CHAPTER 2
What Do Managers Need?

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From national and international perspectives, there have been clear calls for a move toward ecosystem-based approaches to management and numerous efforts to define it. However, many managers remain unclear about just what an ecosystem-based approach entails and are seeking tangible advice for moving forward with implementation.

An ecosystem approach to management is intended to directly address the long-term, sustainable delivery of ecosystem services and the resilience of marine ecosystems to perturbations. It encompasses both a process for the development of policy actions and a conceptual framework for the formulation of policy principles, goals, and objectives. Most importantly, the ecosystem-based management (EBM) concept helps guide the development of these goals for a given ecosystem, that is, conserving the delivery of the full range of services from a particular system.

Fortunately, EBM has now been implemented in several marine areas, including areas within the United States, Canada, Australia, New Zealand, and the European Union (Garcia et al. 2003; Lafolley et al. 2004; SAFMC 2004; Frid et al. 2005; NOAA 2006; Merrick et al. 2007; Rosenberg et al., chap. 16 of this volume). However, challenges remain, relating to both the scientific support structure for EBM and to taking management actions (e.g., Sandifer and Rosenberg 2005). There are institutional as well as technical issues to be resolved, as we discuss below. The strategies for attaining ecosystem goals—that is, the general management approach—and tactics or specific measures taken to realize these strategies are the essence of implementation and will be specific to a particular ecosystem and management setting. Here we describe the principles of EBM and the challenges to developing strategies and tactics for implementation of an ecosystem-based approach to policymaking.

EBM Principles for Managers

From a management perspective, five principles can guide the development of an ecosystem-based approach (see box 2.1): (1) setting goals that include the full range of ecosystem services, (2) determining the spatial scale for management planning, (3) integrating across sectors of human activity (e.g., transportation, fisheries, energy production, recreation), (4) accounting for cumulative impacts within and across sectors, and (5) making decisions under uncertainty. Note that principles addressing these areas should be accounted for in all management planning. Particular to an ecosystem-based approach is that the ecosystem (including humans) and its services become the organizing framework for management (see also Juda 1999; Shepherd 2004; McLeod et al. 2005; Leslie and McLeod 2007).

Setting Goals

Goal setting is a critical function for management planning (e.g., Clark 2002). The setting of goals shapes the effort to develop workable policy in practice. For example, a sole focus on the goal of obtaining a specific level of abundance of a single species or even a group of

Box 2.1. Principles of Ecosystem-Based Management

The essence of an ecosystem-based approach to management rests on five basic principles:

1. **Diverse ecosystem service provision**:EBM focuses on the ability of the ecosystem to continuously provide the services that support human well-being and includes recognition that humans are inherently part of the ecosystem. Such ecosystem services go beyond simple extractive uses, such as fisheries harvest, and can be categorized as having provisioning, supporting, regulating, and cultural roles for society (MA 2005; McLeod and Leslie, Chapter 1 of this volume).
2. **Importance of natural boundaries**:Management recognizes that natural boundaries are more relevant to the conservation of ecosystem services than artificial boundaries (e.g., between legal jurisdictions) and that these natural boundaries are highly porous.
3. **Integrated management**:Management strategies of the various sectors of human activity that potentially impact a particular marine ecosystem can affect one another and require some level of management integration if those impacts are to be adequately controlled.
4. **Accounting for cumulative impacts and necessary trade-offs among services**:Impacts of human activities on a given ecosystem are often cumulative across time and space, with each activity or impact contributing to overall ecosystem change and the cumulative effect determining how the ecosystem continues to function. Moreover, policy decisions are not likely to have the same effect on all services. Some explicit decisions that involve trade-offs in services among sectors must be made. If management is not integrated across the sectors of human activities, these trade-offs are often implicit or completely ignored, with potentially disastrous and usually unintended results.
5. **Making decisions under uncertainty**:Management decisions should be made in the context of a precautionary approach as elaborated by the US Commission on Ocean Policy (2004), that is, by relying on the best available information and management practices from the beginning, weighing decisions in light of the level of uncertainty of available information and the level of potential risks to the ecosystem, and including continued gathering and analysis of information, with periodic reassessment and modifications of permit conditions or other requirements.

species (e.g., marine mammals) may place great constraints on subsequent policy choices. Each statute—for example, from the United States, the Magnuson–Stevens Fishery Conservation and Management Act (MSA), the Marine Mammal Protection Act, or various wetlands protection laws—sets goals for that activity or sector, most often in isolation from others or as if the impacts of areas of management concern are of minor importance. This approach shapes overall ocean policy by isolating decisions among sectors. In an ecosystem-based approach, goal setting is based on the concept of sustaining the delivery of a full range of ecosystem services (McLeod et al. 2005; Palumbi et al. 2009) and ensuring that the ecosystem does not lose its inherent resilience, that is, its ability to absorb perturbations and recover (Walker and Salt 2006; Leslie and Kinzig, chap. 4 of this volume). Addressing these ecosystem-level goals cannot be achieved by each sector in isolation. It necessitates integration.

Establishing goals for conserving services and maintaining or enhancing resilience will be affected by the scale defined for each ecosystem. There is no one "correct" scale for management, and the boundaries between ecosystems will always be fuzzy, porous, and zones of conflict. Nonetheless, the intent of focusing management effort at the ecosystem scale—whatever that might be in a particular situation—is to facilitate the ability of policymakers to consider factors affecting the production of the full range of ecosystem services and to have a coherent basis for evaluating impacts on ecosystem resilience. Managers need to focus on more natural or scientifically delimited boundaries of ecosystems, such as major biogeographical features or the well-established limits of large marine ecosystems (LMEs) (Sherman and Skjoldal 2002; Fanning et al. 2007), rather than on the often artificial borders established by political jurisdictions (e.g., state borders, territorial sea lines, limits of the exclusive economic zone). As NOAA

(2004) concluded, "The chief goal of any delineation scheme is to develop a geographic frame of reference that is useful in describing biological populations, their interactions, and the effects of human activities that influence ecosystem outcomes."

Determining the Spatial Scale

In a sense, using ecosystem boundaries rather than jurisdictional boundaries should minimize the number of factors outside the boundaries of the management system that need to be considered. It is never possible for natural systems (particularly marine systems) to be entirely self-contained, and many factors that affect ecosystems cross arbitrarily defined boundaries. For example, climate change is likely an external driver that cannot be "managed" within the boundaries of any one marine ecosystem. However, action can still be taken within a given ecosystem to help mitigate and adapt to climate change (see Kliskey et al., chap. 9 of this volume; Leslie and Kinzig, chap. 4 of this volume). Also, market forces for services are likely to be affected by multiple ecosystems. However, it is better to be able to consider ecosystem functioning, and the impacts of human activities on resulting services, as completely as possible.

Clearly, there are effects of the choice of boundaries with the setting of specific ecosystem goals. If ecosystem boundaries are defined at a small scale, goal setting may be simplified, but attaining those goals will be more difficult because there will likely be more external factors. If boundaries are broad, then the dimensionality of the goals will increase substantially, simply because there are likely more "parts" to the ecosystem. Yet, policy could be more coherent across the sectors of human activity and might work better in attaining goals by being more inclusive of all the human impacts within the ecosystem. For example, managing just the estuary of a single watershed may be workable and allow clear goals to be set, but it may be very difficult to achieve ecosystem-level goals without the ability to manage interactions with drivers occurring at a larger scale. On the other hand, global action to address marine ecosystem protection may be effective in one sense, but setting goals at the global scale may be next to impossible. In practice, a balance must be found in setting ecosystem boundaries between these two extremes. Realistic boundaries for EBM, certainly at the regional scale, are generally going to be larger than the watershed of a single, small estuary but may be smaller than an LME. Delineating a finite number of regional ecosystems that can become the foci of management efforts will entail a compromise between our understanding of biological populations and oceanographic processes and the established structure of human institutions and political jurisdictions (NOAA 2004). For the United States, one approach worth considering (and that advocated by the US Commission on Ocean Policy [2004]) would be the ecoregions defined by the eight regional fishery management councils (fig. 2.1).

Integrating Across Sectors

Integrating management across sectors of human activity, such as linking up fisheries management actions with water quality management and coastal development, is key to an ecosystem approach. However, while critical, such integration is not independent from the other principles. It is possible to integrate management actions (and there is substantial literature on integrated management, e.g., Cairns and Crawford 1991; Cicin-Sain and Knecht 1998) without a focus on the goals of maintaining the ability to provide a full suite of ecosystem services or maintaining resilience. Integrated management without ecosystem goals might improve efficiency of management and streamline some regulations and controls, but it will not help to ensure ecosystem

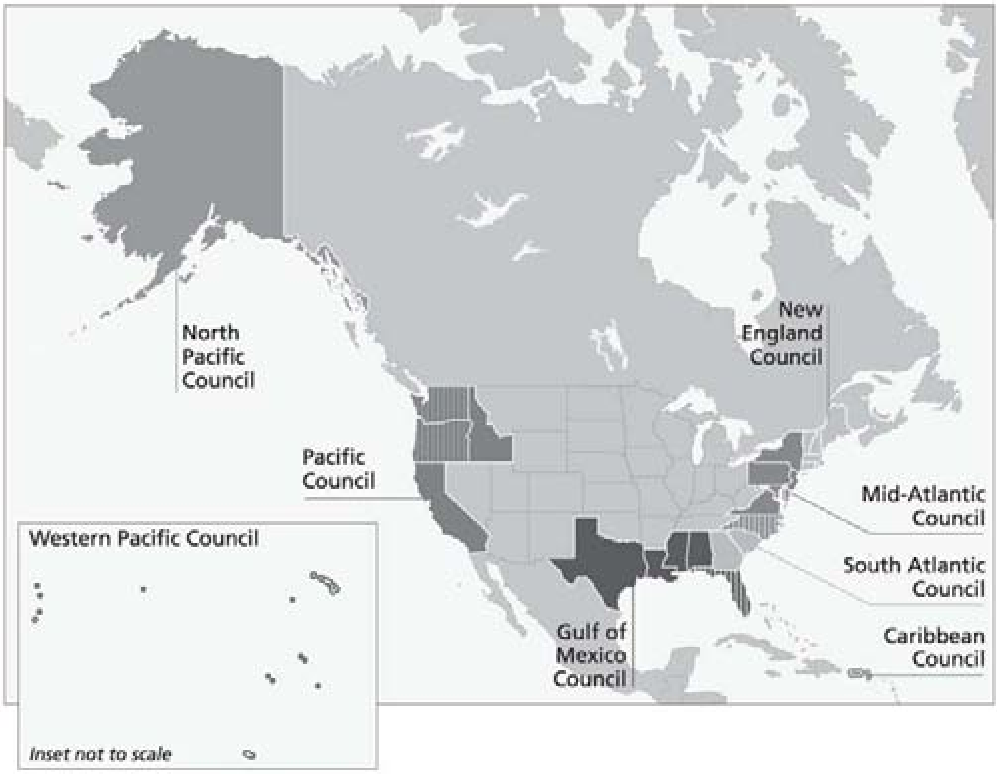

Figure 2.1 Eight regional fishery management councils manage the harvest of resources within the United States. Several states, illustrated with vertical lines, belong to more than one council. For example, Oregon and Washington are both members of the Pacific and the North Pacific councils. The US Commission on Ocean Policy (2004) advocated that these ecoregions be used to define the boundaries of regional marine ecosystems in US waters.

resilience. As discussed in chapter 1, it is the integration across sectors that enables policy to address conflicts and synergies and allows simplification of management to meet multiple objectives. Similarly, integrating the scientific advice for a given ecosystem will reveal policy options as well as new avenues for investigation beyond any one discipline's or sector's conventional view.

Accounting for Cumulative Impacts and Trade-offs among Services

Recognizing and accounting for the cumulative effects of human activities is difficult but, nonetheless, necessary for management to address EBM goals. A simple example is modification of wetlands. In a thousand-hectare area, perhaps filling or dredging a hectare or two may not affect the functioning of the wetland (such functions include sediment trapping, exporting of productivity, providing nursery and feeding areas for a variety of species, and supporting recreation and other cultural activities). But suppose two hundred permits are requested for one hectare each over time? At what point are the ecosystem services provided impaired? Should permits be issued on a first-come, first-served basis, or some other criterion? At what point do the minor impacts of each individual permit cascade into a major cumulative effect? Are the services provided by the filled or dredged areas more important than the natural wetland areas? To what limit? These questions relate directly to the principle of evaluating trade-offs between different services and user groups.

Under sector-by-sector management, trade-offs within a sector may be considered, but those among sectors are largely ignored and often remain unaccounted for. Suppose coastal development of harbor facilities is to be managed. What are the trade-offs between space for recreational vessels, commercial fishing vessels, and commercial transport vessels? What about working waterfront areas versus tourist areas, or natural coastal areas and developed areas? How should the decisions be made? In a sector-by-sector management system, fisheries managers might comment on harbor needs but might not have direct input into the management process for coastal planning. Recreational and commercial fishing interests each might push for as much space as possible, but other than political pressure, what is the means of resolving the trade-offs between these groups? What is the forum for considering overall need and for evaluating effects—both potentially beneficial and negative—on other sectors or industries? About the only process currently available in the United States is the environmental-permitting system operated by the state coastal zone management agencies and the US Army Corps of Engineers and related environmental impact analysis requirements. However, this system also typically deals with one permit at a time. Generally, no comprehensive, regionwide evaluations are conducted, and without some clear analysis of alternatives, political considerations may dominate. There are often transport plans, coastal zone management plans, fishery plans, and others, but the trade-offs among these sectors can only be evaluated if planning is integrated (box 2.2).

> **Box 2.2. Regional Ocean Councils**
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> Both US ocean commission reports (POC 2003; USCOP 2004) included substantial consideration of regional ocean councils. Such councils or other regional coordinating mechanisms provide an opportunity for the cross-sectoral discussions, associated information gathering, and clearinghouse functions that must occur in order for an EBM approach to be implemented. It is important to link the efforts to create coordinating bodies with the development of science infrastructure in order to build a coherent system. Regional councils or other coordinating entities do not supplant the need for sectoral management plans, though hopefully they would bring new considerations to bear as well as create better management across the board. Recent interest at the state level, as expressed through the initiation of several interstate, ecoregional alliances, provides leadership examples that the federal government could emulate and opportunities to establish regional governance entities.

Making Decisions under Uncertainty

There is inevitable uncertainty in the status and dynamics of any ecosystem, our knowledge about that system, and the effects of potential management actions. Management must determine how to proceed in implementing policy with imperfect information and substantial uncertainty in almost all cases. Given the focus on conserving ecosystem services and resilience in an EBM approach, a precautionary approach to management (Rosenberg 2002; USCOP 2004; Rosenberg 2007) is clearly necessary; that is, to avoid irreversible changes, be more cautious when uncertainty about the impacts of an activity is greater, and evaluate potential impacts before allowing activities to move forward, rather than allowing them first and trying to recover later.

Challenges to Implementing Ecosystem-Based Management Policies

Implementing an ecosystem-based approach under the five principles outlined here is no simple task. From a manager's perspective, there are both incentives and disincentives to apply these principles. The clear incentive is that an ecosystem-based approach is more comprehensive, and theoretically it should result in more effective and successful management if success is to be measured principally in terms of long-term sustainability and the continued delivery of necessary and desired ecosystem services. Comprehensiveness is more effective because it does not ignore the interaction between management actions nor the cumulative nature of impacts, as often occurs with sector-by-sector management. It is unlikely in real systems that these interactions and cumulative effects are negligible and can be safely ignored (Halpern et al. 2008). EBM attempts to deal with these interactions and cumulative effects up front, where choices and trade-offs can be made consciously, as opposed to simply allowing them to happen with unknown and unconsidered consequences.

For example, water quality, coastal development, and fishery productivity are almost certainly related in most systems because the former two human impacts affect the productivity of fisheries habitat. While some efforts over the last 10 years have been made to include the consideration of fisheries habitat in the fishery management process (Rosenberg et al. 2000), these fall far short of integration, because neither the goals for each sector nor the impacts of each on the other are jointly addressed. Rather, the mandate to protect essential fish habitat relates mostly to potential impacts of fishing itself, along with weak provisions to consult with other sector managers on actions that might impact habitat. There is no consideration of trade-offs nor a clear focus on a broader range of ecosystem services. Clearly, managing ecosystem services such as essential fish habitat in a more integrated way will be very challenging. When the mandate was first created in the 1996 amendments to the MSA (NMFS 1996), several groups such as the National Association of Home Builders became concerned that home building would be impacted by fishery management planning (Rosenberg, personal observation). Bringing together more sectors brings a broader array of constituencies into the management arena.

If all the sectors are managed separately, there is no real opportunity to leverage actions across the ecosystem as a whole. This will only occur if an integrated or comprehensive management approach is taken where all managers involved consider the same things and, to the degree possible, use a common approach (Rosenberg and McLeod 2005; Palumbi et al. 2009). Consider, for example, the complex set of marine protected areas in the Gulf of Maine (fig. 2.2). Each area was established for a different purpose and usually for a single sector or part of a sector, such as a specific fishery. The areas do not complement or leverage one another, and the result is an overlapping set of requirements that have been somewhat effective in providing some ecosystem protections, such as leading to partial fish stock recovery (Rosenberg et al. 2006) or habitat protection (Collie et al. 2005; Grizzle et al. in press). But these successes are fragmentary and fall far short of EBM goals of maintaining ecosystem services as a whole, even though each may have had some success for a given particular resource. If the protected areas were designed to meet multiple purposes and rationalized to be a non-overlapping set of protections, then they would also be more coherent to the affected community on the water.

Beyond just the creation of protected areas, if the goals for ecosystem services and resilience were considered together, it should be possible to simplify the rules to determine whether sets of activities should be prohibited

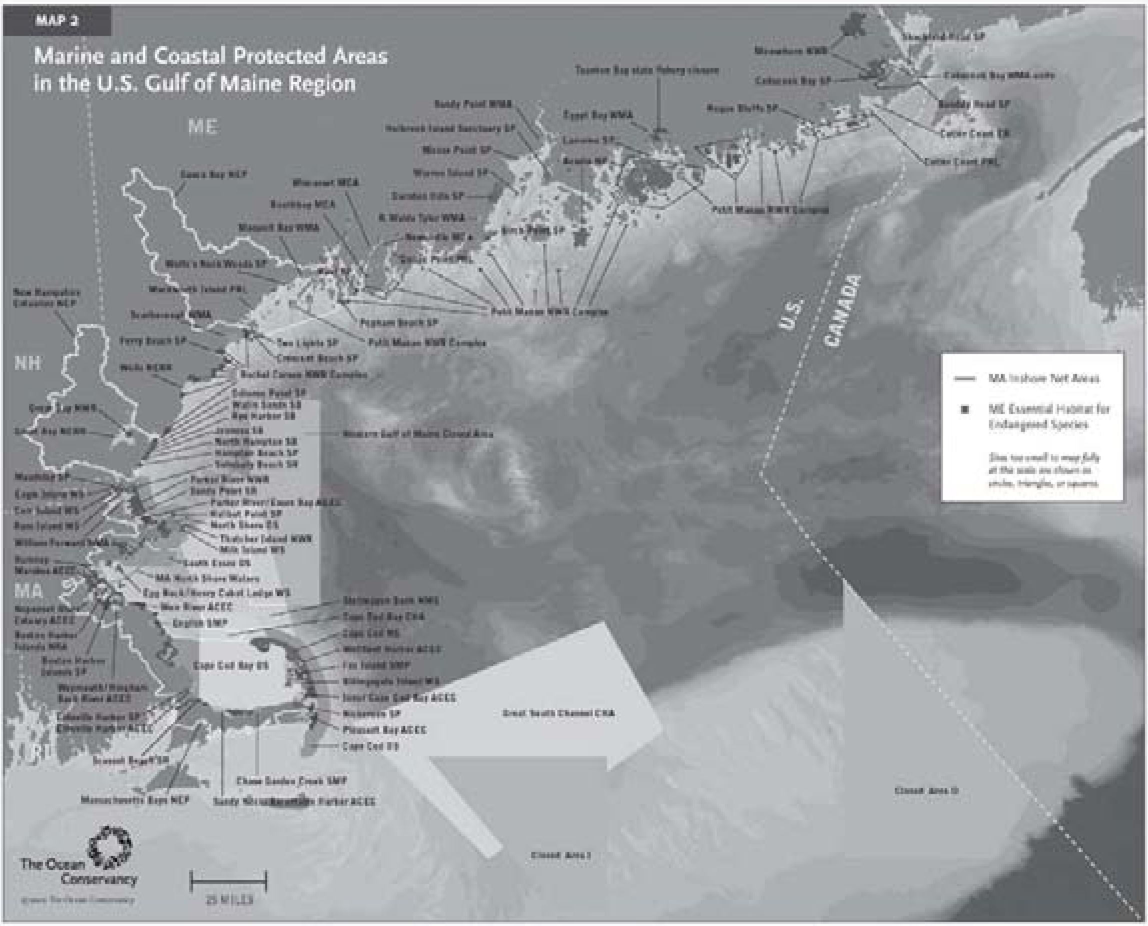

Figure 2.2 Closed areas in the Gulf of Maine illustrating the complexity of management on a sector-by-sector basis. Adapted from Recchia et al. 2001 and reprinted with the permission of The Ocean Conservancy.

or allowed within different areas in a system of contiguous zones, much as occurs on land. While many interest groups are wary of a zoning approach in the ocean, the results may ultimately be more coherent and simpler that the current fragmented approach (Crowder et al. 2006; Young et al. 2007).

Current sector-by-sector management has a set of procedures that is well known by those tasked to implement policy. The mandates are reasonably clear—for example, to achieve optimum fishery yields, or fishable and swimmable waters. Taking an ecosystem-based approach means changing those procedures. As with most human activities, change is difficult. As a result, managers are likely to be conflicted with respect to their desire to implement EBM. The goals of EBM are widely accepted by managers, but the changes needed to attain those goals mean working outside of the existing boundaries for sectoral management. Management implementation in each of the sectors of ocean activities, such as fisheries, water quality, habitat conservation, protection of species at risk, transportation, or energy development, is intensely controversial and already difficult under the current system. Getting managers to take on EBM, with its new controversies, broader constituencies, and more-complex decision making that involves trade-offs and interactions with other sectors, even if it may be the right thing to do, is a major challenge and will require that new mandates and management systems be developed carefully (USCOP 2004).

In statutory language, the goal of maintaining the full range of ecosystem services across sectors is addressed in only a general sense, as noted above. For example, the MSA calls for fisheries to be managed for optimum yield, defined as maximum sustainable yield as reduced by relevant social, economic, and ecological considerations. The 2007 reauthorization of the MSA strengthens the role of science in setting these limits and takes some steps toward developing ecosystem plans but still focuses on fisheries yield as the primary goal. The extent to which a specific plan should include reductions from maximum yield is a matter for fishery management councils to decide and justify. Technically, it may be justifiable to decide that only a very low yield will be allowed because it is more important to produce another service at a high level (e.g., allow only a low yield of forage species because of the desire to increase whale-watching opportunities near shore, or a low yield of an anadromous species because of hydropower or transportation needs). But is it reasonable to expect that a council set up to manage fisheries and composed of officials, representatives, and individuals knowledgeable about fisheries will decide to reduce fishery productivity to meet the needs of another sector when that other sector has only minor involvement in the fishery management process, and vice versa? To take another example, recreational and commercial fisheries both depend on port facilities in one way or another. But port facilities may impact natural barriers that provide storm protection, or water quality, or habitat conservation. Should we expect fishery managers to reduce fishery yields to reduce the demand for ports? While these examples are intended to be illustrative and not exact (each is far more complex than described here), the problem should be clear. If trade-offs are only considered within a sector, then policy choices will be made implicitly and not explicitly with regard to the suite of ecosystem services from any given system.

It is the governance structures at the federal, state, and tribal levels that must set the goals for policy and the approach to making decisions with respect to trade-offs among services. That is, legislative bodies must create the mandates, because each administrative agency at the various levels does not have a sufficiently broad purview to cover the spectrum of services. At the administrative or implementing level, specific coordinating mechanisms must be put in place to work through the interactions between management actions, and these coordinating mechanisms must be able to make decisions that have real impacts on the individual agency actions. That means that the statutory mandate has to set up means to create decision rules or give the authority to some entity to create those decision rules for how to resolve conflicts and interactions.

Then too, there are human resource and funding issues. Most managers and scientists see development of an ecosystem-based approach as something additional to do, not a different way of doing things. Natural resource agencies and science efforts are often understaffed and underfunded. Providing more funds and resources for regulatory efforts may not be the most popular political initiative in debates over spending priorities. But EBM will not happen without additional human resources and funding, even if the long-term prospect is a more coherent and efficient system that better maintains provision of critical ecosystem services.

Developing the Science for an Ecosystem-Based Approach to Management

Natural and social scientists certainly understand that marine ecosystems, including the roles of humans and their individual and collective actions within those systems, are highly interconnected (Shackeroff et al., chap. 3 of this volume). While the principles given above are not necessarily universally accepted in the scientific community, there is broad agreement on the interconnectedness and complexity of marine ecosystems and the importance of taking a more integrated approach to management (McLeod et al. 2005). So, does it follow that scientists want and are prepared to implement an ecosystem-based approach and are waiting for managers to act? And does it follow that managers want to implement EBM and are just waiting for scientists to provide a workable blueprint?

The role of science in policy and management is to provide advice on conservation limits, impacts, and projected changes in the ecosystem (including humans) under different management scenarios. A key area of advice should relate to ecosystem resilience, that is, the ability of the system to recover from both acute and chronic impacts (Leslie and Kinzig, chap. 4 of this volume). This is reflected in statements describing the precautionary approach, for example, those that emphasize the avoidance of irreversible changes. Science is not policy but, rather, informs policy and management. Scientists certainly want management to work better and thus have the same incentive as managers to support a more comprehensive approach to management, such as EBM, that accounts for interactions and cumulative impacts. But many of the same disincentives for managers apply to scientists as well. The current system of sectoral management requires scientific advice using generally known procedures and involves scientists from a limited number of disciplines and with specifically applicable expertise. The mandates are well known, and the constituencies scrutinizing the advice are well established. While scientific advice in almost all sectors can be highly controversial, it is reasonably predictable, though often limited in its influence on how management proceeds in practice. Still, it is critically important to recognize that questions raised by managers must fit within the existing scientific framework for a particular sector. Otherwise, those questions will remain unanswered.

Change is as difficult for scientists to accept as for managers; a new requirement to work outside of their “known world” and with other scientists and managers who have widely different backgrounds, expertise, and perceptions is likely to be intimidating or unacceptable for some. Additionally, in many scientific analyses, the first step is often to simplify the problem to make it as tractable as possible. Considering ecosystem interactions and cumulative impacts in management decisions is a major complication that makes analyses much more difficult. For example, procedures to develop fishery stock assessments and measure fishery performance with regard to accepted conservation standards are well known and routinely implemented (see Hilborn and Walters 1992; NRC 1998). Management is, nonetheless, difficult and controversial, and by extension, so is the scientific advice underpinning the management decisions. However, the inclusion of the cumulative impacts of habitat changes and fishery effects as well as trade-offs with, say, energy development, coastal land use, or water quality are much more complicated, and procedures for doing so are poorly defined to date. Under the time pressure to move forward with management, providing advice in an already contentious environment will become a key challenge for scientists when such interactions are included.

Developing a Scientific Advisory Structure for EBM

If a scientific advisory structure is to be developed for EBM, do we know enough about ecosystem interactions, cumulative effects, and trade-offs between services to provide useful advice to management? Clearly, detailed knowledge of ecosystem structure, functioning, and dynamics is incomplete and uncertain in virtually all cases. But we do know some of the key interactions, we have observed changes in numerous ecosystems, and we have sufficient information from other, similar ecosystems to advise management on likely impacts of human activities. We also know, to a great extent, the consequences of many types of human impacts and of the past and present management of those human activities. In addition, there is little uncertainty about what needs to be done about major problems such as overfishing (i.e., reduce exploitation) and wetlands loss (i.e., reduce filling, channeling, and loss of sediment and water flow).

For many ecosystems, it should be possible to begin to synthesize systemwide patterns of change by combining information obtained across various sectors, such as fisheries, energy production, water quality changes, and coastal development. This amounts to a baseline assessment of the status of an ecosystem that can be used to evaluate the likely effects of new activities and the potential impact of changes to management (USCOP 2004; DEFRA 2005). It is also important to not only be forward-thinking, but also develop a historical perspective of ecosystem changes (e.g., Jackson et al. 2001; Rosenberg et al. 2005), rather than assume the current state of the environment is all that can be achieved. This is particularly critical as rebuilding and recovery plans are formulated for various ecosystems.

Many sectors of human activity have extensive infrastructures for science advice to guide management. One of the most highly developed systems provides science advice to support fishery management. The field of fisheries science is rather small, with only perhaps a few hundred scientists providing advice for marine fisheries nationwide within the United States and a few thousand engaged in science and research on fisheries within academia and all levels of government. However, the federal, state, and tribal agencies responsible for fisheries almost invariably include a scientific advisory staff and, often, active researchers. The federal government has regional fishery science centers around the country that include research, monitoring, and management advice as part of their missions. In fact, NOAA's National Marine Fisheries Service (NMFS), the primary federal agency responsible for marine fisheries, marine protected species, and fishery habitat conservation, is composed roughly of two-thirds science personnel and associated budget to support them and only one-third management and policy implementation. NMFS staff routinely collaborate with researchers in other federal agencies (e.g., the US Fish and Wildlife Service and the US Geological Survey) and with those in state and tribal agencies and in academia.

The federal, state, and tribal scientists work together to provide advice to federally managed fisheries and for a number of other fisheries managed by interstate bodies such as the Atlantic States Marine Fisheries Commission. For federally managed fisheries, the management plans are crafted by eight regional fishery management councils made up of state and federal officials and knowledgeable constituents from the region, with scientific support provided by a mature network of federal, state, tribal, and academic fisheries scientists and a growing number of social scientists. Those management plans are submitted by the councils to NMFS for approval and implementation. Approval is contingent upon the plans meeting, in the judgment of the US secretary of commerce through NMFS, ten national standards for management and other provisions laid out in the MSA, which was updated and reauthorized in early 2007. Several of the national standards and provisions of this law relate directly to scientific advice, including the mandate to use the "best science available" in setting management goals, strategies, and tactics. For example, the MSA requires the plans to prevent overfishing and, in cases where overfishing has occurred, to rebuild overfished stocks to a level able to provide maximum sustainable yield on a continuing basis. Fisheries scientists use well-developed methods for estimating maximum sustainable yield or related reference points and for estimating stock status. Improved methods are being developed and implemented on an ongoing basis as they are accepted within the scientific community. In addition, the MSA requires consideration of impacts on habitat from fishing and other activities as part of considering ecosystem-level effects, but it does not require implementation of an EBM approach to fisheries management. However, it does now mandate a study of how EBM might be applied.

The scientific advice for each management plan is required to undergo extensive peer review before it is deemed the "best available." To this end, there are regional peer review workshops, panel reviews, and sometimes special external reviews, including some by the National Academy of Sciences, that evaluate the scientific advice for each fishery in great detail. These peer reviews are far more extensive than the usual academic review of journal articles with panels of four to ten or more scientists considering the methodology, data, and conclusions in detail. Alternative data and analyses are considered, public comment and scrutiny are included as well as comment and submissions from constituent groups, and in general the reviews are held to a very high standard. Each of the regional fishery management councils has a science and statistical committee (SSC) to review the results of the peer reviews and ensure that the council is receiving the best advice possible. Recent changes to the MSA require the use of these SSCs in setting conservation limits for each target stock of fish. However, the advice provided by the SSCs is typically limited to the fishery sector, with little consideration of information from other sectors such as coastal zone management, port management, coastal development, and so forth. While this may be changing incrementally in practice (e.g., see SAFMC 2004), there is as yet no policy requirement or established procedure to incorporate scientific information from these other sectors into fishery management decision making or vice versa.

This is a very highly developed system that is costly, laborious, and reasonably effective, but still fisheries management is very far from perfect. Stocks are still overfished, advice is not always followed (e.g., Sandifer and Rosenberg 2005), and it is sometimes incorrect. The review system notwithstanding, data are often inadequate despite the infrastructure, and everyone working within the system would probably agree that the scientific enterprise to support fishery management is substantially underfunded. Despite these problems, fisheries management has begun to turn around some of the long-standing problems of overfishing and stock rebuilding. Although such change is happening more slowly than many would like, it is based upon clear and supportable scientific advice (Rosenberg et al. 2006).

There is no comparable scientific advisory system for other important marine sectors, such as coastal development, habitat management, coastal tourism, transportation management, or even energy development. That is not to say there is no science advice for these sectors, but the scientific structure underpinning decision making is far less developed and institutionalized, and there is less infrastructure to provide supporting research, monitoring, evaluation, and the preparation of targeted scientific advice in a standard way. Also, there are no clear parallel institutions to NOAA's regional fishery science centers, not even for something as fundamental and important as water quality or energy. Of course, the Environmental Protection Agency has laboratories and monitoring systems and works directly with state monitoring programs, but these are not integrated into the management process regionally or nationally as is the case for fisheries.

The intent of the foregoing brief description of the fishery management system is not to laud or defend fishery science and management, but rather to provide context for consideration of the challenges to developing the scientific infrastructure for broader ecosystem-based management. Creating a system for the provision of advice for ecosystem-based management across a number of sectors will require a number of changes, including those listed in box 2.3. Much of the expertise for such a science advisory process already exists, and many of the activities already under way have laid a foundation. The institutional infrastructure can be virtual, but it must exist in some form and will take resources and an ongoing commitment from government to make it work. There are clearly new areas to develop, including the creation of ecosystem scenario analyses that can be used to guide management. Perhaps most importantly, EBM scientific advice must be interdisciplinary to a greater extent than has been attempted in the past within any one sector (Leslie et al. 2008).

For example, exploring the interactions and trade-offs between management policy options requires a significant interdisciplinary effort among numerous and diverse areas of both natural (e.g., biology, ecology, fisheries, genomics, oceanography) and social (e.g., anthropology, economics, political science, sociology) sciences. This is a critical area of work for implementation of EBM because one of the reasons for moving toward a more comprehensive management approach is in order for trade-offs to be considered explicitly, rather than having the trade-offs continue to occur as the unintended consequences of various management actions. One option is to value the services, using a common methodology or ecological "currency," and then develop decision tools that allow relative values of different policy scenarios to be compared (see Wainger and Boyd, Chap. 6 of this volume). But the valuation task itself is complex, as many ecosystem services do not yet have established market values, and some may never have such values. Development of a process to place widely accepted market values on a variety of ecosystem services is a very active area of research combining economics and other social sciences with the natural sciences of ecosystem dynamics (e.g., Meyerson et al. 2005). Another approach would be to consider one key property, such as biodiversity, as a common focus of management and basis for comparison of management alternatives (Palumbi et al. 2009). Recent work has related conservation of natural biodiversity to maintenance of several important ecosystem services, including fishery productivity and resilience in both marine (Worm et al. 2006; Palumbi et al. 2009) and terrestrial (e.g., Butler et al. 2007) systems.

Recent Progress and Next Steps

There is no current policy mandate to synthesize scientific knowledge across sectors to support EBM, and no comprehensive administrative framework exists to support integrated ocean management in the United States despite calls for such from both ocean commissions (POC 2003; USCOP 2004). The Bush Administration's US Ocean Action Plan (US Executive Branch 2004) response to the USCOP (2004) report included an explicit commitment to ecosystem-based resource management. Additionally, the newly reauthorized and amended MSA requires some evaluation of EBM for application to fisheries, and a comprehensive system could be developed using the fisheries advisory system as a model. Creating ecosystem assessments using the scientific infrastructure for EBM suggested above is an important step in synthesizing our current state of knowledge and will provide a basis for management and for planning a future research agenda (USCOP 2004; DEFRA 2005).

One ray of hope is provided by the recently released national Ocean Research Priorities Plan and Implementation Strategy developed by the US Joint Subcommittee on Ocean Science and Technology (JSOST 2007). This is the first comprehensive ocean research plan that involves every agency of the US government concerned in any way with ocean research. The overarching goal of the plan is "to provide the guidance to build the scientific foundation to improve society's stewardship and use of, and interaction with, the ocean." The plan focuses on three central elements of ocean science and technology: (1) capability to forecast ocean and ocean-influenced processes and phenomena, (2) development of scientific support for EBM, and (3) deployment of an ocean-observing system. These three—ocean forecasting, EBM, and ocean observing—permeate the entire document and its twenty national research priorities organized within six societal themes. The JSOST (2007) further recognized the breadth of scientific support and integration that would be needed to implement EBM, stating that "a multi-dimensional, multi-disciplinary effort to enhance current understanding of ecosystem processes, determine which interactions are most critical, and assess the dynamics of the natural and human factors affecting those interactions" would be necessary (see also box 2.4). Full development and implementation of the Integrated Ocean Observing System (IOOS) and other ocean and coastal observatories will provide a foundation of monitoring data that could enable and enhance management in many ocean sectors. An IOOS that includes not only high-resolution measurements in time and space of the physical and chemical properties within an ecosystem, but also biological attributes, and that incorporates high-resolution data on human activities within that ecosystem, would open up an entirely new world of information for management. Such a system and its related information flows would enable forecasting of ocean processes and phenomena, including severe storms, currents, status of fishery stocks and other biological resources, and human health risks. The requisite tools are rapidly becoming available, with a variety of data collection methods—from measurements of waves, temperature, currents, and productivity in real time with buoys, satellites, and radar to the monitoring of fishing activity with vessel-monitoring systems, and shipping with automated identification systems (USCOP 2004), and even development of a wide range of biological sensors (JSOST

Box 2.3. Some Requisites for Effective Science Support of Marine EBM

1. **Involvement of a wide range of professionals**: assessing the status and trends of major ecosystem services within reasonable ecosystem boundaries (such as the fishery management council regions; see fig. 2.1).
2. **Synthesis of information across sectors**: within each ecoregion and the creation of a dynamic data management system to track the latest observations of the natural system and associated human activities. These data need to be geographically referenced so that they can be overlaid on the ecosystem.
3. **Mechanisms and models for projecting changes**: due to management policies within each sector on all of the services within the region so that policy options can be explored in scenario analyses for the ecosystem.
4. **Peer review mechanisms to validate analyses**: in the synthesis and the scenarios (2 and 3 above; note peer review of 1 should be done within the sectoral science process) and peer review of the best advice and its translation into language readily understandable by managers, resource users, and the public.

Box 2.4. Data Integration for Marine EBM

Since many scientific efforts are focused within a given sector, assembling data for a more comprehensive view of a marine ecosystem and the human activities within that ecosystem is remarkably difficult. Sampling frames are disparate, time series are fragmentary, and data, particularly on business activities, are often considered confidential. Because so much of scientific recognition is based on publication, scientists are also often reluctant to make data they have collected freely available until they have published all the results they intend to publish, which may take a lifetime in some cases. Overcoming the hurdle of assembling comprehensive data is a major issue for implementation of EBM.

Data sets covering as many aspects of the natural system as possible, as well as the human activities within that system, must be geographically specific with well-accepted and documented procedures for interpolation to provide a clear picture of ecosystems in time and space. A dynamic atlas of each ecosystem will ultimately need to be assembled in order to support EBM.

2007; Sandifer et al. 2007). Using these new tools would allow management to operate on a spatial and temporal resolution that has never before been possible. However, developing new management strategies and tactics that can take advantage of such high-resolution information is an important area for growth and research.

A Way Forward

Implementing an EBM approach in practice is a major, revolutionary change in many aspects of ocean policy. Integration, focus on sustainability of services and resilience, and consideration of trade-offs between sectors reframe many of the long-standing debates over management measures for ocean activities. While incremental steps to improve management and account for the broader impacts of human activities within sectors of marine ecosystems are important and can be made, these are not a substitute for implementing an ecosystem-based approach to management. EBM will require major, overarching changes because integration and negotiating trade-offs are fundamentally different from tinkering around the edges of the existing management process. This does not mean that there is no role for sectoral management. Some fundamentals still pertain: Overfishing must still be prevented; contaminants and habitat damage must be minimized; protected species must still be protected. These are societal choices that will not be eliminated by an ecosystem-based approach. But a broader set of societal choices can now be made under EBM because interactions, cumulative effects, and trade-offs are of primary concern.

To implement EBM effectively, managers will need at least five things:

1. A comprehensive and clear legal mandate requiring the application of ecosystem-based management in the sector for which they have management responsibility and authority, and a mechanism to address cross-sectoral impacts, interactions, and trade-offs—this mandate must include the process of goal setting and a requirement to use a precautionary approach with respect to maintaining the delivery of ecosystem services.
2. An outline of what is expected of a manager operating under EBM requirements—this road map needs to be clear and as unambiguous as possible.
3. Summaries of the factors that might affect or be affected by each sector (e.g., fish, energy, water quality, tourism, coastal development, ports, transportation) in instructive and usable formats—it is critical that such information be made available to sectoral managers in action-relevant form through a structured process that includes peer review.

4. Scientific information that is cross-sectoral but also has clear relevance to a given sector (e.g., how water quality affects fisheries; how coastal development affects fish habitat)—such information must be provided, to the greatest extent possible, in geographically specified format so managers and their constituents can readily determine the potentially affected places, regardless of whatever inferences or generalizations may be drawn from it. Uncertainties associated with the data also need to be clearly stated.

5. A forum for comprehensive ocean planning—such planning must bring together the goals, scientific information, management efforts, and implementation in an integrated whole (fig. 2.3).

Are managers ready to use such advice as it develops? Many are already beginning to do so. For fisheries, the mandates to protect habitat (Rosenberg et al. 2000) and bycatch of nontarget species (Harrington et al. 2005) have helped set the stage for consideration of ecosystem-based effects more broadly (e.g., see

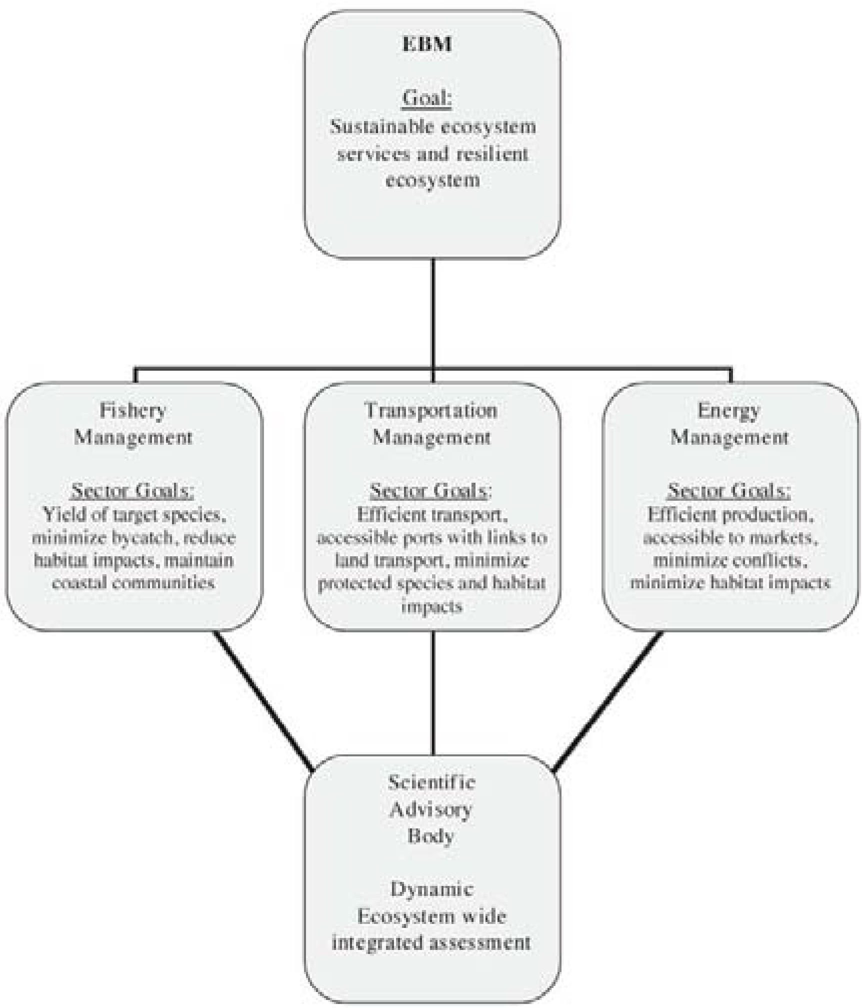

Figure 2.3 Framing ecosystem-based management (EBM) goals across sectors.

NOAA 2006; Merrick et al. 2007). In the energy, coastal development, and pipeline and cabling sectors, consideration of mitigation of impacts on habitat has been part of the management process for several years. These within-sector approaches, while not fully developed EBM, are the first steps toward a more comprehensive system.

Despite the difficulties that come with change, for scientists, managers, and constituents, EBM is clearly an approach whose time has come. We know enough to begin, and we have tried some of the first steps. Perhaps most importantly, there is wide recognition that we need to go beyond the conventional approaches to management of marine resources because sector-by-sector efforts have too often failed to prevent ecosystem degradation (MA 2005).

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