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Introduction to Ecosystem Management

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Park and wilderness managers face significant challenges and opportunities in the stewardship of park and wilderness resources for present and future generations. Serious problems have emerged that require management approaches incorporating cooperation between many institutional sectors of society. Populations of "heroic species," such as grizzly bears and wolves, have disappeared or nearly disappeared from many landscapes. Other animals that range across park and wilderness boundaries are increasingly affected by a wider diversity of uses. Natural disturbances, such as fire, have been disrupted. Air pollution may be having a variety of effects on park and wilderness ecosystems. Development is encroaching on park and forest boundaries. Resource allocation choices are far more costly economically and politically than in the past. At the same time, communication barriers exist between managers of park and wilderness areas, adjacent landowners, and various user groups.

Basic information about plant, fish and wildlife, and human populations in and around park and wilderness areas is frequently lacking. Even though managers care deeply about the resources they manage, they must often function in a reactive mode, knowing that the tasks at hand are at best overwhelming, at worst hopeless.

To develop an improved conceptual approach to managing change in park and wilderness areas, the University of Washington College of Forest Resources, the National Park Service, and the USDA Forest Service convened an Ecosystem Management Workshop, April 6-10, 1987. Thirty-three scientists, planners, and managers gathered for a week at the University of Washington's Pack Forest to discuss these issues in a retreat environment. Their names and affiliations are included in the List of Participants at the back of the book. Even though the perspectives at this workshop were diverse, they did not totally reflect the diversity of interests found in park and wilderness management. Participants were selected for their disciplinary expertise, or for their orientation toward certain aspects of natural resource management.

The workshop focused on cooperative approaches to park and wilderness ecosystem management. It served as an interdisciplinary forum for the expression of ideas and was not intended as a vehicle to arrive at a consensus on issues of park and wilderness management. Subjects discussed included ecosystem management problems and issues, the increased insularity of natural areas, impacts of expanding use of natural areas, opportunities for mitigation via cooperative ventures, planning approaches to deal with ecosystem management questions, legal tools that help or constrain ecosystem manage-

ment, and summary recommendations designed to guide management thinking about ecosystem management issues in parks and wilderness areas.

Three perceptions repeatedly surfaced at the workshop and are worthy of introductory mention. First, the term "ecosystem management" means different things to different people: it is a buzzword for park expansion, a way to manage only natural areas (e.g., Chase 1987), and a process by which all multiple wildland uses can be coordinated. Discussion revealed erroneous perceptions that the term "ecosystem" applies only to lands managed for park or wilderness values.

Second, participants with biological expertise tended to underappreciate the role that people play in defining both the problems and solutions for park and wilderness issues: people are both managers and components of park and wilderness ecosystems. The biocentric orientation dissipated as the week progressed.

Third, some participants were suspicious of the motives behind the workshop, wondering if one agency (National Park Service) might attempt to use this process to control what goes on in another (Forest Service). Given the competitive relationship of the two agencies, and the fact that many national parks are contiguous with wilderness managed by the Forest Service, such perceptions are well grounded historically. But the workshop objectives were just the opposite: to foster cooperation between agencies managing similar resources, often for similar objectives (in this case, park and wilderness management). While the "land grabbing" perception was not dispelled during the week, it faded from the discussions and hopefully will continue to decline as these agencies embrace the ecosystem management concept.

SYSTEMS, ECOSYSTEMS, AND ECOSYSTEM MANAGEMENT

The workshop began with considerable ambiguity surrounding the meaning of the concepts "ecosystem" and "ecosystem management." These concepts have been used across the country and in other parts of the world, in both formal and informal ways, for decades. But they suffer from the same semantic difficulties as "diversity," "carrying capacity," "stability," and other resource-related terms: they mean different things to different people. For the reader who may not be familiar with these concepts, a brief background discussion of systems and systems analysis, as these terms are applied to wildlands, is appropriate.

The study of nature and man is a study of systems (Odum 1971). A system can be defined as an organized or connected group or set of objects, principles, or ideas related by some common function or belief (Dickey and Watts 1978). There are generally natural or social elements in the system and physical and behavioral connections between the elements. When the system contains living organisms, it is frequently called an "ecosystem." Ecosystems have boundaries, but the boundaries are defined arbitrarily.

The concept of "system" provides the basis for a conceptual model that can be used in decision making related to park and wilderness management. Systems analysis emphasizes the relation of system components to each other and to the rest of the system. Implicit in this approach is a search by logical process for alternatives to achieve clearly defined system objectives.

Several definitions were initially proposed at the workshop for the term "ecosystem." Many others are available in environmental and ecological textbooks. A working definition was agreed upon: an ecosystem is any part of the universe chosen as an area of in-

terest, with the line around that area being the ecosystem boundary and anything crossing the line being input or output. This definition encompasses more specific areas having geologic, biologic, legal, and social components.

For parks and wilderness areas, an adaptation of a graphic device used in set theory and known as a Venn diagram is useful to illustrate the relation of park and wilderness ecosystems to neighboring landscapes (Figure 1-1). Several implications of our working definition of "ecosystem" for park and wilderness management follow.

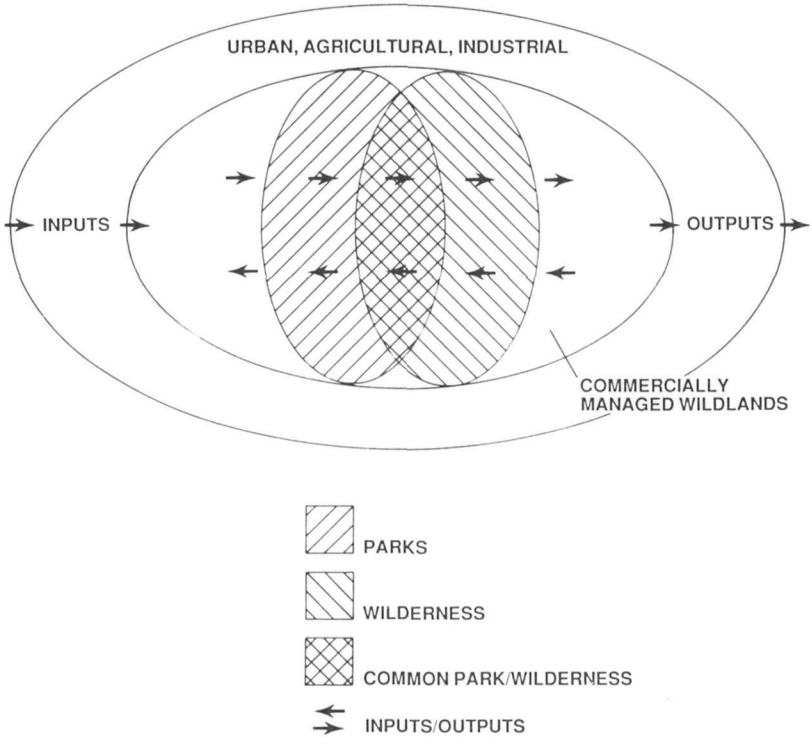

Figure 1-1. Relation of park and wilderness ecosystems to neighboring landscapes.

Ecosystems are spatially variable. A vegetation management problem in one park or wilderness area may have different spatial boundaries than the same problem in another park or wilderness.

Ecosystems are temporally variable. A given problem may have one set of spatial boundaries now and quite another a decade from now. The form of the problem and the solution may change over time.

Different ecosystem components may have different boundaries, implying a set of overlapping and interacting systems. For example, some vegetation management problems could potentially be confined within a park or wilderness area. A wildlife management problem may influence and be influenced by adjacent land uses and social values; the boundaries of the ecosystem for that issue would encompass those adjacent lands. Visitor use of an area may be strongly affected by the regional social system.

Politically defined boundaries frequently do not contain all the ingredients (resources,

people, etc.) necessary to resolve resource management issues. There will be inputs and outputs for any ecosystem, and any lines drawn around park and wilderness ecosystems will have flows across them: people, animals, air, and so forth. Political boundaries can be seen as "permeable membranes" through which continuous flows of energy, organisms, and ideas pass. External (or exogenous) factors may influence or be influenced by the ecosystem.

The ecosystem concept may be applied to all lands, not just those managed for natural values. Lands managed for timber production, quarried for minerals, and so forth, are also ecosystems with similar components and interactions. Recognizing the connections between the parts of the system will be important in every use, but not every action will affect adjacent lands or require significant interagency coordination.

These implications can be placed in a management context by summarizing four biological and social system properties that underlie successful environmental assessment (Holling 1978).

1. *Ecological systems are continually changing.* Such dynamic variability determines part of the structural and functional aspects of ecosystems. Low intensity, frequent burning in a mixed conifer forest, for example, has had a significant controlling influence in historically open, pine-dominated forests (Parsons 1981, van Wagtendonk 1985). Continually changing social systems are intuitively apparent and reinforce the concept of reciprocal influence that components of a social system have on each other.

2. *There may be substantial spatial heterogeneity in impacts from a particular action.* Impacts may not be gradually diluted over space, like the ripples of a wave from a rock thrown into a pond. Some affected people are near at hand; others are quite distant. Ecological consequences may occur nearby or at distant points. The presence of automobile exhaust along the Interstate 5 corridor near Seattle creates a soup of hydrocarbons that become photochemically active downwind and show up as increased ozone levels near Mount Rainier; the ozone levels near the source are much lower (R. Edmonds and T. Basabe, University of Washington, pers. comm.).

3. *Systems may exhibit several levels of stable behavior.* With disturbances of either human or nonhuman origin, ecosystems may evolve into systems different from any that existed before, and may stabilize at one of several levels. When goats were removed from Hawaiian parks, alien grasses and trees increased, while native trees were not able to reinvade the previously grazed areas (Mueller-Dombois and Spatz 1975). Similarly, a decline in a major economic institution may not signal a return to earlier social conditions but an evolution of a unique social system with a new set of structural characteristics.

4. *There is an organized connection between parts, but everything is not connected to everything else.* For example, each species in a biological system has a limited set of connections to other species. The moose-wolf interactions at Isle Royale in Michigan, while complex and not yet fully understood, have been effectively studied without total knowledge of every species or energy linkage in the Isle Royale ecosystem (Peterson, this volume). Similarly, agencies have extensive political constituencies that are directly and indirectly influenced by each other. However, many social groups are not affected by park or wilderness decisions and are not interested in them. It is not necessary to know all the linkages to move ahead, although the important ones should be understood in advance.

In summary, the ecosystem concept, with its biological and social components, can be

applied to any geographical area. The manager can be administering a grazing allotment, a commercial forest, or a park or wilderness. It is a flexible concept recognizing variability in time and space. Given that management actions will occur in changing environments, the important linkages between components must be known in order to be able to predict effects. Past effects, although a good guide, may not always be a road map to future effects.

Ecosystem management involves regulating internal ecosystem structure and function, plus inputs and outputs, to achieve socially desirable conditions. It includes, within a chosen and not always static geographic setting, the usual array of planning and management activities but conceptualized in a systems framework: identification of issues through research, public involvement, and political analysis; goal setting; plan development; use allocation; activity development (resources management, interpretation); monitoring; and evaluation. Interagency coordination is often a key element of successful ecosystem management, but is not an end in itself. Success in ecosystem management is ultimately measured by the goals achieved, not by the amount of coordination.

GOAL DEFINITION FOR PARK AND WILDERNESS ECOSYSTEMS

Park and Wilderness System Dynamics

Considerable confusion has resulted from a widespread misconception of the dynamics of ecosystems. Such systems are envisioned as having a natural balance or static equilibrium that in fact does not exist. Although periods of stability may exist, and multiple levels of stability can be defined (Holling 1978), park and wilderness ecosystems are nonequilibrium systems. A "balance of nature" occurs only over short and constrained periods: the constant in these systems is change. This fact is fundamental to establishing realistic goals for park and wilderness management.

Components of these ecosystems cannot be defined at a particular level that will unequivocally be perceived as "natural." The word "natural" evokes diverse value judgments that are difficult to reconcile. Plant species have reacted individually to climatic changes for millennia, so that the communities seen today on the landscape are in part a result of past climatic shifts (Figure 1-2) and the differential colonization rates associated with each species (Brubaker, this volume). They represent the state of the vegetation of the ecosystem today, but are not necessarily representative of some past equilibrium vegetation mosaic.

Knowledge of sustainable yields of herbivores and the relationships between predator and prey populations (Figure 1-3) suggests that equilibrium levels of animals may be maintained infrequently (Peterson, this volume). Similarly, visitor uses of wildland areas have changed over time, and are not always directly related to population growth (Figure 1-4). Even standards of appropriate behavior change; it was once considered quite appropriate to feed bears and kill carnivores in national parks. Park and wilderness management, therefore, is the management of change where the basic values and knowledge underlying management may change.

Complex ecosystem models that incorporate either human culture or nonhuman biological components accurately are not likely to emerge in the near future, if ever. In plant ecology, the evolution of theory has moved away from the grand unifying theory proposed by Clements to more diverse views (Christensen, this volume). Some of the

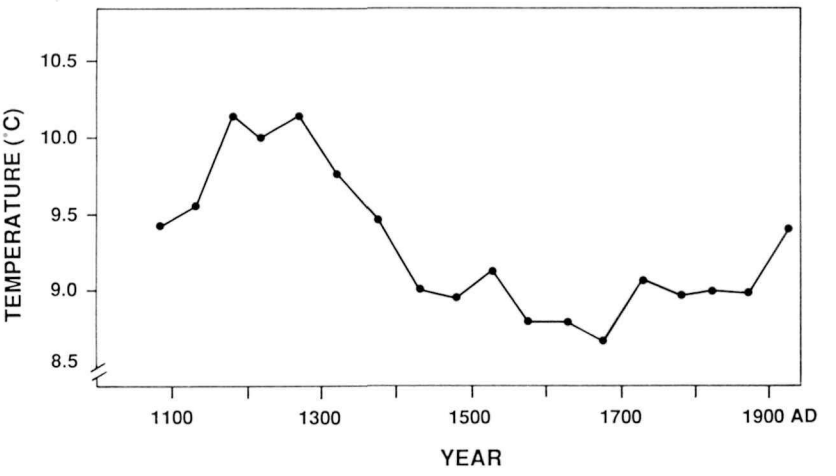

Figure 1-2. Climate over time (average temperature) as an indicator of a nonequilibrium system. Source: Brubaker, this volume.

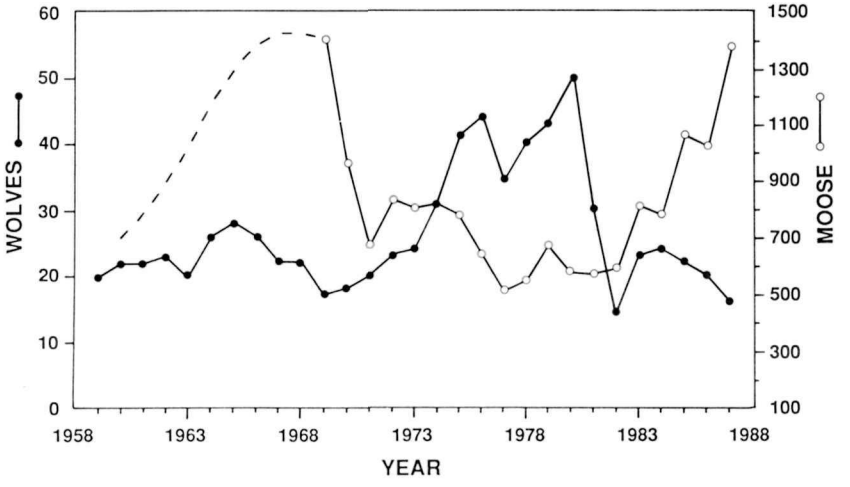

Figure 1-3. Wildlife relationship (predator-prey populations) as an indicator of a nonequilibrium system. Number of wolves in relation to number of moose in the Isle Royale ecosystem, 1959-87. Source: Peterson, this volume.

newer models, particularly in the area of conservation biology—such as managing for minimum population size (Salwasser, this volume)—or in landscape ecology (Forman and Godron 1986), are in embryonic stages or are still untested theory. Methods to measure intrinsic (existence) values of parks and wilderness do not exist (Irland, this volume). Therefore, while system models offer no panacea for predicting precise effects of park and wilderness management, they can provide frameworks for assessing the importance of data gaps, identify interrelationships between components, and assist in defining monitoring plans to measure effectiveness of management actions.

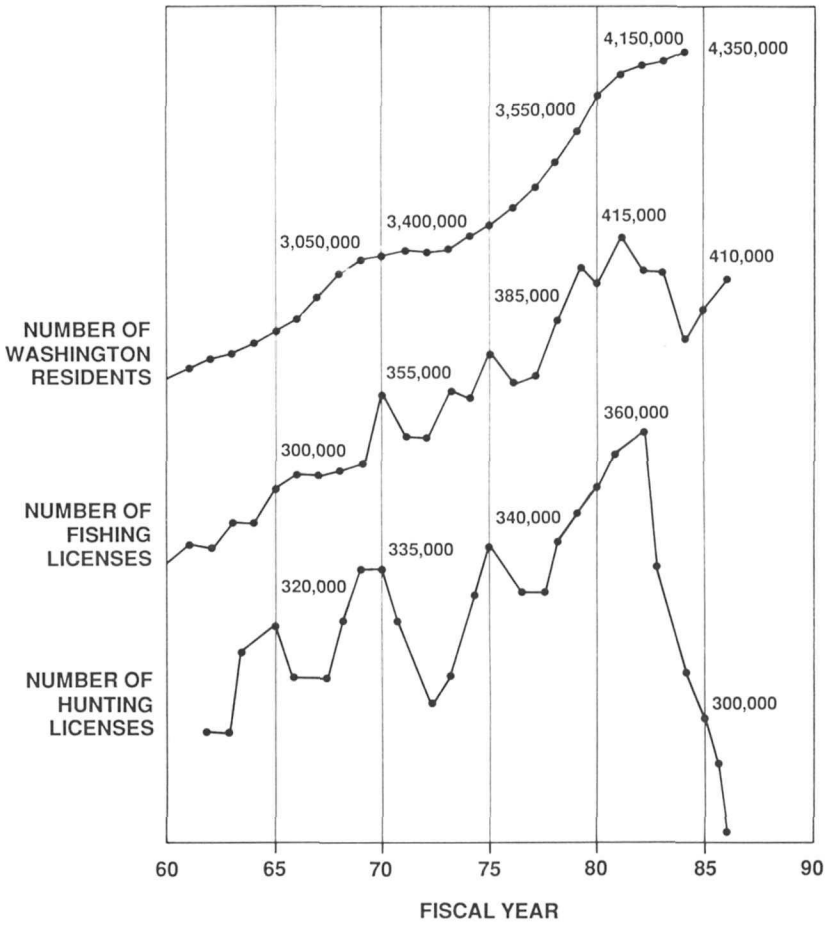

Figure 1-4. Wildland visitor uses, in relation to population growth in the state of Washington, as an indicator of a nonequilibrium system.

Ecosystem Goals in Parks and Wilderness

The National Park Service Organic Act of 1916 states that the mission of the Service is to conserve "the natural and historic objects and the wildlife therein . . . for the enjoyment of present and future generations." The legislation is very object oriented, and several papers have reviewed the evolution of process-oriented management (e.g., allowing lightning fires to burn; Agee 1974, Graber 1985). The Wilderness Act (1964) projects a similar mission. Wilderness land is to be "protected and managed so as to preserve its natural conditions." It is to be "administered for the use and enjoyment of the American people . . . unimpaired for future use and enjoyment." Analyses have also been done on the intent of this legislation (Hendee et al. 1978, Crandell 1987). At a minimum, the conservation-preservation mandate in the two statutes imposes a legal obligation on park and wilderness managers to manage these lands to maintain "natural" conditions, and to protect them from adverse external impacts (Keiter, this volume).

A major shift in National Park Service policy occurred in the mid-1960s with the Leopold Report on wildlife management in parks (Leopold et al. 1963). This landmark

report recommended a primary goal of management to restore national parks to "the conditions which prevailed when the area was first visited by the white man": a "vignette of primitive America." The report suggested that a pre-Columbian vegetation mosaic could be restored by reinstituting natural disturbance processes, particularly fire, to park landscapes. Since that time, reintroduction of fire has occurred in many parks. The report provided a stimulus for a positive shift in park, and later wilderness, policy by emphasizing the need for active management.

Despite the widespread influence of the Leopold Report, the creation of a static "vignette of primitive America" is probably not a desirable or feasible goal for future park and wilderness management. To use any narrow window of time as the basis for establishing management goals is inappropriate for systems characterized by nonequilibrium conditions. In fact, the four centuries preceding the voyage of Columbus to America had anomalously warm weather, which has not since recurred (Brubaker, this volume). Vegetation conditions, wildlife populations, and disturbance processes were different then. Similarly, an attempt to reconstruct the scene of 1870 is an inappropriate goal, because it imposes static conditions on systems that are inherently dynamic. Although Leopold and other committee members are reported to have later stated that they wished the "vignette" language had not been used, this issue has never been formally resolved.

Recent discussions have attempted to shift away from the goal of recreating a "vignette of primitive America" to one of restoring and maintaining "natural processes" (Parsons et al. 1986). The vignette might now be termed a "moving picture" (Christensen et al. 1987), although national policy does not formally recognize this perspective. The "moving picture" scene implies that a dynamic, continually changing landscape, primarily in response to nonhuman processes and disturbance factors, is more realistic than an implied static landscape.

The word "natural" remains difficult to define because it incorporates value judgments that cannot be scientifically resolved. If natural process management is assumed to mean evolution free of human influence, implementation of natural process management as a sole goal for park and wilderness management will be difficult to accomplish. Disturbance patterns did not stop at park and wilderness boundaries in primeval times; such boundaries were nonexistent. Disturbances, such as lightning fires, that once entered these areas from adjacent lands may not now, because of different land uses outside parks or wilderness. Some previous disturbances had a human origin (Indian fires) and are not present now.

Most of the wildlife species near the top of the food chain have large territories, and cross park and wilderness boundaries regularly or seasonally. Some, such as the grizzly bear, wolf, and cougar, are already missing from their recent natural ranges in parks and wilderness areas. Factors outside the boundary such as hunting or habitat manipulation (or in the case of Forest Service wilderness, hunting inside the boundary or livestock grazing), and fishing (except for some "catch and release" programs) inside most parks and wilderness, are evidence that management without significant human influence is not a realistic goal for many ecosystem components.

Areas outside the park or wilderness will usually be managed for other than park and wilderness values. Extinctions of wildlife in parks or wilderness may occur because of loss of essential habitat outside the area. Preservation of such species has received considerable attention by federal land managers.

Colonizations of park and wilderness areas by species native to the surrounding

region may be difficult to categorize as "natural" range extensions or alien intrusions. The native flora and fauna at the time of park or wilderness establishment are most often viewed as static lists, with further colonizations or extirpations considered a deviation from "natural" conditions. Recognition that plant and animal ranges are not static will be important in determining alien or native plant and animal range extensions and contractions.

Despite its utility, natural process management can create a number of external problems for park and wilderness managers. Since ecosystem components may range beyond park and wilderness borders, it follows that deleterious effects (from the perspectives of neighbors), natural as they may be, can be exported to surrounding areas. Disturbances such as fire have potential exogenous effects: smoke can create air pollution, fires can cross park or wilderness boundaries, and the habitat of rare or endangered species may be affected. Wildlife may carry native diseases to livestock outside the boundary; large carnivores may prey on livestock or endanger human lives.

Laws for social purposes other than park and wilderness preservation (e.g., the Clean Air Act, the Clean Water Act, and the Endangered Species Act) constrain management options and effectively preclude a natural process policy inside parks and wilderness for reasons discussed above. They can, however, be used to protect the areas from external influences. Air pollutants—primarily acid rain in the eastern United States (Schofield, this volume) and photochemical oxidants in the western United States (Grigal, this volume)—are predicted to affect both aquatic and terrestrial components of park and wilderness ecosystems. Air quality legislation can be used to impose significant legal constraints on adjacent landowners or managers (Keiter, this volume) to protect parks and wilderness.

In summary, the concept of natural systems remains viable, but only in a dynamic and flexible context. Change, and sometimes unpredictable change, is essential to the natural systems concept. The application of this concept will continue to be experimental, just as all management approaches in natural systems are (Walters 1986). An easy systems "fix" to predicting effects of management actions is not on the horizon.

Managing Uncertainty

Social and biological information will probably improve over time but will never allow precise prediction. Given the political boundaries of park and wilderness ecosystems and unavoidable and uncertain human influence, change will occur in those systems. If managers take no action, that decision is itself a decision for a particular type of change.

Alternatively, a four-step approach can be used as a process to meet park and wilderness ecosystem goals: (1) define goals and measurable targets for ecosystem condition, (2) define the ecosystem boundaries for the primary components, (3) develop management strategies to achieve goals that transcend political boundaries, and (4) establish a program to assess the effectiveness of the management strategies in achieving the identified goals. Adequate definition of ecosystem-level problems and solutions may not occur if political boundaries are used as ecosystem boundaries.

Define the Goals. Goals should be phrased in terms of ecosystem condition and represent desired conditions for primary components. Workshop participants felt that they were not the appropriate group to define these goals, although some broad statements fostered consensus. Most important, the goals should preserve options for the future.

This point means maintaining the indigenous diversity of these areas in the largest context, to ensure not just species richness (number of species) but structural and successional diversity across the landscape. The scale of the landscape is larger than any traditionally dealt with in natural resources management.

Although our ability to quantify appropriate geographic scales and desired levels of diversity is relatively weak, there is agreement that maintaining diversity over a large area is different from maximizing diversity on every site. Maximum species richness of sites may occur in early successional periods for many ecosystems. For example, losing old-growth stages of those systems may result in loss of species richness over the whole area as well as significant losses in structural and functional diversity. A possible diversity goal might be to maintain viable populations of all native vertebrates within the region that encompasses the park or wilderness. Each park or wilderness would contribute those habitats and degrees of protection from human activities that best complement conditions on adjoining lands. This would be an application of "total area," or gamma, diversity (Whittaker 1972, Salwasser et al. 1984). This broad-scale diversity as a management goal has been largely ignored, yet may be quite relevant to the purposes of park and wilderness management (Samson and Knopf 1982).

Workshop participants also agreed that thresholds for minimum acceptable ecosystem conditions should be set. But these thresholds should be flexible enough to accommodate visitor preference, conflicting legislation, and other detractions from unattainable, ultimately pristine conditions (Mealey, this volume).

Define Ecosystem Boundaries for Primary Components. Each component, whether it be populations of grizzly bears or giant sequoias, will most likely have a different ecosystem boundary. These boundaries may range beyond political (park and wilderness area) boundaries. Some may involve other federal land; others, state or private lands. Interest groups may also be defined as components, either because they are the focus of management (e.g., backcountry visitors) or because they may have positive or negative influences on management strategies designed for other components of the system.

Adopt a Management Strategy to Achieve Component Goals. Ecosystems generally are too complex to manage as unified wholes. One approach to ecosystem management, therefore, focuses on components but recognizes the linkages between various parts of the system. The strategy for one component may be more complex than the strategy for another, and may possibly conflict with management of another component.

Management strategies should also take into account the defined ecosystem boundaries. Regional or national strategies may need to be developed. Examples of regional strategies are grizzly bear recovery areas in the northern Rockies and Cascades, spotted owl population areas in the Pacific Northwest, and red-cockaded woodpecker population areas in the South and Southwest. An example of national initiatives may be the efforts to deal with air pollution, although the scope of these problems varies by region. Air pollution issues have been and remain a federal legislative concern.

Monitor Effectiveness of Management Strategies. Ecosystem condition goals create needs for information on ecosystem components, natural disturbance processes, and rates of change. This information is used to monitor progress toward the chosen goal. It is only within well-defined system management objectives that needs for information

is only within well-defined system management objectives that needs for information can be defined: obtaining and using information to track an ecosystem component or process that is unrelated to management is wasted effort.

Natural resources management, including park and wilderness management, is an experiment (Macnab 1983, Walters 1986). We simply do not know precisely the outcome of most management strategies. Many of our goals will therefore be achieved through hypotheses that are continually tested and refined. Two common themes emerge through these strategies. The first is that people are a part of the management solution. This is true of visitor preference as well as external costs (predator effects on livestock) and benefits (economic returns to local communities). The second theme is that because "naturalness" is subjectively defined, park and wilderness preservation goals will have to be stated in more precise system-component terms depending on the values represented by the individual area. These themes comprise the core of the chapters to follow.

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