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Natural Resource Management: The Need for Interdisciplinary Collaboration

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Abstract

Human influence is now so pervasive that every ecosystem on Earth is being managed, whether intentionally or inadvertently. It is therefore imperative for scientists and managers to work together so that appropriate management regimes can be put in place wherever possible. However, it is not always clear what is appropriate, and the difficulties that often arise when scientists and managers work together can be even further compounded by the inclusion of lay stakeholders in the decision-making process. The expansion of interdisciplinary undergraduate and graduate programs would help both scientists and managers to deal more effectively with sociological issues and to understand how economic and demographic changes impact on natural resources. In addition, continuing education programs in these areas should be made available to established professionals to help them deal with new challenges. The concept of ecosystem services should be used to communicate the importance of various ecosystem components and processes to a broader audience. Consensus on a management regime can often be achieved through adaptive management. The process by which interdisciplinary collaboration can lead to new insights and research initiatives is exemplified by a resource management study on the island of Kosrae, Federated States of Micronesia. As a paradigm of natural resource management, microcosms like this small island community offer a unique opportunity for training and education.

Key words: interdisciplinary education; continuing education; ecosystem services; adaptive management; Micronesia.

Introduction

As a result of population growth and technological development, human influence has now penetrated into every ecosystem on earth. Due to changes both intentional and inadvertent, pristine ecosystems no longer exist. Even the decision to leave an ecosystem alone by designating it as a preserve can be equivalent to doing harm if nothing is done to ensure the maintenance of processes on which population and biogeochemical dynamics have come to depend, such as periodic fire, occasional flooding with water of a characteristic quality, or predation by wide-ranging top carnivores. Management plans must be developed even for preserves. Unfortunately, the extent of the impact of a management practice is seldom understood completely. For many kinds of ecosystems, there may indeed be no scientific basis for establishing appropriate uses and viable management regimes.

Humans rely on ecosystems, from intensively managed agricultural fields to extensively managed watersheds and even oceans, for a variety of goods and services. We clearly need a broader scope of understanding to manage this great diversity of ecosystems, but even scientists who feel they have something to contribute to this effort often find that they lack the technical knowledge needed to ensure that an entire ecosystem will behave as desired or

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expected. For instance, conservation biologists whose initial training was focused on the characteristics of threatened and endangered species may now find themselves having to work across a scale reaching from molecular genetics to hydrology to landscape interactions and beyond. The complexity of caring for an ecosystem exceeds the capacity of any one individual.

To add to the problem, scientists and managers have often found it difficult to work together, even when they share a common goal. Further complications arise when the close collaboration of stakeholders is sought. Top-down efforts to control the use of ecosystems by indigenous peoples, commercial harvesters, or recreation seekers, to name just a few common types of stakeholders, are less and less likely to be successful. A greater variety of people than ever before are bringing their own experiences to bear on the question of how to extract goods and services from ecosystems. Thus, it is essential to understand how to link the biological reality of ecosystems with human needs and influences, and a necessary first step toward this end is to understand how to coordinate the diversity of interests and available talents.

If we are to increase our understanding of how ecosystems function, as well as our ability to conserve them and promote their wise use, people with different interests and talents must learn to work together. In this paper, I describe the sociological and intellectual barriers that must be overcome so that we can conduct the kind of teamwork that is necessary to manage natural resources, and I offer an overview of the kinds of approaches being tried. To illustrate these points and to carry the discussion to an international dimension, I present the example of a problem in natural resource management on a small Pacific island.

Educating Both Scientists and Managers

Fortunately, the stigma that was once attached to ecologists who work on problems related to natural resource management is diminishing. Finding an academic program that includes meaningful exposure to the political, economic, and sociological contexts for ecosystem management is also becoming easier. For instance, partnerships between graduate programs and community organizations are providing opportunities for students to put their resources and talents to use in addressing local issues (for example, Pringle 1999). However, it is still difficult to find an academic position in which an assistant professor can continue to follow an interdisciplinary research direction. Novice scientists moving into research and resource management positions with government agencies and nongovernment organizations may be more successful in their search, but there is still a strong tendency to emphasize a disciplinary focus in the early stages of a career. The question of when in a career to expand to an interdisciplinary approach remains hotly debated.

The problems inherent to the increasing complexity of management issues and the need for an interdisciplinary approach affect not only scientists but also managers of ecosystems, such as park superintendents, wildlife biologists, and watershed managers. These professionals must, like scientists, keep abreast of advances not only in their own field, but in related disciplines as well. Working closely with scientists on teams is clearly advantageous, and both managers and scientists have called for closer collaboration to meet shared goals (for example, Clark 1999; James 1999). The need for scientists to increase their awareness of management issues was highlighted by a survey of papers published over the last 30 years in *The Journal of Applied Ecology*. The survey indicated that most of these papers lacked clear recommendations and that very few had been written by people associated with organizations concerned with land management or policy development (Pienkowski and Watkinson 1996).

For managers, opportunities for continuing education with appropriate depth are limited. Technical courses may not be offered at convenient times and places, and little guidance is provided on suitable approaches for working with different audiences, especially when different cultures are involved (for example, in international settings). Nevertheless, the tradition of continuing education, using such formats as workshops, distance learning, and short courses, is common in some professional fields, such as engineering and forestry. Building on this tradition would help to bring together ecologists and managers and encourage them to interact meaningfully to meet common goals. The same formats could be used to learn about new perspectives in the biological and social sciences.

At the same time that scientists and managers are becoming aware of the need to expand their scope and work together, stakeholders—including both lay people and policy makers—are showing a greater interest in ecosystem management. If their quality of life, across a spectrum ranging from subsistence to recreation, depends on an ecosystem that may be managed by an "outsider" with other priorities, these stakeholders are likely to work,

whether covertly or openly, to gain a voice in that management. Even as our scientific understanding of how an ecosystem functions is lagging behind our needs, the goals, capabilities, and activities of these other significant groups are expanding rapidly. It is therefore important that we scientists open up a dialogue that includes interested parties with little or no professional training, including the use of such techniques as conflict resolution, to work toward the goal of integrating the social, economic, and political aspects of resource management with its ecological aspects.

Using the Concept of Ecosystem Services

Most people now recognize that ecosystems provide an array of services ranging from clean water to beautiful scenery (Daily 1998), but we also know that not every ecosystem can provide every service (see, for example, Ewel and others 1998a). We also realize that any given type of ecosystem can provide a particular service only under a prescribed range of conditions. The concept of ecosystem services is thus emerging as a useful mechanism for communicating among scientists, managers, and the lay public and for focusing scientific attention on particularly important data gaps. Describing how an ecosystem provides a product or service to society is an effective way of articulating why that ecosystem should be protected in some way, as well as providing a modest level of understanding into how the ecosystem functions. For scientists and managers, it helps to establish priorities for identifying which components and processes are especially important to protect. For laypeople, the concept of ecosystem services provides insight into the hierarchy of functions of an ecosystem and the role that managers must play in establishing priorities. The identification of specific ecosystem services is often the first step in the formulation of a strategic plan to accomplish some management goal.

The easiest kind of ecosystem service to understand is the production of goods that are directly useful to people. The oceans produce fish, and forests produce wood, for instance. Other ecosystem services are more complex because they involve transformations. For example, clean water will be readily available if a forest is protected to filter out nutrients that might otherwise cause eutrophication. The more indirect or intangible the product, however, the less credence or support there is likely to be. Will keeping bogs intact really slow down the greenhouse effect? Will screening out nonindigenous species really make a difference? (Aren't there good species introductions as well as bad introductions, and who's to say that this one won't be good?) Perhaps the most abstract ecosystem service of all is the provision of biodiversity. Why should the existence of an invertebrate found only on the top of one mountain stop the development of a complex of observatories that can dramatically increase our understanding of the universe? Is it really fair and apt to liken a small, insignificant fish to the last rivet that will hold a flying airplane together? In a country where a substantial proportion of the population believes that creationism should be taught as an alternative to the theory of evolution, doing a better job of communicating the importance of the unique products of evolution is a compelling task.

Understanding how an ecosystem functions is only the first step toward developing a sustainable plan for using the goods and services it offers. Translating that understanding into a workable management plan is another task entirely. The manager has a particularly critical role in this process, because of the need to interface with stakeholders as well as scientists. He/she must have the skills necessary to keep abreast of scientific advances, as well as the ways in which the goals and capabilities of the stakeholders are changing.

Adaptive Management: One Approach

The process of adaptive environmental assessment and management is intended to unite scientists, managers, and stakeholders in the common goal of solving management problems (Holling 1978; Walters 1986). This scientific, hypothesis-posing approach to management can help to provide answers to specific ecosystem management questions. It also offers a conceptual procedure for the manager to follow when faced with novel situations. However, it does not always work, often for social rather than ecological problems (Walters 1997).

Under the best of circumstances, the first step in the adaptive management process is for a team of scientists, managers, and stakeholders to collaborate in the construction of models that represent the diverse outcomes of alternative policies. Simulations of possible strategies can suggest which practices are likely to be most successful if a suitable computer model can be constructed. This process should also reveal important data gaps, and an experiment is often necessary to fill enough of those gaps to shed light on how the ecosystem will respond. Both stakeholders and managers assist with the monitoring effort. At the end of this process, the entire team should agree on the most appropriate

policy in view of the (often large) uncertainties about the outcome of different policy choices.

Failures in adaptive management can occur at every stage (Walters 1997). Knowing when to complete the modeling and move on is critical, because the modeler's expectations almost always exceed the usefulness of the models. Knowing how much and what kind of additional research is really needed is also critical, because considerable time and momentum can be lost in the pursuit of data that, in the end, do not provide significantly more information. The nature and scale of each experiment that is planned depend in part on its irreversibility and the degree of uncertainty in its success.

Walters (1997) blames such failures on three attitudes: (a) fear of expressing uncertainty about the results of a proposed action; (b) scientists' self-interest in determining what additional research is needed, and (c) fear or unwillingness to consider inaction as a reasonable policy. Others blame them on a lack of clear and reasonable objectives (Rogers 1998; Johnson and Williams 1999), conflict among management agencies with different agendas (Gunderson 1999), and the absence of a talented leader or facilitator with outstanding communication skills (Michael 1995; Gilmour and others 1999; Schindler and Cheek 1999). Large unique ecosystems (such as the Everglades) are especially daunting, and low-risk experiments may be hard to design (Gunderson 1999). When management must favor only a subset of ecosystem services, adaptive management may simply not be appropriate.

Perhaps one of the most important reasons why adaptive management sometimes fails is lack of experience and especially the lack of confidence in modeling on the part of many scientists, managers, and the lay public. The ability of models to "embrace uncertainty" and reflect the range of potential outcomes to possible decisions is poorly appreciated, even by scientists. Moreover, few scientists are capable of carrying out the kind of interactive simulation modeling that works well in adaptive management. Finding a manager and stakeholders who are receptive to it can also be difficult. In spite of the significant proven ability of models to provide insight in many areas of ecology (as well as other sciences), model simulation is still a technique that holds no attraction for many ecologists and provokes distrust in the general public.

In spite of these problems, adaptive management can be used effectively to bring together stakeholders, managers, and scientists to address the unpredictable results of interactions between people and ecosystems. Modeling is not an essential component, although it is particularly helpful in anticipating (or interpreting) the surprises that are likely to result (Gunderson and others 1995). Lee (1999) points out that adaptive management appeals most to natural scientists, for whom experimentation is a way of life, but that achieving a consensus—however it is reached—is really the main goal. In fact, policies are themselves experiments; much can still be learned long after decisions are made (Lee 1993).

Moving across Disciplines

Ecologists do not currently have easy access to information from the social sciences that can help them establish a working relationship with managers and stakeholders. For instance, they sometimes have a very limited understanding of the market forces that influence the stakeholders and affect the resource. Ecologists who have no experience with development issues may not recognize that the nature of environmental problems has changed dramatically, and that economic changes related to such phenomena as globalization and an increase in the relative importance of private investment over public aid have a dramatic effect on the environment and the scale at which managers must operate (di Castri 2000).

The impact that people have on ecosystems depends as much on the socioeconomic and demographic factors that motivate human actions as it does on the ecological characteristics of an ecosystem. Market forces play an important role in direct natural resource use, such as timber harvest. Global economic relationships have a more indirect but still profound effect on ecosystems—for example, through their effects on tourism and the local economies that depend on it. Subsistence economies, while buffeted by global forces, can still have important consequences for land-use activities and should not be ignored.

Collaboration between ecologists and economists is increasing, but there is still little interchange between demographers and ecologists. The effect of migration on resource extraction is one example of the importance of this intersection between disciplines. For instance, if male workers migrate and send remittances home to their families, the demands they make on their new environment may be less, because most purchases are made at home; if whole families migrate, however, new households are established and greater levels of resource extraction are likely to result (see, for example, Locke and others 2000).

Knowing what kinds of pressures an ecosystem is likely to experience, as well as the appropriate ways of managing such pressures, depends on having

access to the expertise of colleagues who work in these disciplines. But providing the appropriate information to one's colleagues is only part of the job. To be effective, it must be conveyed with the clarity needed to stimulate further cooperation and collaboration, and this requires a full understanding of the characteristics and needs of these various colleagues.

Attacking Interdisciplinary Problems: Lessons from a Small Island

The relationships among people, management, and natural processes are especially evident on islands where subsistence economies are important. When people, the economy they create, and the resources on which they depend are directly and clearly interdependent, the domains of biological scientists, social scientists, and local managers coincide. Well-bounded land masses, ease of censusing socioeconomic and demographic data, and ready access to decision makers make islands particularly appropriate for interdisciplinary research on natural resources. A synopsis of research being carried out on a small Pacific island, where more than half the population still depends on a subsistence economy, provides several examples of the benefits that an interdisciplinary approach can bring to the resolution of natural resource management problems.

The Federated States of Micronesia (FSM) is one of the political units carved out of the former United Nations Trust Territory that was held by the United States after World War II. On the island of Kosrae, which is the easternmost state in FSM and the only one to comprise a single island, mangrove swamps represent 15% of the land area and provide the equivalent of nearly $1 million in tangible ecosystem services, primarily accruing to people who depend on a subsistence life style (Naylor and Drew 1998). This subsidy represents about 10% of the median per capita income of its (approximately) 8000 residents. Although the island has abundant natural resources that sustained a somewhat smaller population for millennia, a rapidly growing population and a declining per capita income threaten to exceed the capacity of these natural resources to continue to provide adequate support.

For generations, mangrove trees have been harvested for construction projects; they are now harvested primarily for firewood, although the rate is not yet rapid enough to change canopy species composition (Ewel and others 1998b). Mangrove crabs (*Scylla serrata*; often called "mud crabs" elsewhere) are also harvested, especially to supply tourist hotels and a small export market. An economic valuation indicated that the sale of mangrove crabs was worth more than firewood (Naylor and Drew 1998). Household surveys revealed that the crab harvesters resented the firewood harvesters, because canopy gaps in the forest are believed to degrade crab habitat. More recent surveys have revealed a lack of understanding of (and hence lack of support for) natural resource management (K. Bonine personal communication).

The initiation of a new project investigating the interaction between crab and firewood harvesting practices resulted in a lesson in how compression in time can occur on islands. A series of community meetings held to inform the local people about the new project and elicit their cooperation (for example, by leaving traps untouched and by reporting the capture of tagged crabs) alerted them to the possibility that mangrove crabs might in fact be overharvested. Enthusiastic policy makers not directly associated with the project sent a bill through the Kosraean state legislature that imposed substantial constraints on crab harvesting. In addition to being enacted without the benefit of adequate supporting data, the precipitous change in policy threatened to cripple the effort to collect the very data intended to demonstrate whether or not regulation was needed; that is, it prevented adaptive management. The legislation also stipulated that a regulation and monitoring force be created, even though the bureaucracy was already hard-pressed to support its existing employees, thus fostering a situation that could drive crab harvesters into forming a black market with the potential to defy any subsequent attempts at resource management. This is a clear illustration of the ways in which scientists conducting research on natural resource management issues may find themselves drawn into policy discussions, even in an international arena, whether they are prepared or not.

Because resource management has not been necessary on Kosrae until recently, there are few people with any formal education in this field, although there are talented and dedicated individuals who are largely self-taught. Consequently, there is little support for the centralized, top-down management of what has come to be regarded as a common resource. In such situations, translating research data into management policy requires far more than the formulation of esoteric recommendations. Convincing resource managers that a certain strategy is appropriate may not be difficult, but helping them to gain acceptance for these recommenda-

tions and put them into practice is somewhat more challenging.

In Kosrae, the most influential people outside the government are ministers. The church became the focus of community life after missionaries helped the island's inhabitants recover from the combined effects of disease and natural catastrophe early in the 20th century. It is now the center of activity in each of the five main communities on the island, and the opinion and advice of the ministers carry a great deal of weight, even when it comes to natural resource management issues. The ability to communicate effectively with influential local leaders, such as the ministers of Kosrae, and with other stakeholders who may not speak the same language—figuratively or literally—is therefore a prerequisite for scientists who wish to conduct research and make subsequent recommendations.

Could adaptive management work in a place like Kosrae? A formal modeling exercise might be viewed with skepticism by both managers and stakeholders, although simple models could be used to teach the basic principles of resource management. In any case, bringing stakeholders to the table as full participants in the decision-making process is just as essential in Kosrae as it is anywhere else, and scientists must find ways of communicating with everyone. In the absence of top-down management, adaptive management is the next best strategy to try to win over both government agencies and communities.

In Kosrae, policy making follows different trajectories, but in many ways it is more transparent and occurs at a faster rate than in a more industrialized society. Conducting research on an island such as Kosrae allows a scientist to address a resource management problem on a smaller scale of ecological and socioeconomic complexity without diminishing its importance. Studies performed at such microcosmic scales offer a useful way of training scientists and managers in the art of conducting interdisciplinary research and working together with a community to develop a management plan.

Conclusions

The press of human intrusion into ecosystems at all latitudes around the world has created an urgent, almost desperate need for ecologists and social scientists to work together more closely. Understanding how an ecosystem functions is not enough to be able to manage it. It is also essential to incorporate the perspectives of other disciplines, such as economics and demography, into management plans and to communicate rationales and strategies effectively to scientists, managers, and stakeholders. The concept of ecosystem services is helpful for establishing priorities in management, but a method such as adaptive management is needed to obtain consensus on specific issues. While much can be learned from any individual management effort, island societies, as microcosms, offer a unique venue for experimentation. Innovative techniques for communication, interdisciplinary interaction, and the development of appropriate management practices can be applied more easily in these relatively simple, limited systems.

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