, establishing contracts (formal or informal) that define the entitlement(s), and monitoring and enforcing the entitlement(s). The three other property rights reflect society's preferences for an environmental property rights regime and are therefore normative.

From an economics perspective, an ecosystem such as an LME can be viewed as a matrix of environmental and biological attributes, some of which either yield or contribute to as "inputs" (*e.g.*, prey, habitat) a variety of goods, such as food, and services, such as assimilation of waste, over time that benefit humankind (Costanza *et al.* 1997). The variety of resources in an LME stems from heterogeneity in biological (*e.g.*, fish populations), physical (*e.g.*, sediments, currents, space), and chemical (*e.g.*, dissolved nutrients and salts) attributes and their structure (*e.g.*, trophic relationships, current systems) and function (*e.g.*, regulate prey populations, recycle nutrients). From this perspective, an LME is a differentiated capital asset that provides humans with flows of environmental goods and services not unlike what Rosen (1974) described for humanmade capital assets (*e.g.*, houses, automobiles, vessels, docks).

In theory, each LME attribute is potentially a resource when it contributes to goods and services valued by humans, sometimes indirectly. For example, the megafaunal prey (*e.g.*, polychaetes and shrimps) of commercially important Atlantic cod stocks across the Northeast U.S. Shelf Ecosystem and the biogenic (*e.g.*, bryozoan colonies, sponges) and sedimentary (*e.g.*, sand waves, glacial gravel deposits) habitats of those prey are not themselves in demand by seafood consumers, but they do contribute to Atlantic cod production. Likewise, microorganisms in sediments are essential to primary productivity because they recycle nutrients in detritus.

However, there are several reasons why not all resources are candidates for property right entitlements at a point in time. First, there is no need to conserve resources that are not scarce because there is more than enough to satisfy demand at zero price. For example, salinity and the concentration of dissolved carbon in the open ocean do not limit photosynthesis. In other cases, the cost of gathering information on a resource may be too great (*e.g.*, population dynamics of deepsea fishes), or there may be relatively cheaper substitutes (*e.g.*, production of manganese from deepsea nodules or of energy from temperature gradients). Finally, where resource attributes can be delineated, it might cost too much to monitor and enforce entitlements, or the institutions that govern use might preclude ownership. Many resource attributes thereby remain in the public domain until such time that technological innovations or changes in people's preferences make them economical (Barzel 1989; Cheung 1970).

We can contemplate which of an LME's many resource attributes are not viable candidates for property rights at this time. Diffuse and fluid resources, such as water temperature, concentrations of dissolved nutrients (*e.g.*, nitrogen, phosphorus, trace metals) and currents and related oceanographic phenomena such as warm-core rings and El Niño all limit the survival or transport of fish larvae and, therefore, eventual recruitment to harvestable stocks, but they are indivisible and nonexclusive. Such resources are sometimes classified as public goods (or public bads).[27] Plankton communities -- phytoplankton, copepods, microorganisms, fish larvae -- are similarly off limits at this time.

We can also nominate a class of LME resources that is suitable for property rights definitions given today's information, technology, and demand. These include the measurable stocks of renewable fishery resources, mineral deposits, ocean space, and, conceivably, highly migratory species such as herring, tunas, salmon, marine mammals, and sea turtles. The migratory species present problems due to relatively high transactions costs, but recall the 1911 Pacific Fur Seal Treaty in which Russia, Japan, and Canada contracted harvest rights to the United States in return for annual compensation.

Finally -- and importantly -- entitlements to resource attributes can be bundled using geographical coordinates as implied by Gordon (1954), Cheung (1970), and Pollnac (1984). Doing so will include many of the resource attributes that currently defy divisibility/partitioning, but which are known to contribute to a good or service in demand. A spatial orientation is critical to LME property rights structures because it moves benefits out of the public domain where they will be dissipated by too rapid use and depletion into the calculus of a government, commons, or private owner. Of special importance to fisheries is management of discards and habitat, but interactions -- and tradeoffs -- with other resource attributes, including marine mammals, minerals deposits, and ocean space are important too.

Design Principles for Property Rights Structures

Bundling LME resource attributes within spatial boundaries raises several questions regarding geographical scale and what logically belongs in a bundle from the perspectives of ecology, economics, and sociocultural theory. Coexistence and coevolution of marine species and the chemical and physical surroundings are important considerations so as to control losses from "externalities," or "spillover effects." By externalities, economists are referring to situations where interdependence between production practices and people's welfare ("utility") are exogenous to the decisionmakers.[28] In other words, entitlements intermingle owing to an inability to completely delineate property rights because it is too costly or because of institutional constraints (Cheung 1970; Russell 1994). Although positive externalities are equally germane, externalities that damage the property interests of others receive the most attention. For example, otter trawl and dredge fishing tear up lobster pots and other types of fixed gear. However, groundfish and scallop fishermen have no incentive to restrict their fishing practices or to invest in different technologies (hook-and-line fishing for cod or cage culture of scallops) when fishing grounds and/or lobster stocks are nonexclusive.

The Coase Theorem (Coase 1960) teaches us that externalities do not result in a misallocation of resources (aside from wealth effects) in a utopian world of perfect knowledge, zero transactions costs, and complete property rights assignments to all resources. Where externalities crop up due to changes in technology or peoples' preferences, property rights are exchanged in order to maximize total net value. In reality -- and this is certainly the case for the nascent assignment of property rights in an LME -- the transactions costs of delineating resources (*e.g.*, costs of information) and negotiating and enforcing new contracts can preclude exchange. Thus, it is prudent to consider ways to bundle LME resources that are consonant with today's ecological and socioeconomic information, but are also flexible to change.

First, the 50 vast LMEs probably can be subdivided into smaller areas in order to incorporate principal interactions among attributes and reduce externalities. The division could be based on physical features that "enclose" enduring species assemblages of marine species (marine communities) over time, and that largely entrain energy flow and nutrient recycling across trophic levels. The physical features may be geologic, such as trenches or deepwater slopes that limit seasonal migrations, or oceanographic, such as areas where upwelling or eddies occur. For example, scientists divide the Northeast U.S. Shelf Ecosystem into four subsystems: Georges Bank, the Gulf of Maine, Southern New England, and the Mid-Atlantic Bight (Sherman *et al.* 1996). Competitive or mutually exclusive uses of the same areas -- potentially, minerals extraction, transportation, and/or endangered species protection -- could be accommodated through contracts, litigation or "combination sales" (Demsetz 1967). For example, the National Audubon Society has managed bird sanctuaries, cattle grazing, and oil production at its Rainey Wildlife Sanctuary in Louisiana where the public is excluded (Baden and Stroup 1981).

Moving in the other direction on the spatial scale, whole subsystems might be subdivided into parcels of same uses or zoned for different uses based on smaller landscape or seascape features, but geopolitical lines (*e.g.*, state waters in the United States) probably are arbitrary criteria, and fragmentation of communities and habitat requirements would be counterproductive if it substantially interfered with the basic ecosystem functions of energy flow and nutrient cycling (Costanza and Folke 1996).

Scale also has socioeconomic and geopolitical determinants that will affect design. The cost of monitoring and enforcing property rights will be a function of scale, and monopoly power in markets for LME goods and services would be illegal. Dividing LME's into smaller units might help resolve or minimize transboundary disputes with other countries where resource attributes are mostly fixed in their location and can be zoned or otherwise allocated among users.[29]

Coexistence is only a necessary -- not a sufficient -- condition for bundling LME resource attributes. Strong complementarity and separability should also be guides when deciding what resources to bundle in a geographic area. User groups' local classifications (*e.g.*, commonly known fishing grounds) also need to be taken into consideration. Joint ecologic relationships that have coevolved to a high degree of specificity over time, such as species-specific predation, commensalism, and habitat dependence, are strongly complementary and, therefore, should justify inclusion in a bundle. Special attention should be given to possible cascade effects (see Christensen *et al.* 1996).

Unions made on the basis of joint ecological relationships should be overlaid by technology to see where joint production by fishing gear or interactions with other technologies (*e.g.*, sand and gravel mining) might combine ecological bundles. For example, in their study of the New England multispecies trawl fishery, Kirkley and Strand (1988) rejected the hypothesis of nonjoint production of several groundfish species, including Atlantic cod and haddock, and concluded that "[m]anagement of one species independent of other species or of an aggregate output will not prevent overfishing or economic waste."

In contrast to jointness, strong separability implies ecologic independence among resources and, in economics, an ability to substitute environmental inputs in order to produce different outputs. Ecological separation of species populations with closely related niches -- *i.e.*, competitive exclusion -- is a criterion for separate bundles provided technologic interactions are minimal. In stark contrast, "regulatory bycatch" -- a political economy artifact of single-species thinking (*e.g.*, groundfish and lobster caught in sea scallop dredge gear) -- defies any ecologic-economic rationale for separability.

The rationale for using observed technology to determine resource bundles needs to be qualified. The technologies we observe in fisheries reflect the mostly nonexclusive history of marine resources that created incentives for rapid capture of target species. Institutional change that includes property rights will change investment decisions, conceivably to technologies that are more selective and less destructive of habitat. For example, production of the Japanese scallop increased over 30-fold after fisheries cooperatives in Japan substituted fixed-gear culture technology for dredging.

PROPERTY RIGHTS REGIMES AND MANAGEMENT OF LME RESOURCES

Institutions

North (1992) succinctly defines institutions as "the rules of the game in a society," or "the humanly devised constraints that shape human interaction." We are especially interested in how property rights regimes influence use of the natural environment (Hanna *et al.* 1996).

Hanna (1998) appears to have been the first to discuss at length the role of institutions in marine ecosystem management. Economic development and sustainability depend on an institutional environment that promotes the following management functions: integrate multiple objectives, control transactions costs, promote socially appropriate time horizons, engender legitimacy among users, and be flexible to change. No specific type of property right regime is endorsed (state, common, private), but decentralized decisionmaking is favored over centralized economic planning on these grounds. The Conference of the Parties to the Convention on Biological Diversity has likewise recommended "decentralized systems" among its dozen principles of ecosystem management (UNEP 1998).

A discussion of institutions addresses how a society's "rules" for exclusion, transfer, and enforcement rights influence use of entitlements and affect long-run economic performance and resource sustainability. Such a discussion has several considerations.

First is the notion of sustainability itself. Nobel laureate economist, Robert Solow, expressed a perspective that is likely shared by most economists when he remarked that preservation of an individual species or habitat is "fundamentally the wrong way to go in thinking about [sustainability]" (Solow 1992). Instead, he emphasizes the important fact that people substitute goods and services for one another: "If you don't eat one species of fish, you can eat another species of fish," and thereby defines sustainability as, "an obligation to conduct ourselves so that we leave the future the option or capacity to be as well off as we are" (Solow 1992).

The Ecological Society of American (ESA) also embraced "long-term sustainability" when it defined ecosystem management as follows:

> *Ecosystem management is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function. Ecosystem management does not focus primarily on 'deliverables' but rather on sustainability of ecosystem structures and processes necessary to deliver goods and services* (Christensen *et al.* 1996).

Although one wonders about its view on substitution, the ESA did downplay notions of constancy when it endorsed homeorhesis (*i.e.*, tendency of a system to return to its previous trajectory) over homeostasis (return to a predisturbed state), and cautiously suggested "biomanipulation" as a means to enhance "deliverables." Biomanipulation includes predator control and the selective removal of close competitors, artificial habitats that enhance survivorship or productivity, and "fertilizing" waters with inorganic or organic nutrients (*e.g.*, sewage) to increase primary productivity or the growth of detritovores that are prey for target species.

Economists, anthropologists, sociologists, and ecologists are likely to agree about many of the ecosystem structures and functions that need to be sustained, if not about specific components. For example, instead of maximum sustainable yields being determined for individual species (stocks), the aggregate biomass yields from species in a community that are in demand by consumers (whether for food, ritual, or other uses) might be sustained, although not necessarily at the natural maximal level. Predator control and culture could increase yields beyond that observed for conventional fisheries. On the other hand, alternative uses of the same area -- recreation, preservation, minerals extraction -- may prove more valuable than only commercial fishing in some areas.

At a higher level of ecologic organization, biological diversity as it relates to ecosystem functions (photosynthesis, nutrient recycling, energy flow) and responses to disturbance (resistance and resilience) probably should be maintained. This is not an endorsement of community-type diversity indices that would maintain a constant number or kind of species or their abundance (*e.g.*, the Shannon-Wiener index). It concerns ecosystem "health." Systems require redundancy to be homeorhesically stable; therefore, entitlements to harvest functionally similar competitors might be attenuated. Likewise, predator control should not proceed to the point of trophic cascades. "Fishing down food webs" -- *i.e.*, depleting long-lived, high trophic level fish and then transitioning to low trophic level invertebrates and planktivorous fish -- is not a sustainable fisheries policy because piscivore populations do not recover (Pally *et al.* 1998).

A second consideration with direct ties to institutions is uncertainty and variability. The environmental influences of temperature, currents, and food supply on commercially and recreationally valuable fish populations are poorly understood and highly variable year-to-year and over longer periods of time (McGlade 1989). Fishing technologies and markets are also difficult to predict. Institutions that are able to adapt quickly to change and to experiment and innovate to gain new knowledge -- *i.e.*, adaptive management (Walters 1986; McGlade 1989; Larkin 1996) -- would be consonant with LME management.

The mention of commercial and recreational fishing in one sentence raises a third important function of institutions, namely resolving multiple-use or goal conflicts cost effectively. The myriad resources of an LME -- renewable, nonrenewable, space -- have scores of uses and values that can be competitive or mutually exclusive. In addition to seafood and recreation, a short list includes energy, waste disposal, transportation, and preservation of marine mammals. Addressing conflicts through the political process by rent-seeking is costly for a society because it uses scarce productive resources to transfer or otherwise alter the distribution of benefits, not to increase economic growth (Rowley *et al.* 1988). Market exchange or direct negotiations among affected parties (Coase 1960; Demsetz 1964; Pollnac 1992), or resorting to courts to settle liability claims (compensation), will resolve problems with minimum transaction costs. Divisibility, exclusion, and transfer rights are important here.

Related to multiple-use conflicts are a host of transboundary problems that most LME property rights regimes will confront. To be of any value, an LME, such as the Northeast continental shelf (Sherman *et al.* 1996), will be large enough to subsume the principal ecosystem and human dynamics. Yet, no LME is insulated from the rest of the world, and vice versa. Surface currents pass through LMEs and carry with them nutrients, plankton, and pollutants. Many species of marine finfish (*e.g.*, tunas), mammals, and sea turtles migrate through several LMEs in a year. Fishing effort is derived from consumer demand for fish products -- including foreign demand -- and, therefore, from people's preferences and incomes. Technological advances in power, food processing, transportation, and electronics eventually find uses in marine fisheries. Development and other economic activities within coastal watersheds impact nursery grounds and generate pollutants that are carried to LMEs. LMEs straddle geopolitical boundaries.

Accountability for management decisions is widely cited as a principle of ecosystem management (Christensen *et al.* 1996; Hanna 1998; UNEP 1998). Here, the theory of agency, which is a branch of the economics of transactions costs and, therefore, involves property rights regimes (Eggertsson 1990), is germane. In an agency relationship, an owner delegates or transfers some rights to an agent for their mutual benefit. Such relationships exist in all types of human organizations, including those involving natural resource management. Accountability is weakened by the costs of gathering information to monitor the agent. The scope of agency problems might be a function of the scale of an LME holding if resource management is centralized.

Scale has other economic and social ramifications. Economic ramifications relate to competition in markets for goods and services and to the transaction costs of exclusion and enforcement. Monopoly power is not in society's best interest when compared to competition because too little is produced. Regarding transactions costs, it is unclear whether there are scale economies to owning large parcels (Demsetz 1967). Scale -- along with degree of social and cultural diversity within any given stratum -- also has a strong influence on factors such as enforcement and mutual monitoring (Ostrom 1990).

Finally, there is the issue of temporal scale. Much of the misguided criticism about sacrificing the environment for short-term profits stems from situations where resource attributes are nonexclusive (Cheung 1970) or property rights are "incomplete, inconsistent, or unenforced" (Hanna *et al.* 1996), including the right to transfer entitlements to others. Coupled with exclusivity, transferability allows entitlements to move into the hands of people who value the resources more highly, and it also increases the value of property entitlements in the present by factoring in demands by future generations.

CONCLUSIONS

This report has described a framework for assessing and monitoring the salient socioeconomic and governance elements of LMEs. The assessment and monitoring framework consists of 12 steps that, if applied, are expected to produce the essential information required for adaptive ecosystem management (Christensen *et al.* 1996). The 12 steps are:

- Identify principal uses of LME resources
- Identify LME resource users and their activities
- Identify governance mechanisms influencing LME resource use
- Assess the level of LME-related activities
- Assess interactions between LME-related activities and LME resources
- Assess impacts of LME-related activities on other users
- Assess the interactions between governance mechanisms and resource use
- Assess the socioeconomic importance of LME-related activities and economic and sociocultural value of key uses and LME resources
- Identify the public's priorities and willingness to make tradeoffs to protect and restore key natural resources
- Assess the cost of options to protect or restore key resources
- Compare the benefits with the costs of protection and restoration options
- Identify financing alternatives for the preferred options for protecting/restoring key LME resources

One of the most challenging aspects of ecosystem management, especially for LMEs, is "[t]he mismatch between the spatial and temporal scales at which people make resource management decisions and the scales at which ecosystem processes operate" (Christensen *et al.* 1996). Christensen and his coauthors, writing for ESA, went on to lament that "we have identified few mechanisms to translate the actions occurring within individual forest ownership or local fishing communities into strategies to reconcile competing demands for resources or promote a regional vision for sustainability."

We have argued in this report that the property rights paradigm could very well be the framework necessary to design LME resource management policies for long-term economic growth and resource sustainability. Property rights establish the incentives and time horizons for resource use and investment (Libecap 1989). Property rights structures could be designed using ecological, economic, and sociocultural principles related to jointness and separability on spatial scales that bundle resource attributes instead of leaving them exposed to overexploitation in the public domain. Property rights regimes need to translate a society's legitimate goals for use of its LMEs into concordant rules for exclusion, transfer, and enforcement.

ENDNOTES

1. The policies are based on the following principles: 1) managing along ecological boundaries; 2) ensuring coordination among federal agencies and increased collaboration with state, local, and tribal governments, with the public, and with Congress; 3) using monitoring, assessment, and the best science available; and 4) considering all natural and human components and their interactions.

2. Since 1992, all four of the primary land management agencies (National Park Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and Forest Service) have independently announced that they are implementing or will implement an ecosystem approach to managing their natural resources, and each has been working to develop its own strategy (GAO 1994). Several other agencies, including the Natural Resource Conservation Service, Department of Defense, Department of Energy, Bureau of Indian Affairs, Bureau of Mines, Bureau of Reclamation, Minerals Management Service, U.S. Geological Survey, Environmental Protection Agency, and National Aeronautics and Space Administration, have engaged in significant ecosystem management activities (CRS 1994).

3. The only work on this is a brief sketch by Broadus (Sherman 1997; Sherman *et al.* 1993) and an unpublished white paper, "LME Socioeconomic Module (Sociocultural Submodule)," prepared for the NMFS Office of Science and Technology (1315 East-West Hwy., Silver Spring, MD 20910).

4. As explained below, we define property as a benefit (or income) stream, and a property right is a claim to the benefit stream that government agrees to protect from those who may covet, or somehow interfere with, the benefit stream (Bromley 1992).

5. Externalities are unintended harmful or beneficial effects incurred by a party that is not directly involved with exchange, production or consumption of the commodity in question.

6. Some recreational uses, for example beaches, are intermediate cases. An individual's use of a beach may not interfere with others, at least *up to a point*, after which beach (or parking) congestion would make use of a beach like a consumptive use in that my use may prevent you from gaining access to the resource.

7. Input-output studies could be used to identify linkages among sectors within an area. See, *e.g.*, Rorholm *et al*. (1967), Grigalunas and Ascari (1982), King and Story (1974), and Tyrrell *et al.* (1982), for examples of such studies for other marine areas.

8. Property value studies also give general support for the relatively high residential demand for, and the correspondingly relatively high value of, shoreline proximity (*e.g.*, Edwards and Anderson 1984).

9. Other LME-related sectors, such as retail or wholesale seafood, may also be somewhat dependent on activities in the LME.

10. These values should include market and nonmarket values, gross and net values, and net benefits to consumers and producers.

11. Excellent guidelines on fisheries data needs are Brainerd *et al.* (1996), Kitts and Steinback (1999), and FAO (1999).

12. It appears certain that further work in this area will require incorporation of a great deal of complexity, nonlinear relationships, and dynamics. Previous work using general equilibrium models (Ayres and Kneese 1969) and systems approaches may be productive.

13. Also see Dyer *et al.* (1992) for an examination of sociocultural considerations in assessing oil spills.

14. Public policies are also shaped by political expediency that may favor the minority that is composed of a specific user group over society. Special interest

effects occur when an issue is important to a specific group, while most members of society are unaware of, or disinterested in, its outcome. In these cases, it becomes politically expedient for politicians and policy makers to agree with the minority -- even when the decision is detrimental to society or economically inefficient. Often these conflicts take the form of a tug-of-war between stakeholders -- each of which claim to represent what is best for society -- and between stakeholders and the actual interests of society.

15. A succinct explanation of these methods is provided by the National Academy of Sciences (1997).

16. Many improvements in methods have been made, but reliable quantification and acceptability of passive use value as a measure of damages are still a subject of lively debate (*e.g.*, Portney 1994; Diamond and Hausman 1994; Hanemann 1994).

17. Common examples of resource valuation involve determining the value of oil and gas leases, tradable fishing licenses, and government concessions. These cases are relatively straightforward in that they involve the use of market information on anticipated revenues and costs over time. An important issue, discussed further later, concerns estimating the change in the value of a marine asset due to changes in pollution or fishery regulations, for example.

18. An NRR is thus formally defined as a network of NRCs whose existence is defined by the interactions among the social, cultural, human, economic, and biophysical capital that are part of, or closely linked to, the resources of an LME (Dyer and Poggie 1998).

19. The NRC may encompass more than one port.

20. Of course, this argument, in part, provides the justification for international donors and programs including the GEF.

21. The following examples are excerpted from Grigalunas (1998).

22. This section draws heavily from a recent report prepared for the Regional Programme for Preventing Pollution in East Asia Seas (Grigalunas and Opaluch 1998).

23. As note earlier, passive use losses may arise if individuals feel worse off when they learn of the adverse effects of a spill on wildlife, beaches, and other natural resources -- even if they do not use these resources themselves. People might be willing to pay to prevent such losses, much as they might pay to preserve, say, an historically or culturally significant building or site, even if they never actually visit it. Many improvements in methods have been made, but reliable quantification and acceptability of passive use value as a measure of damages are still a subject of lively debate (*e.g.*, Portney 1994; Diamond and Hausman 1994; Hanemann 1994).

24. This section is drawn from Grigalunas and Opaluch (1998).

25. See Musgrave (1969) for further discussion of benefit-cost analysis and financing when capital markets are not perfect, when social and private discount rates differ, and when the distribution of benefits and costs are important.

26. Note, however, that NRDA can also be considered a pollution prevention measure, to the extent that it provides an incentive for vessel operators to exercise more care (Grigalunas and Opaluch 1988; Grigalunas 1997).

27. Pure public goods are nonrival and nonexcludable; and pure private goods are rival and excludable. Examples of pure public goods include national defense, where food and clothing are examples of private goods.

28. Anthropological theory can be especially helpful in teasing out the different utility functions that may be held by different stakeholder groups due to social or cultural variances in preferences.

29. The basic idea here involves zoning certain resource attributes the way that real estate is zoned on land. For example, does a timber stand that stretches across the U.S.-Canadian border have to be jointly managed? Probably not if lumber production is the only commodity -- but maybe so if the most valuable use of the forest is habitat for a wandering endangered species. Likewise, does the Hague Line across Georges Bank present a problem for sustainable use of sea scallop resources? Probably not, since scallop resources are relatively sedentary. The line does present a problem for migratory groundfish. However, zoning or some other means of allocating shares even in the migratory-type cases may or may not result in larger authorities (government or private), depending on scale efficiencies and other things. Small authority A could purchase small authority B (or be joined by Congress or an international management authority). Or A and B may be able to negotiate contracts (treaties) that specify levels/locations of activities -- *e.g.*, unitization of common-pool oil fields.

GLOSSARY

Abiotic -- reference to the nonliving portion of the environment.

Adaptive management -- regulation or control of resource use that adapts in response to the results of management actions. It is also a learning process as managers observe environmental responses to actions and learn how the system reacts to a given set of measures.

Alien species (a.k.a. introduced, exotic, or nonindigenous species) -- a species that has been transported by human activity, intentional or accidental, into a region where it does not naturally occur.

Asset (a.k.a. capital asset) -- a physical entity with embodied wealth (such as a house or fishing vessel) that provides a flow of valuable services over time.

Assimilative capacity -- capacity of the ocean to dilute, absorb, or modify wastes such as sewage or heat.

Bathymetry -- the measurement of the depths of oceans, seas, or other large bodies of water.

Beliefs -- opinions or convictions that shape social relationships or perceptions.

Benefit-cost analysis -- a comparison of the economic benefits of using a productive resource with the opportunity cost of using the resource. Projects or regulations are evaluated based on how they change net economic value.

Biodiversity (biological diversity) -- the diversity of life that occurs at several hierarchical levels of biological organization. Usually defined by three levels: genetic, species, and ecosystem.

Biotic -- the living portion of the environment.

Commensalism -- having benefit for one member of a two-species association, but having neither positive nor negative effect on the other.

Complementarity -- LME resources that are closely linked such as organisms that have mutualistic relationships.

Consumptive use -- occurs when one person's use of a resource prevents others from using it. For example, the shellfish, finfish, or waterfowl I take in the LME are unavailable for others to catch. Hence, consumptive use of natural resources in this sense is like consumptive use of common private goods exchanged on markets, such as a pizza or a pair of shoes.

Contingent choice -- a direct economic valuation technique that is dependent on choices that respondents make in response to hypothetical questions or situations such as the ranking of environmental options.

Contingent valuation -- a direct economic valuation technique that ascertains value by asking people their willingness to pay for a change in environmental quality. The information that is sought from respondents is conditional on some hypothetical market context such as the nature of the change, how it will be implemented, and what it will cost.

Cost effectiveness -- minimization of costs in order to achieve a given end, such as the selection of the alternative(s) with the lowest cost per unit.

Direct use -- refers to the physical use of a resource onsite or *in situ*. Common examples of direct use include commercial and recreational fishing, beach use, boating, and wildlife viewing. Most direct use is targeted by participants who set out to visit a beach, to fish at a particular location, and so forth. Direct use also may be *incidental*, for example, when a person traveling by boat unexpectedly sees whales or marine birds while en route to a destination.

Ecology -- the branch of biology that involves the study of the relationships among organisms and the interaction between organisms and the physical environment

Economics -- is the study of the choices people make to allocate scarce resources among alternative uses to satisfy human needs and desires.

Economic value -- the most people are willing to pay to use a given quantity of a good or service; or, the smallest amount people are willing to accept to forego the use of a given quantity of a good or service.

Ecosystem -- the biotic components of a community, and the abiotic elements of the environment that interact with these components.

Ecosystem health -- the state of ecosystem metabolic activity levels, internal structure and organization, and ability to resist external stress over time and space.

Environmental resources -- in the most general sense, all renewable and nonrenewable resources of the LME. Sometimes used to refer to water and air resources as opposed to natural resources such as fisheries or oil.

Estuary -- a semienclosed body of water that has a free connection with the open sea, and within which seawater is diluted measurably with freshwater that is derived from land drainage.

Eutrophication -- enrichment of a waterbody with nutrients, resulting in excessive growth of phytoplankton, seaweeds, or vascular plants, and often in oxygen depletion from decomposition of plant material.

Externalities -- unintended harmful or beneficial effects incurred by a party that is not directly involved with production or consumption of the commodity in question.

Fishery -- commonly, the actions by, and the interactions among, fishermen using certain gear to catch certain fish in a certain area at a certain time. Also, the stock(s) of fish being fished for.

Fuzzy logic -- mathematic technique capable of using qualitative, linguistic, and imprecise information. Relationships are based on a linguistic implication between an antecedent and its corresponding consequent.

Goods and services -- any commodities or nonmaterial goods (services) such as assistance or accommodations that yield positive utility.

Governance -- the formal and informal arrangements, institutions, and mores which determine how resources or an environment are utilized, how problems and opportunities are evaluated and analyzed, what behavior is deemed acceptable or forbidden, and what rules and sanctions are applied to affect the pattern of resource and environmental use.

Governance module -- considers the formal and informal efforts to manage human behaviors that affect the LME, and encourages patterns of conduct which are in accord with the natural world.

Government -- the political direction and control exercised over actions of the members, citizens, or inhabitants of communities, societies, and states.

Government or institutional failure -- inefficient delivery or use of scarce resources by the public sector.

Habitat -- the place where an animal or plant lives.

Homeorhesically stable -- tendency of a system to return to its previous trajectory or a return to normal dynamics rather than some undisturbed state.

Hydrography -- measurement of waterbody arrangement and movements, such as currents and water masses.

Hydromodifications -- modification of ocean, estuarine, and riparian areas and features such as currents, depth, or the configuration of the coastline and adjacent waters.

Indirect use -- occurs when, for example, wetlands or other LME habitats contribute to the abundance of wildlife or fish observed or caught elsewhere in the LME. In effect, the ecological services of the wetland or habitat help "produce" the wildlife or fish concerned, although the link between the direct use and the ecological services provided by the wetland or habitat may not be apparent to the recreational participant.

Input-output models -- a systematic method that both describes the financial linkages and network of input supplies and production which connect industries in a regional economy, and predicts the changes in regional output, income, and employment. Input-output analysis generally focuses on economic activity and the self-sufficiency of an economy, unlike cost-benefit analysis which focuses on changes in net national benefits from use of a productive resource.

Institutions -- the humanly devised constraints that shape human interaction, or the rules that govern human behavior.

Integrity of ecosystems -- when subjected to disturbance, an ecosystem sustains an organizing, self-correcting capability to recover toward an end-state that is normal and "good" for that system.

Interaction matrices -- the use of matrices to organize LME activities and resources by listing them on each axis. Matrix cells represent potential interactions or linkages between the components listed in a particular column and row of the matrix. These matrices have the capacity to inventory, organize, and explore relationships or linkages among human uses, ecological components, and processes of the LME.

Jointness -- interdependence among a system's components, such as spatially or temporally related species of an LME.

Large marine ecosystem -- a geographic area of an ocean that has distinct bathymetry, hydrography, productivity, and trophically dependent populations.

Legitimacy -- perception of conforming to established social rules or standards.

Management -- the act of influencing, directing, or controlling use of a resource.

Market failure -- the inability of the market to allocate resources efficiently. The major causes of market failure include: 1) imperfect competition (monopoly), 2) imperfect information, 3) public goods, 4) inappropriate government intervention, and 5) externalities.

Markets -- a collection of buyers and sellers who interact, resulting in the exchange of goods and services.

Modeling -- a simple representation or abstraction of a feature of the real world that reveals important relationships, processes, or elements of the feature.

Monitoring -- to observe and record changes with regard to physical, biological, or social conditions related to an LME.

Maximum sustainable yield -- largest long-term average yield or catch from a stock under prevailing ecological and environmental conditions.

Nonconsumptive use -- refers to cases where one person's enjoyment does not prevent others from enjoying the same resource. For example, my viewing of marine mammals in the LME, other wildlife, or attractive views does not prevent you from enjoying the same resources.

Nongovernmental institutions and arrangements -- informal norms and rules of behavior embodied in social arrangements and organizations such as nongovernmental organizations (NGOs)

Nonjoint production -- production of a single or few elements of an LME without regard to relationships to other elements.

Nonuse (passive use) -- refers to the enjoyment individuals may receive from knowing that the resources exist ("existence value") or from knowing that the resources will be available for use by one's children or grandchildren ("bequest value") or others even though the individuals themselves may not actually use the resources concerned.

Normative -- analysis leading to a recommendation or prescription that is based on value judgements or that reflects society's preferences.

Norms -- the "understood" rules for appropriate behavior. This is broader than social organization and includes nonsocial behavior.

Nutrient pollution -- pollution such as sewage, agricultural runoff, or atmospheric deposition which increases nutrients available for primary production. Increased nutrient levels may lead to eutrophication.

Open access -- access to the resource is free to anyone who wants to use or harvest it because there is no ownership of the resource.

Overexploitation -- level of exploitation where the resource level has been drawn down below the level that on average would support the long-term maximum yield of the fishery.

Passive use -- see "Nonuse."

Phytoplankton -- passively drifting or weakly swimming usually microscopic plant organisms. They are the most important community of primary producers in the ocean.

Productivity -- usually in reference to primary productivity, the rate of assimilation of energy and nutrients by green plants (photosynthesis) and other autotrophs (chemosynthesis). Usually expressed as grams of carbon per square meter per year.

Property -- is a benefit (or income) stream associated with a property right.

Property right -- a claim to the benefit stream that some higher body -- usually government -- will agree to protect through the assignment of duty to others who may covet, or somehow interfere with, the benefit stream.

Property rights structures -- various types of property rights arrangements, all of which exhibit attributes of the five dimensions of property rights. For example, private and common property each exhibit the following dimensions to varying degrees: 1) the goods and services that owners can derive benefits from; 2) divisibility, the richness of entitlements to complex resources with multiple attributes; 3) exclusion of others from using or damaging the owner's entitlements; 4) the right to transfer ownership of entitlements; and 5) enforcement of property rights.

Public good -- a good that can be used by anyone and for which one person's use does not diminish the good's value for others.

Rent seeking -- actions by individuals and interest groups designed to restructure public policy in a manner that will either directly or indirectly redistribute more benefits to themselves.

Resources -- anything that has value; living and nonliving components of nature such as fish, oil, water, and air.

Resource valuation -- calculation or estimation of the economic value of a natural resource.

Separability -- independence among resources and in economics, an ability to substitute environmental inputs in order to produce outputs. Therefore, these resources may be managed or utilized separately due to the lack of strong linkages to other LME components.

Social and cultural factors -- in addition to factors related to economics such as benefits, capital, and labor, considerations such as social structure and social organization, people's knowledge and views (norms and values) about their work, and how this relates to the resource.

Social conflict -- when the existing order is perceived as oppressive or unfair, parties try to meet their needs by destroying their opposition and by replacing those who make the rules.

Social costs -- costs associated with the disruption of communities, households, and related social structures resulting in the loss of human potential.

Social forces -- factors related to human behavior as shaped by group life, including both collective forces (group construction) and the ways in which people give meaning to their experiences (self-reflection).

Social impact assessment -- an evaluation of the likely outcomes and impacts of a specific policy or regulation on a designated target group or groups, as well as likely ripple effects to other groups.

Social networks -- comprises the sum total of one's group membership and relationships.

Social systems -- represents an arrangement of statuses and roles that exist apart from the people occupying them.

Socioeconomic -- pertaining to the combination or interaction of social and economic factors and involves topics such as distributional issues, labor market structure, social and opportunity costs, community dynamics, and decisionmaking processes.

Socioeconomic benefits -- benefits to humans gained through utilization of resources, including both economic and social benefits.

Socioeconomic module -- application of economic and social science analysis to LME management. Six major elements of analysis include: human forcing functions (*i.e.*, ways in which human activities affect the natural marine system); assessing impacts; feedback of impacts to human forcing functions; the value of ecosystem services/biodiversity; estimation of nonmarket values; and integration of economic and social science and natural science assessments.

Spillover effects -- sometimes referred to as externalities, an unintended effect (positive or negative, benefit or cost) imposed on others and not borne by the party responsible for the effect.

Stated preference methods -- general category of indirect valuation methods that includes contingent choice or contingent valuation methods. Individuals are asked to makes choices regarding their willingness to pay or to rank environmental options.

Stocks -- generally referred to as LME assets since such natural resources can be utilized as inputs for economic processes. In fisheries science, a fish stock is used as a unit for fisheries management.

Subsidiarity principle -- as related to levels of governance, suggests that authority belongs at the lowest level capable of effective action.

Sustainability -- resources are managed so that the natural capital stock is nondeclining through time, while production opportunities are maintained for the future.

Sustainable development -- development that recognizes the need to maintain capital stock and future production opportunities.

Tradeoffs -- compromises among resource uses that are required because some bundles of entitlements defy divisibility/separability.

Transaction costs -- a collection of costs involved with gathering information on, and otherwise delineating, a resource; establishing contracts (formal or informal) that define the entitlement; monitoring and enforcing the entitlement.

Transboundary -- resources or economic impacts such as pollution that straddle political boundaries, usually national borders. For example, transboundary stocks occur on both sides of a given national border.

Trophic (trophic level) -- position in food chain determined by the number of energy-transfer steps to that level. Plant producers constitute the lowest level, followed by herbivores and a series of carnivores at the higher levels.

User group -- a group of individuals that utilize a resource in a specific manner such as inshore lobster fishermen.

Utility -- the level of satisfaction that a person gets from consuming a good or undertaking an activity.

Value -- market and nonmarket values, gross and net values, and net benefits to consumers or goods and services.

Values -- ideals, customs and beliefs of a given society.

Welfare -- the prosperity or, more broadly, the well being of a person or group.

REFERENCES CITED

Acheson, J.M., editor. 1994. Anthropology and institutional economics. Lanham, MD: University Press of America.

Alchian, A.A. 1977. Economic forces at work. Indianapolis, IN: Liberty Press.

Ayres, R.U.; Kneese, A.V. 1969. Production, consumption and externalities. *Am. Econ. Rev.* 59:282-297.

Baden, J.; Stroup, R. 1981. Saving the wilderness: a radical proposal. *Reason* 13:29-36.

Barzel, Y. 1989. Economic analysis of property rights. [*In:* Political economy of institutions and decisions series.] New York, NY: Cambridge University Press.

Brainerd, T.; Clay, P.; Hakserver, D.; Hall-Arber, M.; Kellogg, C.; Kitts, A.[W.]; McCarron, D. 1996. Commercial sector reference document on identification and prioritization of economic and sociocultural data elements. [Report *to:* ASMFC Committee on Economics and Social Sciences.] Washington, DC: Atlantic States Marine Fisheries Commission.

Bromley, D.W. 1992. The commons, common property, and environmental policy. *Environ. Resourc. Econ.* 2(1):1-17.

Caddy, J.F.; Sharp, G.D. 1986. An ecological framework for marine fishery investigations. *FAO Fish. Tech. Pap.* 283; 152 p.

Cheung, S.N.S. 1970. The structure of a contract and the theory of a non-exclusive resource. *J. Law Econ.* 13:49-70.

Christensen, N.; Norman, L.; Bartuska, A.M.; Brown, J.H.; Carpenter, S.; D'Antonio, D.; Frances, R.; Franklin, J.F.; MacMahon, J.A.; Noss, R.F.; Parsons, D.J.; Peterson, C.H.; Turner, M.G.; Woodmansee, R.G. 1996. The report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecol. Appl.* 6(3):665-691.

Clark, J.R. 1996. Coastal zone management handbook. Boca Raton, FL: Lewis Publishers.

Coase, R. 1960. The problem of social cost. *J. Law Econ.* 3:1-44.

Cordell, J. 1984. Defending customary inshore sea rights. *Senri Ethnol. Stud.* 17:301-326.

Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P.; van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387:253-260.

Costanza, R.; Folke, C. 1996. The structure and function of ecological systems in relation to property rights regimes. *In:* Hanna, S.; Folke, C.; Maler, K-G., eds. Rights to nature: ecological, economic, cultural, and political principles of institutions for the environment. Washington, DC: Island Press; p. 13-34.

Costanza, R.; Norton, B.G.; Haskell, B.D. 1992. Ecosystem health: new goals for environmental management. Washington, DC: Island Press.

Couper, A. 1983. The *Times* atlas of the oceans. New York, NY: Van Nostrand Reinhold.

Crawford, J.S. 1984. An economic input-output analysis of the marine-oriented industries of New London County, Connecticut. [Masters Thesis.] Storrs, CT: Univ. of Connecticut.

Creed, C.F.; McCay, B.J. 1996. Property rights, conservation and institutional authority: policy implications of the Magnuson Act reauthorization for the Mid-Atlantic region. *Tulane Environ. Law J.* 9(2):245-256.

CRS [Congressional Research Service]. 1994. Ecosystem management: status and potential. Summary of a workshop convened by the Congressional Research Service. Washington, DC: Congressional Research Service.

Cumberland, J.H. 1966. A regional inter-industry model for analysis of development objectives. *Reg. Sci. Assoc. Pap.* 17:65-95.

Daly, H.E. 1968. On economics as a life science. *J. Polit. Econ.* 76:392-406.

Demsetz, H. 1964. The exchange and enforcement of property rights. *J. Law Econ.* 7:11-26.

Demsetz, H. 1967. Toward a theory of property rights. *Am. Econ. Rev.* 57:347-359.

Diamond, P.; Hausman, J. 1994. Is any number better than no number? *J. Econ. Perspect.* 8(4):45-64.

Doeringer, P.; Moss, P.; Terkla, D. 1986. The New England fishing economy: jobs, income and kinship. Amherst, MA: Univ. of Massachusetts Press.

Downs, A. 1967. Inside bureaucracy. Boston, MA: Little, Brown and Company.

Dyer, C.L.; Gill, D.A.; Picou, J.S. 1992. Social disruption and the Valdez oil spill: Alaskan Natives in a natural resource community. *Soc. Spectrum* 12(2):105-126.

Dyer, C.L.; Griffith, D. 1996. An appraisal of the social and cultural aspects of the multispecies groundfish fishery in New England and the Mid-Atlantic regions. Bethesda, MD: Aguirre International.

Dyer, C.[L.]; Poggie, J.[J., Jr.] 1998a. Application of the natural resource region as a unifying human ecosystem theory. [Unpublished paper.] Kingston, RI: Univ. of Rhode Island.

Dyer, C.L.; Poggie, J.J., Jr. 1998b. Integrating socio-cultural variables into large marine ecosystems: the natural resource region model. [Paper prepared *for:* NOAA Workshop on Large Marine Ecosystems.] Kingston, RI: Univ. of Rhode Island.

Dyer, C.L.; McGoodwin, J.R. 1994. Folk management in the world's fisheries: lessons for modern fisheries management. Boulder, CO: University Press of Colorado.

Edwards, S.F.; Anderson, G.A. 1984. Land use conflicts in the coastal zone: an approach for the analysis of the opportunity costs of protection of coastal zone resources. *J. Northeast Agric. Econ. Counc.* 13(1):73-82.

Eggertsson, T. 1990. Economic behavior and institutions. New York, NY: Cambridge University Press.

EU [European Union]. 1998. Overview of the [Integrated Coastal Zone Management Demonstration P]rogramme. <*http://europa.eu.int/en/comm/dg11/iczm/overview.html*>. Accessed September 1998.

FAO [U.N. Food and Agriculture Organization]. 1999. Guidelines for the routine collection of capture fishery data. *FAO Fish. Tech. Pap.* 382; 122 p.

Freeman, A.M., III. 1993. The measurement of environmental and resource values: theory and methods. Washington, DC: Resources for the Future.

GAO [General Accounting Office]. 1994. Ecosystem management: additional actions needed to adequately test a promising approach. *GAO/RCED*-94-111. Washington, DC: General Accounting Office.

Gordon, H.S. 1954. The economic theory of a common-property resource: the fishery. *J. Polit. Econ.* 62:124-142.

Grigalunas, T.A. 1997. Benefit-cost framework for marine pollution prevention and management in the Malacca Straits. Manila, The Philippines: UNDP/IMO/GEF Regional Programme for Marine Pollution and Management in East Asian Seas.

Grigalunas, T.A. 1998. Practical uses of environmental economics in large scale marine ecosystems. [Paper prepared *for:* Meeting on the Benguela Current Large Marine Ecosystem, Cape Town, South Africa.] Pretoria, South Africa: United Nations Development Programme - South Africa.

Grigalunas, T.A.; Ascari, C.A. 1982. Estimation of income and employment multipliers for marine-related activity in the Southern New England marine region. *J. Northeast Agric. Econ. Counc.* 11(1):25-34.

Grigalunas, T.A.; Diamantides, J. 1996. The Peconic Estuary system: perspectives on use and values. Peace Dale, RI: Economic Analysis, Inc.

Grigalunas, T.A.; Opaluch, J.J. 1988. Liability for oil spills: a new approach for providing incentives for pollution control. *Nat. Resour. J.* 28:509-533.

Grigalunas, T.A.; Opaluch, J.J. 1998. Sustainable financing for ship-based pollution prevention and management in the Malacca Straits. Manila, The Philippines: UNDP/IMO/GEF Regional Programme for Marine Pollution and Management in East Asian Seas.

Grigalunas, T.[A.]; Opaluch, J.J.; Mazzotta, M. 1998. Liability for oil spill damages: issues, methods, and examples. *Coastal Manage.* 26(2):61-78.

Hanna, S.S. 1998. Institutions for marine ecosystems: economic incentives and fishery management. *Ecol. Appl.* 8(suppl.):S170-S174.

Hanna, S.[S.]; Folke, C.; Maler, K.-G. 1996. Rights to nature: ecological, economic, cultural, and political principles of institutions for the environment. Washington, DC: Island Press.

Hanemann, M. 1994. Valuing the environment through contingent evaluation. *J. Econ. Perspect.* 8(4):19-43.

Hennessey, T.[M.] 1994. Governance and adaptive management for estuarine ecosystems: the case of Chesapeake Bay. *Coastal Manage.* 22:119-145.

Hennessey, T.M. 1997. Ecosystems management. In: Soden, D.; Lamb, B.; Tennert, J., eds. Ecosystems management: a social science perspective. Dubuque, IA: Kendal/Hunt.

Hunt, R., editor. 1997. Property rights. [Monographs in economic anthropology 14.] Lanham, MD: University Press of America.

Imperial, M.T.; Hennessey, T.[M.] 1993. The evolution of adaptive management for estuarine ecosystems: the National Estuary Program and its precursors. *Ocean Coastal Manage.* 20:147-180.

Imperial, M.T.; Hennessey, T.[M.] 1996. An ecosystem-based approach to managing estuaries: an assessment of the National Estuary Program. *Coastal Manage.* 24:115-139.

ICGP [Interorganizational Committee on Guidelines and Principles]. 1993. Guidelines and principles for social impact assessment. Belhaven, NC: IAIA.

Isard, W. 1972. Ecologic-economic analysis for regional development: some initial explorations with particular reference to recreational resource use and environmental planning New York, NY: The Free Press.

Juda, L. 1993. Ocean policy, multi-use management, and the cumulative impact of piecemeal change: the case of the

United States outer continental shelf. *Ocean Dev. Int. Law* 24:355-376.

Juda, L. 1999. Considerations in developing a functional approach to the governance of large marine ecosystems. *Ocean Dev. Int. Law* 30:89-125.

Juda, L.; Hennessey, T.[M.] 2001. Governance profiles and the management of the uses of large marine ecosystems. *Ocean Dev. Int. Law* 32:41-67.

King, D.M.; Story, D.A. 1974. Use of an economic-environmental input-output analysis for coastal planning with illustration for the Cape Cod region. Amherst, MA: Univ. of Massachusetts, Center for Water Resources Research.

Kirkley, J.E.; Strand, I.E. 1988. The technology and management of multi-species fisheries. *Appl. Econ.* 20:1279-1292.

Kitts, A.W.; Steinback, S.R. 1999. Data needs for economic analysis of fishery management regulations. *NOAA Tech. Memo. NMFS-NE*-119.

Larkin, P.A. 1996. Concepts and issues in marine ecosystem management. *Rev. Fish Biol. Fish.* 6:139-164.

Lourens, J.; van Zwol, C.; Kuperus, J. 1997. Indicators for environmental issues in the European coastal zone. *Intercoast Network* 31:3-4.

Lee, K. 1993. Compass and gyroscope: integrating science and politics for the environment. Washington, DC: Island Press.

Libecap, G.D. 1989. Contracting for property rights. New York, NY: Cambridge University Press.

McCay, B.[J.]; Acheson, J.[M.], editors. 1987. The question of the commons. Tucson, AZ: University of Arizona Press.

McGlade, J.M. 1989. Integrated fisheries management models: understanding the limits to marine resource exploitation. *Am. Fish. Soc. Symp.* 6:139-165.

McGlade, J.[M.] 1995. Intelligent knowledge based systems for the analysis of coastal zones: design logic of SIMCOAST. *In:* ASEAN-EU Workshop report: interdisciplinary scientific methodologies for the sustainable use and management of coastal resource systems. Coventry, England: Univ. of Warwick.

McGoodwin, J.R. 1990. Crisis in the world's fisheries: people, problems, and policies. Stanford, CA: Stanford University Press.

Musgrave, R. 1969. Cost-benefit analysis and the theory of public finance. *J. Econ. Liter.* 7(3):797-806.

National Academy of Sciences. 1997. Striking a balance: improving stewardship of marine areas. Washington, DC: National Academy Press.

North, D.C. 1992. Transaction costs, institutions, and economic performance. San Francisco, CA: ICS Press.

Ostrom, E. 1990. Governing the commons: the evolution of institutions for collective action. New York, NY: Cambridge University Press.

Opaluch, J.A.; Grigalunas, T.[A.] 1984. Controlling stochastic pollution events through liability rules: some evidence from OCS leasing. *Rand J. Econ.* 15(1):142-151.

Opaluch, J.A.; Grigalunas, T.A.; Mazzotta, M.; Johnston, R.J.; Diamantides, J. 1999. Recreational and resource economic values for the Peconic Estuary. [Report prepared *for:* U.S. Environmental Protection Agency, Peconic Estuary Program.] Kingston, RI: Univ. of Rhode Island.

Pauly, D.; Christensen, D.; Dalsgaard, J.; Froese, R.; Torres, F., Jr. 1998. Fishing down marine food webs. *Science* 279:860-863.

Pollnac, R.B. 1992. Multi-use conflicts in aquaculture -- sociocultural aspects. *World Aquacult.* 23(2):16-19.

Pollnac, R.B. 1984. Investigating territorial use rights among fishermen. *Senri Ethnol. Stud.* 17:285-300.

Portney, P.R. 1994. The contingent valuation debate: why economists should care. *J. Econ. Perspect.* 8(4):3-17.

Rorholm, N.; Lampe, H.C.; Marshall, N.; Farrell, J.F. 1967. Economic impact of marine-oriented activities – a study of the Southern New England marine region. Kingston, RI: Univ. of Rhode Island, Agricultural Experiment Station.

Rosen, S. 1974. Hedonic prices and implicit markets: product differentiation in pure competition. *J. Polit. Econ.* 82(1):34-55.

Rowley, C.K.; Tollison, R.D.; Tullock, G., editors. 1988. The political economy of rent-seeking. Boston, MA: Kluwer Academic Publishers.

Russell, S. 1994. Institutionalizing opportunism: cheating on baby purse seiners in Batangas Bay, Philippines. *In:* Acheson, J.M., ed. Anthropology and institutional economics. Lanham, MD: University Press of America; p. 87-108.

Schultz, C. 1975. Public use of the private interest. Washington, DC: Brookings Institution Press.

Sherman, K. 1997. Large marine ecosystems: assessment and management from drainage basin to ocean. [Paper prepared *for:* Joint Stockholm Water Symposium/ EMECS Conference.] Narragansett, RI: National Marine Fisheries Service.

Sherman, K.; Alexander, L.M.; Gold, B.D. 1993. Large marine ecosystems: stress, mitigation and sustainability. Washington, DC: American Association for the Advancement of Science.

Sherman, K.; Grosslein, M.; Mountain, D.; O'Reilly, J.; Theroux, R. 1988. The continental shelf ecosystem off the northeast coast of the United States. In: Postma, H.; Zijlstra, J.J., eds. Ecosystems of the world 27: continental shelves. Amsterdam, The Netherlands: Elsevier; p. 279-337.

Sherman, K.; Jaworski, N.A.; Smayda, T.J., editors. 1996. The Northeast Shelf Ecosystem: assessment, sustainability and management. Cambridge, MA: Blackwell Science.

Solow, R. 1992. An almost practical step toward sustainability. Washington, DC: Resources for the Future.

Stratton Commission [Commission on Marine Science, Engineering and Resources]. 1969. Our nation and the sea: a plan for national action. Washington, DC: U.S. Government Printing Office.

Tyrrell, T.J. 1982. Estimating the demand for Rhode Island public recreation areas: a combined travel cost - hypothetical valuation approach. *Dep. Resourc. Econ. Work. Pap.* 11. Available *from:* Univ. of Rhode Island, Kingston, RI.

Underdal, A. 1980. Integrated marine policy: What? Why? How? *Mar. Policy* 4:159-169.

UNEP [United Nations Environment Programme]. 1998. Conference of the parties to the Convention on Biological Diversity. Report of the Workshop on the Ecosystem Approach. *UNEP/CBD/COP/4/Inf.* 9. Available *from:* Secretariat of the Convention on Biological Diversity, Montreal, PQ.

USDOC/NOAA [U.S. Department of Commerce, NOAA]. 1993. Report of the NOAA Panel on Contingent Valuation. *Fed. Regist.* 58(10):4602-4614.

Vallega, A. 1992. Sea management: a theoretical approach. London, England: Elsevier Applied Science.

van den Bergh, J.C.J.M. 1996. Ecological economics and sustainable development, theory, methods, and applications. Brookfield, MA: Edward Elgar.

Victor, P.A. 1972. Pollution economy and the environment. London, England: George Allen and Unwin.

Von Moltke, K. 1997. Institutional interactions: the structure of regimes for trade and environment. *In:* Young, O., ed. Global governance. Cambridge, MA: MIT Press; p. 247-272.

Walters, C. 1986. Adaptive management and renewable resources. New York, NY: Macmillan.

World Bank. 1995. Monitoring and evaluation guidelines for World Bank - GEF international waters projects. Washington, DC: The World Bank, Environment Department.

Zeckhauser, R. 1981. Preferred policies when there is a concern for probability of adoption. *J. Environ. Econ. Manage.* 8(3):215-237.