Appendix M:
Scientific Basis for Ecosystem Management – Executive Summary

[*Modified from: The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management (Christianson et al. 1996); also cited in Spence (1996)*]

During this century, human populations and their demands for space, commodities, and amenities from ecosystems have increased by over five-fold. At the same time, evidence has mounted that there are limits to the stress such systems can withstand and still remain viable. Recent symptoms of ecological stress include the collapse of agricultural ecosystems in the southeastern United States and western "Dust Bowl," the spread of desert into rangeland in the Southwest, controversy over the management of old-growth forests in the Pacific Northwest, and the decline of marine fisheries. The impact of forest management activities on breeding habitat for migratory fishes is a dramatic reminder that the sustainability of many ecosystems depends on connections to other systems that do not respect individual ownerships, management borders, or international boundaries.

In recent years, sustainability has become an explicitly stated, even legislatively mandated, goal of natural resource management agencies. In practice, however, management approaches have often focused on maximizing short-term yield and economic gain rather than long-term sustainability. Several obstacles contribute to this disparity, including: 1) inadequate information on the biological diversity of environments; 2) widespread ignorance of the function and dynamics of ecosystems; 3) the openness and interconnectedness of ecosystems on scales that transcend management boundaries; 4) a prevailing public perception that the immediate economic and social value of supposedly renewable resources outweighs the risk of future ecosystem damage or the benefits of alternative management approaches.

Defining Ecosystem Management

Ecosystem Management is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function.

Ecosystem Management must include the following: *1. long-term sustainability as fundamental value, 2. clear, operational goals, 3. sound ecological models and understanding, 4. understanding complexity and interconnectedness, 5. recognition of the dynamic character of ecosystems, 6. attention to context and scale, 7. acknowledgment of humans as ecosystem components, and 8. commitment to adaptability and accountability.*

Sustainability. Ecosystem management assumes intergenerational sustainability (Lubchenco et al. 1991) as a precondition for management rather than an afterthought. Thus, the manager accepts the responsibility up front of managing in such a way as to ensure provision of the opportunities and resources we enjoy today to future generations.

Goals. Ecosystem management is as applicable to intensive utilitarian objectives as it is to the conservation of pristine wilderness; however, goals should not focus exclusively on "deliverables" such as board feet of timber, total catch, or visitor days. Goals must be explicitly stated in terms of specific "desired future trajectories" and "desired future behaviors" for the ecosystem components and processes necessary for sustainability. Furthermore, these goals should be stated in terms that can be measured and monitored.

Sound ecological models and understanding. Ecosystem management is based on sound ecological principles and emphasizes the role of processes and interconnections. Ecosystem management should be rooted in the best current models of ecosystem function. The name "Ecosystem Management" is confusing and has been taken by some to suggest that only science done at the ecosystem level is relevant. Ecosystem Management depends on research performed at all levels of organization, from investigations of the morphology, physiology and behavior of individual organisms, through studies of the structure and dynamics of populations and communities, to analysis of patterns and processes at the level of ecosystems and landscapes.

Complexity and connectedness. The importance of ecosystem complexity and the vast array of interconnections that underlie ecosystem function is certainly one of the most important lessons of ten decades of ecological research and natural resource management experience (Peterson 1993). Biological diversity and structural complexity of ecosystems are critical to such ecosystem processes as primary production and nutrient cycling. Complexity and diversity also impart resistance to and resilience from disturbance, and provide the genetic resources necessary to adapt to longterm change. Extractive or utilitarian management systems such as agriculture, aquaculture or plantation forestry that explicitly reduce complexity and diversity in order to increase productivity of particular ecosystem components may be deficient in key ecosystem processes and, therefore, less stable and less sustainable than intact and diverse natural ecosystems.

With complexity comes uncertainty. Some of our uncertainty regarding or lack of precision in predicting ecosystem behavior derives from the fact that we do indeed have more to learn. However, we must recognize that there will always be limits to the precision of our predictions set by the complex nature of ecosystem interactions and strive to understand the nature of those limits. Ecosystem management cannot eliminate surprises or uncertainty; rather, it acknowledges that, given sufficient time and space, unlikely events are certain to happen.

Recognition of the dynamic character of ecosystems. Sustainability does not imply maintenance of the status quo. Indeed, change and evolution are inherent characteristics of ecosystems, and attempts to "freeze" ecosystems in a particular state or configuration are generally futile in the short term and certainly doomed to failure in the long term. Crises associated with the management of our forests, fisheries, and wildlife have driven home the points that individual resources cannot be managed outside of the context of the full array of ecosystem components and processes and that the spatial and temporal domains of critical ecological processes are rarely congruent with the spatial boundaries and temporal schedules of management.

Context and scale. Ecosystem processes operate over a wide range of spatial and temporal scales, and their behavior at any given location is very much affected by the status and behavior of the systems or landscape that surrounds them (e.g., Levin 1992). There is no single appropriate scale or timeframe for management. Our ignorance of the importance of processes operating over ranges of spatial and temporal scale permitted society to define the boundaries of management jurisdictions with little or no reference to such processes. The importance of context in determining the behavior of ecosystems at a particular location has been the impetus for the advocacy of a "landscape approach" in terrestrial ecosystems (e.g., Noss 1983, Noss and Harris 1986) and the development of the "large marine ecosystem concept" (Sherman et al. 1990).

Humans as ecosystem components. Ecosystem Management acknowledges the role of humans, not only as the cause of the most significant challenges to sustainability, but as integral ecosystem components who must be engaged to achieve sustainable management goals (McDonnell and Pickett 1993, Peterson 1993). Human effects on ecosystems are ubiquitous. Although we should strive to reduce deleterious impacts, current trends in population growth and demand for natural resources will undoubtedly require more intensive and wiser management, particularly to support human needs in a sustainable way. Thus, identifying and engaging stakeholders in the development of management plans is a key ecosystem management strategy. Humans who are part of the ecosystems will, of necessity, define the future of those ecosystems.

Ecosystem management is a necessary but insufficient condition for achieving long-term sustainability. We must also address such daunting issues as human population growth, poverty, and human perceptions regarding the use of energy and natural resources.

Adaptability and accountability. As in all areas of science, current models and paradigms of ecosystem function are provisional and subject to change. Ecosystem managers must acknowledge that our knowledge base is incomplete and subject to change. Management goals and strategies must be viewed as hypotheses to be tested by research and monitoring programs that compare specific expectations against objective measures of results (Holling 1978, Walters 1986, Likens 1992).

Adaptability and accountability are central elements of ecosystem management. Managers must be able to adapt to the unique features or needs of a particular area and to inevitable temporal changes as well. Management must also be able to adapt to new information and understanding. To be adaptable and accountable, management objectives and expectations must be explicitly stated in operational terms, informed by the best models of ecosystem functioning, and tested by carefully designed monitoring programs that provide accessible and timely feedback to managers. Public understanding and acceptance of the experimental nature of all natural resource management are critical to the implementation of ecosystem management protocols.

Ecological Science as a Basis for Ecosystem Management

An ecosystem is defined as *"a spatially explicit unit of the Earth that includes all of the organisms , along with all components of the abiotic environment within its boundaries"* (Likens

1992). Ecosystems vary spatially and change with time, and no ecosystem is closed with respect to exchanges of organisms, matter, and energy.

Spatial and temporal scale are critical. Ecosystem function includes inputs, outputs, cycling of materials and energy, and the interactions of organisms. In order to monitor and manipulate these processes, scientists define ecosystem boundaries operationally. But boundaries defined for the study or management of one process are often inappropriate for the study of others; thus, Ecosystem Management requires a broad view.

Ecosystem function depends on its structure, diversity and integrity. Ecosystem Management seeks to maintain biological diversity as a critical component in strengthening ecosystems against disturbance. This challenge is compounded by the fact that diversity itself is a dynamic property of ecosystems. Thus, management of biological diversity requires a broad perspective and recognition that the complexity and function of any particular location is influenced heavily by the surrounding system.

Ecosystems are dynamic in space and time. Ecosystem Management is challenging in part because ecosystems are constantly changing. Over time scales of decades or centuries, many landscapes are altered by natural disturbances that lead to mosaics of successional patches of different ages. Such patch dynamics are critical to ecosystem structure and function.

While the earth's environment has changed dramatically over its four billion-year history, at no time have its ecosystems experienced change at the rate or in the manner at which it is occurring today. The rapidity of change and the novel character of many human impacts present special challenges to our ability to manage ecosystems sustainably.

Uncertainty, surprise and limits to knowledge. Ecosystem Management acknowledges that, given sufficient time and space, unlikely events are certain to occur. Adaptive management addresses this uncertainty by combining democratic principles, scientific analysis, education and institutional learning to increase our understanding of ecosystem processes and the consequences of management interventions, and to improve the quality of data upon which decisions must be made.

Humans as Ecosystem Components

Ecosystem Management is as concerned with managing human activities as with managing lands and waters. There is little doubt that the resources upon which humans depend are delivered from ecosystems in finite quantity. Even more daunting is the fact that the delivery capacity of these resources is not distributed uniformly across the globe or in patterns that necessarily correlate with human demand.

The mismatch between the scales at which humans make resource management decisions and at which ecosystems operate presents the most significant challenge to Ecosystem Management. Because management jurisdictions rarely match the domain of ecosystems, such mismatches often lead to irreconcilable resource disputes. But to say that ecosystem management is about

managing human activities is not necessarily to call for increased regulation; rather, management strategies must deal constructively with such growing concerns as the rights of private property owners and local loss of jobs.

Science as a Model for Ecosystem Management.

Like scientists, managers and those they serve must accept that knowledge and understanding of ecosystem function and best management practice are provisional and subject to change with new information. Thus, management approaches should be viewed as hypothetical means to achieve clearly stated operational goals. In testing these hypotheses, monitoring programs should provide critical and timely feedback to managers.

Implementing Ecosystem Management.

Ecosystem Management requires application of ecological science to natural resource actions. Moving from concepts to practice is a daunting challenge and will require the following steps and actions.

Defining Sustainable Goals and Objectives. Ecosystem Management recognizes that in order to meet resource demands sustainably, we must value our ecosystems for more than economically important goods and services. *Sustainable strategies for the provision of ecosystem goods and services cannot take as their starting points statements of need or want such as mandated timber supply, water demand, or arbitrarily set harvests of shrimp or fish. Rather, sustainability must be the primary objective, and levels of commodity and amenity provision must be adjusted to meet that goal.*

However good our intentions, management that focuses on commodity resources alone, that does not acknowledge the importance of diversity and complexity, that is not aware of influences of and impacts on surrounding areas, and that concerns itself with short time frames is not likely to be sustainable in the long term.

Reconciling Spatial Scales. Implementation of Ecosystem Management would be greatly simplified if management jurisdictions were spatially congruent with the behavior of ecosystem processes. Given the variation in spatial domain among processes, one perfect fit for all processes is virtually impossible; rather, Ecosystem Management must seek consensus among the various stakeholders within each ecosystem.

Reconciling Temporal Scales. Whereas management agencies are often forced to make decisions on a fiscal year basis, Ecosystem Management must deal with timescales that transcend human lifetimes. Thus, while recognizing the need to make short-term decisions, and while acknowledging that unlikely events do happen, Ecosystem Management requires long-term planning and commitment.

Making the System Adaptable and Accountable. Successful Ecosystem Management requires institutions that are adaptable to changes in ecosystem characteristics and in our knowledge base.

But to view management as experimental is not to advocate capricious implementation of untried or avant garde actions. It is rather to acknowledge the limits of our understanding of even conventional management procedures to the complex array of ecosystem components necessary for sustained functioning.

The Role of Scientists in Ecosystem Management. Adaptive management by definition requires the scientist's ongoing interaction with managers and the public. Communication must flow in both directions, and scientists must be willing to prioritize their research according to which information is most critical. Scientists have much to offer in the development of monitoring programs, particularly in creating sampling approaches, statistical analyses, and scientific models. As our knowledge base evolves, scientists must develop new mechanisms to communicate research and management results. More professionals with an understanding of scientific, management, and social issues, and the ability to communicate with scientists, managers, and the public are needed.

Ecosystem management is not a rejection of an anthropocentric for a totally biocentric worldview. Rather it is management that acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet those needs in perpetuity has limits and depends on the functioning of ecosystems.