# Ecosystem Management: In Search of the Elusive Paradigm'

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### *Abstract*

*Ecosystem management is proposed as the modem way of managing natural resources and ecosystems. Championed as an approach that will protect the environment, maintain healthy ecosystems, preserve biological diversity, and ensure sustainable development, ecosystem management also has been derided as a new label for old ideas. The definitions of ecosystem management are vague. Here I offer seven core principles, or pillars, of ecosystem management to delimit the concept. As with all management paradigms, there is no "right" decision, but rather those decisions that best respond to society's needs. For selecting the most important research needs, the most important criteria are policy relevance and scientific tractability—research that addresses important management or policy problems and is likely to be scientifically achievable. Ecosystem management would be enhanced by developing (1) credible procedures to determine ecosystem health, which is within the domain of social and biological science; (2) scientifically sound options on which to base policy decisions about biological diversity and endangered species; and (3) a clear understanding of the relationship between ecosystem stability and biological diversity, and how each responds to external stress such as altering habitat and harvesting biotic resources. While many other research priorities also are important, the three identified needs meet the specified criteria and are likely to improve implementation of ecosystem management.*

***Key words:*** *ecosystem management; natural resources management: fisheries and wildlife research; ecosystem health; biological diversity; endangered species*

## The Paradigm

What are the implications of ecosystem management for natural resources management—and for research whose purpose is to help implement effective management? With all the talk about ecosystem management, you might assume that the answer would he straightforward. Today, ecosystem management is highly visible in the political world—not quite up there with balancing the budget, reforming the tax code, eliminating the trade deficit, or cleaning up the welfare mess, but certainly well out of the political backwater. Such visibility brings scrutiny, and few of us in natural resources management welcome challenges to our management paradigms or the relevance of our research.

But what is the paradigm upon which ecosystem management is based? Welcome to the world of common words used in uncommon ways—of common words used with multiple meanings —f common words used with mutually exclusive definitions—of new words used in old ways (Fitzsimmons 1996; Freemuth 1996). Has the bureaucracy of government agencies and nongovernmental organizations captured the concept for their own, hut divergent, purposes? How can I or anyone identify the implications of something for which there is little consensus? These are good questions but ones without comforting answers. To start, let me offer a definition of ecosystem management that I have found useful: *"The application of ecological and social information, options, and constraints to achieve desired social benefits within a defined geographic area and over a specified period"* (Lackey 1998). This might sound like one of those precise legalistic definitions where each word connotes difficult policy choices. It is. Each term is imbedded with value judgements, policy trade-offs, and social conflict. The definition also is very similar to commonly used definitions of natural resources management (Wood 1994).

To better understand what ecosystem management is and, perhaps more important, what it is not, I will describe it as a management approach resting on seven pillars, core principles in the sense of supporting the infrastructure of ecosystem management (Lackey 1998):

The first pillar: *Ecosystem management is a stage in the continuing evolution of social values and priorities; it is neither a beginning nor an end.* Just as earlier management paradigms shifted to reflect changing social values and priorities, so will ecosystem management evolve. In fact, we should expect public values and priorities to change. Ecosystem management is not a radical paradigm shift, hut an evolutionary one–an evolution that should be intuitively expected, in view of the changing demographics of North America, especially the overall rise in affluence and increasing urbanization. However, the correlation between a country's affluence and its citizens' concern about environmental (usually defined as related to human health) issues appears weak (Dunlap et al. 1993). Further, scientific understanding evolves, and new information can cause opinions and preferences to change.

The second pillar: *Ecosystem management is place–based and the boundaries of the place must be clearly and formally defined.* This pillar is not as simple as it sounds. The boundaries must be clearly stated and accepted by the affected parties. For example, think about defining an ecosystem that includes a stock (population) of Pacific salmon. Do you include the appropriate watershed and much of the North Pacific? After all, an individual salmon may travel from a stream in a remote inland area to the middle of the North Pacific. Or what about biodiversity issues in the Brazilian rain forest? Many stakeholders (biodiversity advocates) are found in North America but have no direct, physical connection to South America. Their actions very much affect what happens in the rain forest.

As important as it is to define boundaries in ecosystem management, clear and formal definition is rare.

The third pillar: *Ecosystem management should maintain ecosystems in the appropriate condition to achieve desired social benefits.* "Appropriate" is the operative word, defined as "a social choice within ecological constraints." Notice that concepts such as ecological health and integrity are missing from this pillar. Applying the concept of ecosystem health requires specifying the desired or acceptable ecological state clearly and unequivocally (Rapport 1995). However, determining the desired ecological state is a monumentally difficult political and technical challenge.

The fourth pillar: *Ecosystem management should take advantage of the ability of ecosystems to respond to a variety of stressors, natural and man-made, recognizing that all ecosystems have limited ability to accommodate stressors and maintain a desired state.* We all want the benefits from ecosystems, but what types and levels of benefits can he realized before unacceptable consequences occur? This is the domain of the various aspects of natural resource management.

The fifth pillar: *Ecosystem management may or may not result in emphasis on biological diversity* Biological diversity has achieved a political following, which is perfectly appropriate—in the political arena. However, in the technical and scientific arena, we need to he much clearer about why biological diversity is relevant. There is nothing intrinsically important about biological diversity (or the human condition for that matter) unless it is defined as a political value (Shrader-Frechette and McCoy 1993; 1994). For example, if society decides that all species have a legal right to survive, then that becomes the management or policy goal. Society might go further and decide that no individual member of a species should be killed without due legal process—another perfectly valid social choice but definitely not a scientific one. However, because scientists have not yet determined a critical functional role of biological diversity, it does not follow that biological diversity is unimportant. Extinction of a species or gene pool is permanent, and such decisions preclude some future policy options (Rohlf 1990).

The sixth pillar: *The term "sustainability," if used at all in ecosystem management, should be clearly defined—specifically the time frame of concern, the benefits and costs of concern, and the relative priority of the benefits and costs.* Sustainability is a complex concept, and the term should not be used loosely. Many conditions, states, and strategies are sustainable. Selecting which ecological state is preferred is society's choice—a political and social process, not a scientific one. Providing scientific information and the ecological consequences of each option is appropriate; choosing the preferred option is not (Lackey 1995).

The seventh pillar: *Scientific information, important for effective ecosystem management, is but a single element in a decision-making process that is fundamentally one of public andprivate choice.* Decision making is choosing among alternatives. Scientific information is important in assessing the consequences of alternative choices, hut so are other aspects of public choice (Francis 1996).

Each pillar requires some information, often information not currently available. As for identifying information (research) needed to successfully implement ecosystem management, do we want scientists to determine research priorities? It's natural for those of us who do research for a living to treat the scientifically unknown and scientifically uncertain as key issues in public policy and management. It also is easy for us to identify a long, detailed list of critical research needs. But a laundry list of research topics is the last thing needed to successfully implement ecosystem management. Many individuals and committees have developed lists of research that would keep scientists busy, and funded, for many years. Other groups have called for more research on general ecological topics that would justify virtually any type of research. Neither approach is productive for successfully implementing ecosystem management. Instead, I will focus on identifying research priorities that will make a difference in implementing ecosystem management.

## Management Concepts

A number of characteristics tend to differentiate ecosystem management from other management and policy activities (Colby 1991; Grumbine 1994; Keiter 1994; Stanley 1995; Fitzsimmons 1996; Freemuth 1996; Lackey 1998). Earlier, yet similar, discussions and debates by natural resource professionals are reviewed elsewhere (Roedel 1975).

The first characteristic is the use of words with ambiguous and widely divergent definitions, a characteristic not unique to discussions of ecosystem management. For example, what do natural resource managers really mean by sustainability? Rarely used with any precision, its meaning is often intentionally left vague. Some natural resource managers argue that the fundamental purpose of ecosystem management is to maintain ecological sustainability (Wood 1994), but without any serious discussion of what is meant by the term. Does it mean economic activity that is sensitive to environmental consequences, or is it a fundamentally different view of man's "progress"? After all, is anyone explicitly advocating unsustainability in renewable natural resources management?

Biodiversity is another one of those words that is commonly used in discussions of ecosystem management but rarely defined precisely. There are tough tradeoffs for sure, but who is explicitly against biological diversity? What is the opposite political position to being pro-biological diversity? Is it pro-economic growth? Is there even a consensus among analysts on what biological diversity is beyond the most general definitions? Terms such as biodiversity—and you might add terms like life, liberty, and the pursuit of happiness—serve useful roles in some types of dialogue, but they mask the tough choices that individuals and society must make. These kinds of terms are sufficiently vague that they preclude substantive policy debate.

Second, ecosystem management directly affects people. What we decide to do, or not do, about ecosystem management affects each of us. For example, policies on sustainability affect all individuals and organizations, directly and indirectly, both now and in the future. Public policies to encourage or discourage efficiency in food production through direct or indirect tax subsidies or free market policies affect us all. Similarly, ecosystem management is about setting strict limits on social and economic uses of land (Wood 1994) even though some agencies insist that the implications of ecosystem management only extend to their own lands, and certainly not to private lands. Most government land managers talk enthusiastically about how their agency fully embraces ecosystem management, but are careful to limit their purview to their agency's lands. Others contend that the whole idea behind ecosystem management is to break down these artificial political and ownership boundaries and make decisions independent of them. Most private owners, at least, don't consider their property boundaries artificial. Taking someone's property, or diminishing its value, is a serious action—and the aggrieved individual can be expected to protect his rights vigorously.

Third, ecosystem management strikes at the core of our values, ethics, and moral philosophy. What rights, if any, should be granted to the non-human world? How important is this generation's material well-being compared with that of our children? Are our children more important than the natural world? How are the benefits of ecological resources to be distributed within society? Is an individual's creativity and labor to be rewarded or are these benefits to be distributed on the basis of collective or community needs? If human population is a concern, is it moral to coerce people into reducing their fertility? Is it moral not to? Is the separation between society and nature real or imagined? These are not science issues but reflect deeply held moral and religious views. Consequently, defining ecosystem management is itself a highly value-laden process.

A fourth characteristic of ecosystem management is the high degree of scientific uncertainty, especially when predicting future conditions. The political science axiom is true: "If you can answer a scientific question with accuracy, it is surely irrelevant in policy debates." When the political stakes and scientific uncertainty are high, politicians understandably want to pass responsibility to technocrats—ecologists, economists, and other "experts." Some scientists are willing to accept this responsibility. Others are not. Scientists do have a role—an important one—in ecosystem management, but making policy choices is not one of them, at least under current law.

Fifth, ecosystem management carries its share of scientific and political baggage. Depending on one's political perspective, terms such as ecosystem health can imply a good thing, something natural, something not degraded by man. After all, no one is arguing that we ought to be managing to produce "sick" ecosystems—so the debate must be about what is meant by a "healthy" ecosystem. Calls for managing for biological diversity, ecological health or integrity, and sustainability should be viewed like calls for freedom, equality, prosperity, and enlightenment—great for the campaign speech but not for serious analysis.

## Research

Natural resources research serves many purposes. One is to advance our general knowledge. Many management improvements may have been made possible by research that had no identified purpose other than to explore the unknown; however, that is not a criterion that will be used here to set research priorities.

The first criterion I suggest is that research should be policy-relevant. Being relevant does not mean advocating a particular policy position, but it does mean significant interaction among scientists, policy analysts, and decision makers—with scientists not assuming the role of policy advocates. Scientists are not empowered to implement policy and ecosystem management; decision-makers are. For example, scientists may develop a technical understanding of climate change, its cause, the likely ecological consequences, and the associated uncertainties. And more directly related to natural resource management, who decides that non-native species are any less important than native species? There is nothing intrinsically (socially) important about the fact that brown trout came from Europe or that rainbow trout were limited to western North America. It is up to the political process to decide these kinds of questions and to determine which management option should be adopted as public policy.

Secondly, the results of the research should help society make better decisions. "Better" is not easily defined, but two aspects of it are clear: first the decision reflects the will of the governed, second, few unanticipated ecological consequences result from the decision. That means that not only is the research policy-relevant but it must seek the specific type of information needed to improve decision making. For example, research on sustainability will not, in itself, improve decision making. Nor will studying the life history of the Wyoming toad, while an interesting and challenging scientific endeavor, necessarily help make better public choices.

Third, applied research, the type being considered here, should be scientifically tractable—in other words, only those scientific problems that can be resolved in a reasonable time frame should be undertaken. The solution to many technical problems would be very useful in implementing ecosystem management, but the likelihood of finding those solutions anytime soon is remote. Some issues also are not tractable because they are not research questions. For example, should we protect a particular species from extinction? That is a policy decision. Determining if that species is endangered and the ecological consequences of its extinction are purely scientific questions.

Fourth, setting research priorities should avoid applying the machine metaphor to ecological systems, with specific regard to the classical and highly constraining research model of hypothesis testing. The sequential testing of independent hypotheses which are either accepted or rejected is an example (Francis 1996). The hypothesis testing approach works well in research for narrow, mechanistic questions in science, but not for more complex (and typical) research and policy questions. Hypothesis testing may be easier to teach graduate students, but it is an artificial and unnecessary constraint that severely limits the role of research in addressing important policy questions (Francis 1996).

With these criteria in mind, I have identified threeresearch priorities: (1) ecosystem condition; *(2)* biological diversity; and (3) ecological sustainability. Three may not seem to be many, but if we scientists were able to solve any of the three in a credible way, it would be of immeasurable value in implementing ecosystem management.

### Ecosystem Condition

There are certain elements of ecosystems that the public values highly (Dunlap, et al 1993). It follows that we ought to make decisions to enhance these public values. Valued elements clearly include the catch, the angling experience, the quality of the outdoor experience, and many others, less obvious and more difficult to define. What are the ecological states that have these values? It is obvious that the public wants "healthy" ecosystems, but what are these? Do we want natural, unaltered ecosystems? Do we want ecosystems that only appear to be natural? Do we want natural ecosystems, but without natural events such as plankton blooms, disease, and wildfire? Do we want introduced species as part of the ecosystems? After all, the major ecological effects in North America are caused by the introduction of species like wheat, soybeans, cows, pigs—and humans. Are these kinds of introductions acceptable? We want our cake, but just as surely we want also to eat it.

Few discussions of research are complete without invoking the concept of ecosystem "health." Agency heads and politicians wrap their policies in the protective cover of ecosystem health. Who can possibly be against such policies? Ecosystem health must be good ecosystem degradation and impoverishment are obviously bad. Who stands opposed to health? **Is** there anyone who explicitly advocates ecosystem degradation and impoverishment? Such terms are so value laden that they should be avoided, or if used, be clearly defined.

We all want healthy ecosystems, but "health" is largely in the eye of the beholder. Central to the health paradigm are value judgements—deciding which characteristics of the ecosystem are of interest (Costanza 1995; Calow 1995; Rapport 1995). **A** patch of fertile agricultural bottomland with a blue ribbon salmon stream can be equally healthy (or unhealthy) as a Christmas tree plantation, a field of grass being grown for seed, or a pond heavily used for fishing, swimming, paddle boating, and maintaining a duck population to entertain urban strollers. Health depends on the desired state of the ecosystem: therefore our degree of success in achieving the desired state determines how healthy, or how sick, the ecosystem is.

The first priority for research is to develop or adapt proce dnres to determine public values and priorities for ecosystems. I do not mean conducting more public opinion polls that show that everyone is in favor of the environment or desires healthy ecosystems. We don't need more rhetoric on the importance of healthy ecosystems or healthy economies; what we do need is research to help clarify society's expectations. As scientists we need to say to the public and politicians: we can help you with information to achieve the desired state of ecosystems, and we can inform you of the ecological consequences of various decisions, but we cannot —and should not—decide what is desired.

### Biological Diversity

Effective implementation of ecosystem management requires resolution of the biological diversity policy impasse. In fact, some argue that the paramount goal of ecosystem management is the preservation and restoration of biological diversity (Keiter 1994). There is something about biological diversity that the public values, but we do not know what it is. Often the debate over biological diversity degenerates into arguments over the morality of extirpating wolves, salmon, or spotted owls, or it moves into dubious assertions that biological diversity is important because of some unknown, potential future benefit of providing a cure for cancer or another equally dreaded malady. **Or,** a person quotes the number of fish species at risk as convincing proof that the time has come to implement ecosystem management. On the scientific side, the debate may be over the stability of ecosystems and the role of biological diversity in maintaining stability. Stable ecosystems are anything but static, but tend to operate over a range of states (Shrader-Frechette and McCoy 1993; 1994). Few policy debates seem more intractable than the debate about biological diversity and what, if anything, to do about it.

Two very different policy considerations are included in biological diversity, and it is important to keep them separate.

The first is the role biological diversity plays in ecosystems and, in particular, its relationship to ecosystem stability. Advocates of protecting biological diversity often say that diversity should not be reduced because ecosystems need a high degree of diversity to be sustainable. I will address that purported linkage later, but now I want to focus on research needs associated with the other element of biological diversity —its direct value—the tangible or intangible value that people place on species or ecosystems, and which is of crucial importance in ecosystem management.

Society clearly values specific aspects of biological diversity such as cougars, koalas, and condors (Dunlap, et al. 1993). There are also competing values for medicinal plants, ecosystem services, or commodity yields–fish, lumber, electricity, food, skiing, human habitation, transport, and so on. The level of the value is open to debate, but not the fact that there is some value. We have the Endangered Species Act and several international treaties and conventions that attempt to codify such societal preferences, however ephemeral they might be. Let me focus on the science underlying the Endangered Species Act.

The scientific and policy approach used in the Endangered Species Act is essentially species-by-species protection (Rohlf 1990). But does this approach work? People who value all species' right to exist are disappointed in the law, as are those who believe that preserving obscure species is too costly. Nearly everyone supports Siberian tigers and salmon, but few support preservation of smallpox virus. The remaining smallpox virus is located in two laboratories, and it may be destroyed any day now—it is truly an endangered life form. Do smallpox and all other life forms have a right to exist? If life forms are not all of equal value, how do we establish relative priority?

We do not have a credible measure of what the public considers important about biological diversity. At what scale should biodiversity be considered? Should we look at the scale of the Mississippi River watershed—or a five-acre Rocky Mountain meadow? More challenging yet to answering these kinds of questions, political rhetoric masks our scientific ignorance and clouds our vision of policy options. For example, look at the discussion of the Endangered Species Act. Many contend that the act is a simplistic response to complex policy goals. Does it reflect the values and priorities of the public? No simple answer here, but it is the law. The same kinds of questions confront the implementation of ecosystem management.

The specific research need is to formulate a better scientific paradigm on which to base legislation to address biological diversity options. To do this, scientists and analysts would have to determine in a credible way how public values and priorities relate to biological diversity, and develop scientific options for creating laws and policies to implement those values and priorities. It is certainly true that the public highly values charismatic megafauna—the warm "fuzzies" of the animal world—the cats, canines, and kangaroos—and wants those protected even if the cost is high. But how about the competing demands to protect less-appreciated fauna and flora, the viruses, bacteria, nematodes, and insects? What is the relative priority of scarce public and private resources? Is it true that the public values all species and they all ought to be protected at any cost? Perbaps it is really ecosystems that the public values.

Research of this type is difficult to conduct. It requires an effective blending of social and biological science in ways that make individuals in both disciplines uncomfortable. We have to go far beyond traditional public opinion polls and willingness-to-pay surveys. However, to successfully develop a scientific paradigm that will allow politicians to implement effective laws, it is essential that both biological and social scientists be focused on this research question.

## Ecological Sustainability

The third and final research priority for implementing ecosystem management is to resolve a key scientific issue that underpins sustainability (Lackey 1995). Costanza (1995) argues that the goal of sustainability allows for the possibility of positive human interactions with ecosystems, thus moving beyond the simplistic definitions of ecosystem health. Others go further, contending that sustainability is a precondition, an overarching *a priori* societal objective, of ecosystem management.

One of the difficulties in evaluating sustainability and similar concepts is that individual and collective bias color the dialog. Most of ns tend toward a bias that views undisturbed (by man) ecosystems as essentially good—in a word, desirable. Altered ecosystems are perhaps necessary for sustenance but are not ideal—i.e., they are undesirable. In fact, the very concept of "natural" is somehow wholesome and pure and, almost by definition, does not involve man. What are we trying to sustain and for whose benefit?

Another difficulty in reaching consensus on sustainability is that there are strong "fashions" in science, changing schools of scientific thought that are no less powerful than the changes in dress fashion. In this century alone scientists have embraced theories of the balance of nature, ecosystem succession, dynamic equilibrium, and chaos. Even the concept of the "ecosystem" had its fashion heyday in the 1950s and 1960s, and now it is becoming increasingly popular to challenge the existence of "ecosystems." The myth of a pristine, unspoiled continent which might serve as a reference condition has rapidly fallen from favor. North America in 1492 was highly altered by humans and far from pristine. To be caught with an out-of-fashion scientific viewpoint is no less a *faux **pas*** than to be caught in outdated attire.

Once sustainability is defined outside the classic commodity-yield construct, the basis becomes **less** clear (Rapport 1995). Sustainability of fish yields is tractable, at least in a theoretical sense. But when applied to ecosystems, what exactly is meant by sustainability? Sustainability of what? Sustainability over what time frame? Sustainability over what geographic region? Are societal values and priorities assumed to be fixed? Or is societal change anticipated and, therefore, will the meaning of sustainability change? Sustainable development is often used interchangeably with sustainability, but the former appears to have a built-in logical inconsistency (Rapport 1995). Are we dealing with developments that are *sustainable*? Is development sustainable? These are not trivial semantic nuances, but differences that lead to very different policy choices in ecosystem management.

When the concept of sustainability is applied to ecosystems, the implicit basis is the apparent relationship between ecosystem stability and biological diversity (Shrader-Frechette and McCoy 1993; 1994). The stability-diversity question is an old one in biology and there is a large, inconclusive scientific Literature. In short, is high biological diversity necessary to maintain stable ecosystems and permit ecosystem sustainability to be achieved? One of the main reasons offered for maintaining high diversity, often at very high cost to individuals and society, is to ensure stable ecosystems. **Is** this necessary? If it is, then there are benefits for maintaining biological diversity at high levels, even if the cost to individuals and society is high.

Research is needed to determine, in a credible way, the linkages between external **stress** (or harvest), internal biological diversity, and ecosystem stability. It might seem obvious that greater diversity within an ecosystem should result in greater stability, but the data do not clearly support **this** relationship. For example, the core of any strategy for sustainable development is the assumption that we understand the linkage between biological diversity and ecosystem stability, and how they respond to external stress. If scientists cannot defend this purported linkage, we will continue wandering in the proverbial policy desert for a long time.

## A Challenge

What do we need to do to successfully implement ecosystem management? ***First,*** figure out how to get a credible handle on what the public considers to be the "desired" condition of ecosystems—the "health" of ecosystems. The operative word here is credible. Credible, comprehensive information doesn't exist now and therefore anyone can claim the mantle of public support. We all favor healthy ecosystems; we differ on what we mean by healthy. It may well be that it is not technically feasible to solve this research problem for any but the simplest cases.

***Second,*** develop a better scientific paradigm on which to base biological diversity legislation. Policy makers need a replacement for the species-by-species basis used in the Endangered Species Act. This is a tough scientific challenge, but one that is sorely needed in order to successfully implement ecosystem management.

***Third,*** determine the relationships among external stress, biological diversity, and ecosystem stability. The basis for sustainability and sustainable development is stable ecosystems. Stable does not mean "static" or imply "equilibrium," but just how much diversity is required to maintain ecosystems in that desired state.

And finally, we need some straight talk—serious, **sus**tained, and honest. The participants need to be scientists, policy analysts, ecosystem managers, and the various elements of the public. In most of thecurrent dialog, participants wrap their comments in the protective blankets of near meaningless terms—cosystem health, biological integrity, sustainability, biodiversity, stakebolder involvement, community based decision making, and, of course, ecosystem management. The policy questions being addressed in ecosystem management are important and deserve serious analysis, free of semantic mire.

## Endnotes

1. Modified from a lecture presented at Lewis and Clark College, Portland, Oregon, 5 October 1995. The comments and views expressed do not necessarily represent policy positions or research priorities of the Environmental Protection Agency or any other organization.
2. Associate Director for Science, EPA Western Ecology Division, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon, and professor of fisheries (courtesy) and professor of political science (adjunct) at Oregon State University.

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