THE ECOSYSTEM GOAL TEAM OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

EXPLORING AN ECOSYSTEM APPROACH TO MANAGEMENT

A REVIEW OF THE PERTINENT LITERATURE

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INTRODUCTION

> *"People should take care of the land as a "whole organism" and try to keep all the cogs and wheels in good working order." "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." (Aldo Leopold)*

Scientists in a variety of fields agree that an ecosystem approach to management (EAM)[1] holds the most promise for conservation and management of marine resources. Although the concept of ecosystem management continues to evolve, the main thrust of an EAM for marine ecosystems is the inclusion of humans in an integrated view of managing these resources and with the aim to sustain ecosystem integrity. The most important feature of an EAM is the goal to maintain productive, resilient, and healthy marine resources in order to protect the species within that ecosystem and so that the ecosystem can also be used by humans. A basic tenet of EAM is that conserving ecosystem functions and integrity will be, or should be, a fundamental vehicle for sustainable development (Pirot et al., 2000).

EAM differs from single species, sector, activity, or geographic based approaches, as it considers a myriad of multidisciplinary factors including human needs, ecosystem structure and functioning, and other key processes. This approach recognizes the importance of interactions between many target species, while also incorporating social, economic, and institutional perspectives into a conservation regime (Figure 1).

[1] Note: The term ecosystem approach to management (EAM) was selected by NOAA as a preferable term to ecosystem management (EM) because it reflects the notion that the principle activity is the management of human interactions with the ecosystem rather than the complex ecosystem itself. The term EAM is also preferable over EM because the latter implies that it is possible to control and manage an entire ecosystem.

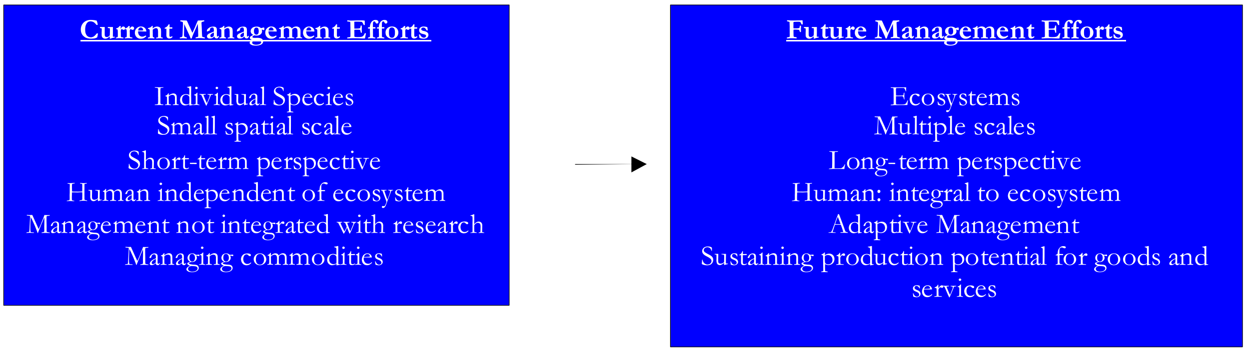

Figure 1: Differences between current management efforts and future management efforts that focus on an ecosystem approach to management.

This review of the pertinent literature on EAM begins by presenting the National Oceanic and Atmospheric Administration (NOAA) definition of EAM and explains EAM concepts as a tool to soundly manage the Nation's marine and coastal resources. This paper assesses the precise definition of an EAM, identifies the main goals and needs for a successful implementation of an EAM strategy, and examines how EAMs have been successfully implemented in the past. The paper then reviews EAM history and outlines some of the goals of EAM. Finally, projects and initiatives in which EAM concepts have been documented are described.

WHY IS NOAA INTERESTED IN AN ECOSYSTEM APPROACH TO MANAGEMENT?

The United States Ocean Action Plan, in response to the 2004 U.S. Commission on Ocean Policy (USCOP) Report, firmly endorses the importance of focusing on EAM because of the belief that ocean use and conservation can only be implemented by managing entire ecosystems. In response to the U.S. Ocean Action Plan, NOAA's Strategic Plan provides NOAA specific guidance for an EAM approach.

According to NOAA's Strategic Plan, the definition of an **ecosystem** is "a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics" (NOAA Strategic Plan, 2004). An **ecosystem approach to management** is one that is "geographically specified, adaptive, takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives" with implementation needing to be "incremental and collaborative" (NOAA Strategic Plan, 2004). The U.S. Ocean Action Plan prescribes that if EAM is not undertaken, then management of the Nation's coastal and marine resources will continue to be insufficient to handle current and future ecosystem stressors.

The transition to an ecosystem approach to management needs to be incremental and collaborative. Although scientists have been studying ecosystem processes for decades, long-term scientific research is still needed. Ecosystems provide multiple benefits, and are vital to human wellbeing. Many of these benefits, such as clean air to breathe, fresh water to drink, fuel for warmth and cooking, and food to eat, have historically been free to all humans as the result of the working of nature. However, many of these ecosystem services are over-used, mismanaged, or degraded. NOAA's transition to an EAM is a large step towards sustainable managing the Nation's resources.

OTHER SELECTED DEFINITIONS OF ECOSYSTEM APPROACHES TO MANAGMENT

Since EAM's inception, numerous scholars, environmental managers, and conservation groups have developed EAM definitions to fit their respective needs and missions and with varying philosophies. Listed below are some of the major EAM definitions found in the literature; these definitions illustrate the range of interpretations different groups have made towards EAM:

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

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

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

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

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

…is an integrated approach to management that considers the entire ecosystem, including humans. The goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need (Scientific Consensus Statement on Marine Ecosystem Based Management, 2005).

The evolving concept of EAM is often the focus of much current debate and, as can be seen from the differences in definitions, EAM has not been uniformly defined or consistently applied by different agencies. A variety of policy choices are available to reduce the degradation of ecosystem services and retain the benefits for people. NOAA is committed to moving toward an EAM of the Nation's coastal and marine ecosystem using the best current scientific information and the most reasonable adoption of EAM for NOAA's mission goals. This will require increased understanding of these complex systems as well as improved integration and collaboration.

HISTORY OF ECOSYSTEM APPROACHES TO MANAGEMENT

In 1995, Vice President Gore's National Performance Review called for agencies of the federal government to adopt a proactive approach to ensuring a sustainable economy and environment through principles of ecosystem management (Interagency Ecosystem Management Task Force, 1995). The Interagency Ecosystem Management Task Force was established in August of 1993 to carry out this mandate. The Task Force formed a working group which conducted case studies to learn about ecosystem efforts to date, to identify barriers to implementing the ecosystem approach, and to identify ways the federal government could assist in overcoming these barriers. Currently, twenty-one federal agencies, including NOAA, have committed to the principles of ecosystem management (Congressional Research Service, 1994).

Numerous international agencies and groups have adopted EAM strategies in their conservation and management efforts. For example, the International Conservation Union (IUCN) Commission on Ecosystem Management (CEM) was one of the first agencies to articulate the notion of sustainable use of ecosystems. The IUCN's CEM aims to enhance understanding and to promote conservation and sustainable use in an equitable way (Convention on Biological Diversity, 2003). The underlying principles advocated by CEM are to strive for flexibility to address management issues in different social contexts.

DOMINANT COMPONENTS OF ECOSYSTEM APPROACHES TO MANAGEMENT

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

1) **Hierarchical Context**: Biodiversity must be examined on multiple scales in order to seek the connections between all levels (ecosystems, landscapes, etc.). An EAM reflects a departure from traditional species-level management schemes and embraces the complexity of ecosystems by utilizing contextual thinking to solve multidimensional ecosystem problems (Grumbine, 1994, 1997). Different spatial and temporal scales must also be given extensive consideration (Yaffe, 1999; Slocombe, 1993).
2) **Ecological Boundaries**: First, the complexities of ecosystem boundaries (including sub-ecoregions) must be defined based on current political, ecological, and geographic boundaries. Some boundaries do not occur naturally but are a human concept imposed for the purpose of quantifying what goes on inside the chosen system (Pirot et al., 2000). When defining ecological boundaries, ecological features

should be characterized using ecosystem indicators to identify major factors and stressors that affect ecosystem health and productivity. Clar (1999) identified two main challenges to defining boundaries: a lack of knowledge on ecosystem function and the fact that human demand often exceeds management possibilities on both spatial and temporal scales.

3) **Ecological Integrity**: The usage of sound ecological models can facilitate our understanding of ecological boundaries and an understanding of what constitutes sound ecological integrity. The best current models of ecosystem function should be the basis for ecosystem management. An emphasis on the interconnections and basic ecological principles of a system should be a major focus of EAM in order to maintain ecological integrity.
4) **Data Collection**: Managers must identify research and information needs and develop a data collection system that integrates data (both information and monitoring data) from various stakeholders. In order to integrate data from stakeholders, managers must first cultivate working relationships with outside agencies and work to identify appropriate expertise for supplying data for management goals. Grumbine (1997) emphasizes that data collection should not only focus on science, but also on the social factors related to resource management.
5) **Monitoring:** Results of management must be systematically monitored using clear, operational goals that are explicatively stated in terms of specific "desired future trajectories" for the ecosystem. It is important that these goals be stated in terms that can be measured and monitored and, most importantly, that monitoring programs focus on long-term goals.
6) **Adaptive Management:** Managers must decide on how to implement plans and achieve long-term goals, including ways to implement management based on lessons learned from previous action. Management must be viewed as experimental and allow managers to remain flexible, adapt to uncertainty, evaluate the significance of change, and establish appropriate mechanisms to periodically reconsider project aims and objectives (McNeely, 2003).
7) **Cooperation:** Interagency cooperation is essential in order to integrate management goals and legal mandates. Such cooperation is also based on the identification of stakeholders based on shared concern for a problem. Sharing power amongst cooperating agencies will facilitate the development of interagency relationships.
8) **Organizational Change:** EAM requires significant deviation from traditional species-focused management; therefore, the structure of management agencies needs to also reflect the priorities of EAM. For example, NOAA recently reorganized to reflect different "goals," one of which was the Ecosystem Goal. This reorganization reflects NOAA's desire to align its scientific expertise with various aspects of ecosystem science.
9) **Humans as Part of Nature:** An EAM must identify the economic issues, human benefits, incentives, and values that will affect the ecosystem and its inhabitants. Humans are fundamental influences on ecological processes and patterns and in turn are affected by ecosystems; thus, human values play a dominant role in EAM goals (McNeely, 2003).
10) **Values:** The ideals of stakeholders are an important consideration when developing an EAM. Grumbine (1994) concludes that the main long-term implication of the

concept of EAM is a transformation of personal and social values towards a more integrative and holistic way of thinking. An EAM must take into account the naturally varying values of stakeholders and values must also be acknowledged and respected during the planning process.

GOALS OF ECOSYSTEM APPROACHES TO MANAGEMENT

A wealth of literature has been written on both the interpretation of EAM and practical considerations in implementing EAM strategies, although most conservation biologists and practitioners of natural resource management have accepted EAM as an emerging philosophy (Jensen and Everett, 1994). Grumbine (1994) examined current and past literature on EAM and identified five main goals of EAM that have been dominant in the scientific literature:

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

Grumbine (1994) emphasizes that the above management goals which seem to be dominant in EAM, are statements endorsing certain values. In other words, stakeholders have placed importance on these goals and tend to select these outcomes over others. There is general agreement in the academic and popular literature that maintaining ecosystem integrity should take precedence over any other management goal. Additionally, an increasing number of papers on EAM do not advocate that humans have any privileged ethical standing over this goal.

The literature notes the difficulty in implementing EAM on a practical level (Brunner and Clark, 1997). Specifically, in order to transform this theoretical approach to a practice based system, Clark (1999) identified the following real-world constraints that must be overcome: 1) minimal knowledge of ecosystem functions and 2) ignorance of immediate human demands on the landscape.

From the existing literature, it is clear that different people and groups ascribe to different meanings of the term ecosystem management, depending on current management approaches and the difficulties and costs of EAM implementation. Yaffe (1999) identified three main approaches for ecosystem management from the literature. The first general approach is one that focuses on the anthropocentric factors in ecosystem management. An anthropocentric approach aims to maximize the number of humans that can use a resource or ecosystem, subject to environmental constraints. A biocentric approach is one that promotes sustainable human use while maintaining the ecological integrity of the ecosystem. The third, an ecocentric approach, promotes sustainable human use while managing at the eco-regional level; this approach focuses on maintaining and restoring ecosystem function (Yaffe, 1999). Omernik (1995) defines ecoregions as "regions of relative homogeneity with respect to ecological systems involving interrelationships among organisms and their environment."

The eco-regional/ecocentric approach is analogous to the Large Marine Ecosystem (LME) system which is defined as:

> "Regions of ocean space encompassing coastal areas from river basins and estuaries out to the seaward boundary and continental shelves and the seaward margins of coastal current systems. They are relatively large regions on the order of 200,000 km^2 or greater, characterized by distinct bathymetry, hydrography, productivity and tropically dependent population." (Sherman and Duda, 1999; Sherman, 1994; Alexander, 1993).

NOAA has chosen to define the marine regions it is responsible for managing using the ecocentric approach of LME's; these regions are distinguished using the following four ecological criteria: bathymetry, hydrography, productivity, and trophodynamics (Sherman et al., 2002). As defined, LMEs encompass most of the world's marine areas of high productivity, including coastal waters annually producing 95% of the world's marine fish catches. One of the main advantages of working in an LME framework is that it permits more accurate determination of appropriate boundaries for a management area, which facilitates the collection and dissemination of data (Cicin-Sain and Knecht, 1993).

The advantage of NOAA incorporating an LME approach towards ecosystem management is that many of the characteristics of an LME are parallel to the EAM characters. For example, NOAA defines an EAM as geographically specified, considers multiple external influences, and strives to balance diverse societal objectives. These same characteristics are directly and indirectly linked to the distinguishing characteristics of LMEs: the ecological criteria defining an LME also tend to define its geography and the external influences that affect it.

STAKEHOLDER VALUES IN AN EAM CONTEXT

"The Commission began by envisioning a desirable future. In this future, the oceans, coasts, and Great Lakes are clean, safe, prospering, and sustainably managed. They contribute significantly to the economy, supporting multiple, beneficial uses such as food production, development of energy and mineral resources, recreation and tourism, transportation of goods and people, and the discovery of novel medicines, while preserving a high level of biodiversity and a wide range of critical natural habitats. In this future, the coasts are attractive places to live, work, and play, with clean water and beaches, easy public access, sustainable and strong economies, safe bustling harbors and ports, adequate roads and services, and special protection for sensitive habitats and threatened species. Beach closings, toxic algal blooms, proliferation of invasive species, and vanishing native species are rare. Better land-use planning and improved predictions of severe weather and other natural hazards save lives and money." (USCOP, 2004, A Vision and Strategy for the 21st Century and Beyond).

As mentioned, humans are an important factor in protecting and restoring the Nation's marine and coastal resources. Participation in EAM involves various governmental jurisdictions as well public and private involvement. The U.S. Commission on Ocean Policy identifies many different uses of marine and coastal ecosystems, such as economic prosperity, safety, and recreation. Implicit within the Commission's vision for the future are the ways in which people value their resources, as well as a related issue of what goods and services ecosystems provide. Of key importance are the trade-offs that are required in order to achieve the vision.

This next section provides an overview of some aspects of the human dimension of an ecosystem approach to management, particularly related to values that the public identifies, how managers can learn of public values, and how managers can use public values to craft and implement more effective and representative policies.

ECOSYSTEM GOODS AND SERVICES

Ecosystem goods and services refer to the benefits humans obtain from the natural system, directly or indirectly (Costanza et al., 1997). Timber, for example, is an ecosystem good, while nutrient cycling is an ecosystem service. Those whose well-being (or "welfare") is affected by the good or service are considered its stakeholders; the welfare of the stakeholder changes when the use of the environmental good changes (Scheffer, Brock, and Westley, 2000). The United Nations report, the Millennium Ecosystem Assessment, lists four categories of ecosystem services that support human well-being (Figure 2). Within these categories are services that correspond directly to an economic value, such as the provisioning of food. Many others, such as the spiritual importance of ecosystems or the regulation of climate, are much more difficult to understand in economic terms.

PROVISIONING	CULTURAL
Goods produced or provided by ecosystems • food • fresh water • fuel wood • fiber • biochemical • genetic resources	*Non-material benefits obtained from ecosystems* • spiritual • recreational • aesthetic • inspirational • educational • communal • symbolic
REGULATING	**SUPPORTING**
Benefits obtained from regulation of ecosystem processes • climate regulation • disease regulation • flood regulation • detoxification	*Services necessary for production of other ecosystem services* • Soil formation • Nutrient cycling • Primary production

Figure 2: Ecosystem services supporting human wellbeing.
Source: Millennium Ecosystem Assessment, 2005.

This kind of economic analyses can translate directly into management decisions that reflect the interests of the public. The USCOP found the representation of non-market roles of ocean and coastal resources as key to sustainable resource use. The USCOP highlights the extreme importance in understanding the economic value of coral reefs in developing restoration and management strategies. A recent study (Cesar, et al., 2002) of parts of the reef systems in the Hawaiian Islands estimates the values of the rich coral reefs of that state to be at least $384 million per year. The vast majority of this benefit is from tourism and recreation, but it also derives from the enhanced value of real estate in areas bordered by coral reefs, the value of the biodiversity of the reef ecosystems, and the values of enhanced commercial and recreational fisheries productivity (USCOP, 2004).

HUMAN VALUES AND ECOSYSTEM RESOURCE POLICY

An ecosystem approach to management calls for incorporating the broad sets of values held by diverse constituents into decisions. These values indicate what end state of an ecosystem (and so its goods and services) is desired by the public as well as what trade-offs the public is willing to make in order to reach that end state. These values and trade-off decisions often conflict with one another. Lee (1993) explains that competition, or "conflict," between the different values is essential to moving toward sustainable use of resources, as it detects error in, and forces corrections to, current and proposed practices.

Trade-offs required by an ecosystem approach takes into account humans' role as both the beneficiaries and cumulative stressors to natural systems. That is, in an action that makes use of a particular environmental good or service that we value, we can contribute to the degradation of another environmental good or service. Or, the action can also degrade that same good that we are using. Hardin's (1968) "tragedy of the commons" explains this predicament well, in which the public good that is shared by all gives little incentive for conservation by an individual, a spiraling process that encourages resource degradation. Other authors take this concept further; for example, Scheffer, Brock, and Westley (2000) argue that decision making often favors resource-degrading activities over those that allow for optimal shared use. The authors attribute this bias to fact that the utilities depending on ecosystem quality are often shared by large diffuse groups, while activities that result in intense resource use and degradation can usually be traced to relatively small and well-organized groups.

To correct this lopsidedness, the authors advocate addressing the interests of a diffuse public by adjusting the market to include the value of all ecosystem services (Pearce and Moran, 1994). This correction would achieve the ecosystem approach to management objective of addressing the multiple stresses and benefits of an ecosystem, while providing a numerical manner in which to compare the uses and impacts. Absent of this significant change in the structure of the economy, broad participation in resource management decision-making processes is critical.

FURTHER UNDERSTANDING STAKEHOLDER VALUES AND SOCIAL SCIENCE RESEARCH

A review of NOAA's social science research (SSRP, 2003) concluded that the agency would better meet its mandates and mission with a stronger representation and use of social science. The recommendation to increase "programmatic" (or "mission- and mandate-driven") social science is particularly relevant to incorporating stakeholder values into EAM decisions.

The NOAA social science research review provides a number of example questions which facilitate support of social science research leading to regulations. These questions include:

1. How does the behavior of different users directly affect the resource in question and what are the direct and indirect interrelationships between different users and different resources?
2. What cultural, social, and economic factors determine the behavior of users of marine and coastal resources?
3. What types of regulations are best suited to accomplish the required behavioral changes, especially considering implementation and enforcement costs?

Social scientists use a wide variety of tools to answer these kinds of questions. For example, participants may be asked to rank (or express in dollar amounts) their preferred scenarios that could result from proposed management decisions. This ranking provides a proxy for participant values as well as indicates the trade-offs they are willing to make (Gregory and Wellman, 2001; Slovic, 1995; Gregory and Slovic, 1997).

Humans' relationship to ecosystems can be divided into the following three inter-related aspects: (1) humans' values that shape the decision making about natural resources, (2) humans' impact on ecosystems, (3) ecosystem's impact on humans. In an EAM context, all three facets are important to decision making, thus requiring integration across different disciplines. Granek et al. (2005) suggest that practitioners dealing with marine issues can look to watershed studies as a good example of such integration, as these studies bring together hydrology, ecology, fisheries, eco-toxicology, engineering, natural resource economics, and social ecology. Within NOAA, the Coral Reef Ecosystem Studies Program in the tropical Pacific islands is a practical example of integrating stakeholder values and research by making social science and local participants an integral factor in the partnership. The research strategy for the Coral Reef Ecosystem Studies program includes representatives of the Guam Environmental Protection Agency, the Guam Division of Aquatic and Wildlife Resources, resource mangers from around the Pacific region, representatives attending the Pacific Regional coral Reef Initiative meetings, and Pacific Island stakeholders concerned with coral reef resource sustainability. The Social Science Research Institute, University of Hawaii (SSRI), assists with the development of a watershed management approach by conducting social and economic impact assessments of watershed activities. SSRI, working with natural and social scientists at the University of Guam, the Palau Conservation Society, and other established interests in the Micronesian Islands, convenes a Watershed Management Steering Committee comprised of members from government agencies, community organizations, and private interests with activities in these watersheds. The steering committee is the mechanism for integrating technical and scientific information, as part of the proposed project, into an appropriate management structure. Committees are established for each island jurisdiction participating in the project. The planning and implementation are developed through consensus among the researchers, agency representatives, and stakeholders and the information is disseminated through local newspapers and television and through direct meetings with the participating communities and island decision-makers. Presentations on the project are given in the local languages by researchers from the islands of Palau and Pohnpei.

The next section of this paper, which reviews data and information synthesis, further addresses research integration. For a substantive overview of the current literature on stakeholder participation, see the document, "Stakeholder Participation: A synthesis of current literature" (Kessler, 2004). Although written for marine protected area management, the literature applies to participation in other processes related to ecosystem approaches to management.

IMPORTANCE OF DATA AND INFORMATION SYNTHESIS IN EAM

The latter portion of this review discusses the science, stakeholder, and policy interactions involved in EAM. Data and information synthesis is the critical component reflecting the appropriate stakeholder involvement in identifying research needs and capabilities to ask and answer the pertinent questions to obtain EAM.

A synthesis or integration of research is expected to result in better policies and regulations, lead to more efficient use of resources and funds, and promote sustainability. The importance of integration in EAM stems from the question: How can science be used more effectively in making decisions? The term 'synthesis', as defined by the U.S. Geological Survey (USGS) Science Synthesis projects, involves the uncovering and merging of information to create new knowledge (USGS, 2005). The mere magnitude of scale and complexity of managing ecosystem level projects requires new knowledge framed for decision makers to make the best decisions for the conditions and functions of the ecosystem as a whole. Integration of multiple sources of scientific as well as social and economic information is taken into account when management decisions are needed in an ecosystem approach to management. When and how this data and information are used is adapted within the evolving ecosystem. Adaptive management refers to actively monitoring such conditions for feedback and altering management actions based on monitoring results (Butler and Koontz, 2005). The European Commission's Sixth Framework Program describes five forms of integration in research. Table 1 is adapted from the European Commission's Framework (2002), but ties in the framework for ecosystem research and management examples.

Integration	*Description*	*Examples*
Vertical Integration	Inclusiveness of all impacted parties in all stages of decision making	Community, city, county, state, regional, national, global
Horizontal Integration	A range of multidisciplinary activities	Social, political, biological, economic, physical science
Activity Integration	Sharing within various facets of a project	Funding, legislative affairs, research, education, enforcement
Sectoral Integration	Different sectors within natural resources	Water, land, air; private, public, academia, or industry perspectives
Financial Integration	Public and private funding	Federal, state, local, industry, philanthropic

Table 1: Types of research integration, adapted from the European Commission's Sixth Framework Program (2002).

A management plan should determine the priority research needs to improve the balance between environmental, social, and political parameters. Improving project design will help ensure clear goals and objectives and effectively manage outcomes. Beginning with the focus to balance environmental and economic improvements fosters success. Achieving the benefits of an EAM must be seen by all stakeholders. Early involvement and sustained participation by a variety of stakeholders will help facilitate public perceptions of benefits (Christie et al., 2005). The Florida Keys National Marine Sanctuary and Protection Act (FKNMSPA) requires that management plans "identify clearly the cause and effect relationships between the factors threatening the health of the coral reef ecosystems in the Sanctuary," and establish a long-term ecological monitoring program {FKNMSPA §7(a)(4) & (5)}.

Data and information support for management has become more tedious as EAM project goals are increasingly complicated. Within EAM, interested and effected parties may be extensive; therefore, anticipating the kinds of information needs should be done soon in the process. The importance of science in policymaking is observed in the emphasis placed on scientific assessments within policy formulation on issues including persistent pollutants, coral reefs, and global climate change (USGS, 2005). Linking data and information from spatial and temporal scales of governing jurisdictions, land, sea, environmental, social, and economic factors are critical.

An important second conclusion is that research information needs are based on objectives and goals of the initiative. The U.S. Forest Service exemplifies two EAM concepts important in implementation: creating EAM goals and objectives and incorporating EAM-related policies for the agency. Butler and Koontz (2005) pointed out the following EAM themes within the Forest Service Policy objectives: sustainability, cooperation and collaboration with public and private entities, more efficient integration of science into management, adaptive management, improving partnerships between land managers and scientists, enhancing the protection of ecosystems, and restoring deteriorated ecosystems.

An additional illustration of a project with clear goals is the Integrated Coastal Management (ICM) Sustainability Research Project, which not only incorporated EAM goals and objectives, but also took steps to extend EAM into the future. The ICM Sustainability Research Project had three main goals, including: 1) to conduct multidisciplinary applied research, 2) to advise ICM projects/organizations, and 3) to train people in multidisciplinary evaluative research. An important aspect of EAM research must include multidisciplinary participation, taking into account epistemology and culture. This was seen in mentoring relationships fostered within the collaboration to provide guidance and evoke challenging thoughts for problem solving (Christie et al., 2005). Mentoring and training future EAM implementers will help maintain momentum of the EAM concepts.

The following examples provide an illustration of research among diverse stakeholder groups engaging in vertical and activity integration (see Table 1). In the Philippines, as within U.S. projects, national laws and policies are neither always welcomed nor provide strength to local management efforts. Policymakers feel incentives are needed to network and collaborate across sectoral lines, while practitioners argue that new governance structures should be adopted to ensure the full vertical integration across institutional boundaries (Christie et al., 2005). How ever an initiative chooses to facilitate EAM, a synthesis of data and information will need to occur among all levels in order to take a holistic approach in an area. The Gray's Reef Marine Sanctuary (GRNMS): Latitude 31-30 Program is a collaborative effort aimed at identifying all the substantial scientific and natural resource management programs in effect along the 31 degrees 30 minutes North Latitude line. Information on current projects and activities underway in this area will help improve understanding and management of Gray's Reef National Marine Sanctuary. The program represents a wide range of federal, state, and non-profit organizations, whose combined investment along this transect offers an extraordinary opportunity to coordinate scientific exploration, conservation, education, and ecosystem-based management in a new collaborative, non-regulatory manner. To coordinate the scientific, educational, and conservation initiatives of these entities, GRNMS has proposed and convened a voluntary council to help guide and coordinate activities in this ecologically important area. The Gray's Reef Marine Sanctuary illustrates a collaboration that integrates various layers of science by building on community stewardship.

INTEGRATING MULTIDISCIPLINARY INFORMATION

Identifying the best ways to use science requires a synthesis of physical, social, economic, and political research. Horizontal integration across science will also combat the segregation of those impacted by decision making. Integration will bring together research across disciplines as well as link research to practical 'on the ground' applications. To bring participants together, the USGS has used collaborative tools such as Decision Support Systems, Joint Fact Finding, and institutional analysis. The Disparate Stakeholder Management (DSM) of Wildlife Issues in the Southern Greater Yellowstone Area involved the DSM approach, which integrates concepts from decision, political, and institutional analysis and public choice economics to help decision makers better describe, measure, communicate, and resolve management issues with disparate stakeholders (USGS, 2005).

Providing technical advice to all stakeholders is challenging due to several reasons. For one reason, the infrastructure and opportunity for sectoral integration among policymakers, scientists, and practitioners is neither well established nor well maintained. Research timetables may be mistimed with public and policymaker expectations. The Aquidneck Island Partnership, created by NOAA Rhode Island Sea Grant and the University of Rhode Island Coastal Resources Center, has dealt with this problem by taking time to understand the local community and issues important to the user groups[2]. Implementing projects early in the process, which displayed immediate results to the stakeholders, helped to gain credibility for the program. Information sharing was noted as an accomplishment for the Gulf of Maine Council. The Gulf of Maine Council promotes the newsletter, the Gulf of Maine Times[3], as a forum for regional issues and accomplishments to be showcased. Such information exchange inspires a sense of community among the various participants (Harris, Huntley, Mangle, and Rana, 2001).

Adaptive management facilitates decision making and is considered a tool in policy formulation and evaluation, the negotiation process, and education. An adaptive management study identified high-level technical expertise interacting at each phase of the process to be helpful in educating other stakeholders. An Australian study used simplified models to assist in synthesizing information for decision making and provided a means to acknowledge unavoidable uncertainty during a series of facilitated workshops (Gilmour, Walkerden and Scandol, 1999). Integrating information into a model provides documentation of participants' understanding of the management issues, strategies, and alternatives. Information flow, rapid acquisition of knowledge, and understanding of value-

2 http://www.crc.uri.edu/index.php?filespec=live_data.php&actid=134

3 http://www.gulfofmaine.org/times/fall2005/index.html

based issues and technical issues can reduce conflicts among stakeholders. Such models are useful in overlaying vertical, horizontal, sectoral, and activity integration, as discussed in the research integration, as shown in Table 1.

Project NEMO, the Nonpoint Education for Municipal Officials Project of the University of Connecticut Cooperative Extension[4] is an example of a practical application of a powerful geographic information systems (GIS) tool integrating water quality and land use connections. The GIS maps are combined with local photographs and computer graphics to educate local land use decision makers. A highlight of NEMO is its ability to conduct an impervious surface "build-out" analysis, which compares current levels of impervious cover to future levels of imperviousness, projected from local zoning regulations. Other examples of projects using GIS have targeted high-priority, large woodlot and stream side property owners for educational programs by adding GIS data layers of soils and property line information. The creativity and integration of data is wide open with the use of GIS for providing visual presentations to help direct changes to land use policies and management (EPA, 1997).

Incorporating sound science into policy decision making is critical. The World Bank and the Global Environment Facility (GEF) have adopted the large marine ecosystem (LME) approach to marine ecosystem research and management. The GEF operational guidelines for international waters (GEF, 1995) require a social science component. The social science component is a critical component in holistic research such as EAM, since humans are affected by, and the cause of, many environmental disruptions. Monitoring and assessing human dimensions in conjunction with ecological parameters requires frequent evaluation and feedback to ensure inclusion of public values and resource uses.

An example of the integration of economics, science, and policy in estuary management involves the Peconic Estuary system in New York. Preliminary analysis of a series of studies in the estuary have been carried out by program managers, scientists, and citizen advisory groups which indicate that 1) estuarine-related activities play a major role in the livelihood of residents; 2) there are economic benefits to users above the costs they incur; and 3) the public holds strong values for preserving key area natural resources. Collection of information on the changes in water quality provides information for scientists and policy makers to consider policies to control pollution. A cost-benefits analysis will show how users of coastal areas are affected by water quality (Sutinen, 2000).

Administrative and organizational factors such as staffing, training, and perhaps an agency's organizational structure, may need to adjust to gain the institutional capacity to fulfill an ecosystem approach to management agenda. Long-term commitment at all levels within staffing, funding, and institutional direction is important to EAM implementation. Being realistic regarding project time horizons and resources is also fundamental to successful implementation. Within the Philippines, 2-3 years was noted as a timeframe to establish clear direction and allow for effective staff contribution to the program (Christie et al., 2005).

[4] http://nemo.uconn.edu/

Leadership commitment to EAM must transcend beyond a leadership regime and be embedded in the organization policy and work ethic. For example, within the U.S. Forest Service, while no single policy document establishes the agency's ecosystem management objectives, the Forest Service policy directives support the concepts of EAM (Butler and Koontz, 2005). These policy directives include the Forest Service Planning Rule, which takes into account the best available science for ecosystem research as a whole and bases decisions on ecological, social, and economic sustainability.

Trained and competent ecosystem experts must be nurtured and rewarded to maintain growth in projects. Long-term commitments to continued education for practitioners should be included within policy reform in order to maintain momentum for such initiatives. A couple of programs which train and encourage advanced expertise and education to address the current and future research and management needed include the Pew Fellowships for Marine Conservation, offered by the Pew Charitable Trusts, (Christie et al., 2005) and the Graduate Scientist Program within the Educational Partnership Program, offered by NOAA.

CONCLUSION

Although the literature does not present a single agreed upon EAM definition, natural resource scientific and management communities agree that the following elements are needed for successful EAM: collaboration, adaptive management, ecological integrity, integrated data and information, and the connection between all landscape levels. Taking ecosystem approaches to management may seem like a daunting task, but as this review has outlined, the task is worth pursuing. NOAA's commitment to EAM is denoted in NOAA's Strategic Plan and the U.S. Ocean Action Plan. NOAA's marine and coastal management, environmental assessments, fisheries management and habitat protection, and cross-cutting programs are designed to expand the Agency's capabilities in EAM. This management strategy will provide a tool for a comprehensive approach to governing the Nation's marine and coastal resources. No single agency can implement EAM alone; therefore, collaboration and cooperation with other natural resource agencies, the public, and private sectors will foster a stewardship of the coastal and marine resources in which future generations can enjoy.

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