Standard Scientific Procedures for Implementing Ecosystem Management on Public Lands

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Summary

Modern ecological ideas, including fundamental principles of conservation biology have not yet been fully embraced by federal land management agencies. Reasons include bureaucratic resistance to new ideas, influence by resource user groups who put maximum resource production above long-term ecological health of ecosystems, lack of external accountability by the agencies, and a misperception by agency personnel that conservation science is poorly developed. The fact that federal land management agencies often do not gather data or make management decisions using up-to-date science hinders their ability to ensure the long-term sustainability of both biological diversity and the specific resources, such as timber and fodder, for which the lands are managed.

For example, agency managers have often defended conventional patterns of timber harvest by arguing that the edge habitat they produce is beneficial to wildlife, even though edges are well known to have multiple deleterious effects on native, forest-interior species. To prevent such poorly informed management decisions, agencies must develop mutually compatible, explicit standards that determine how they will apply modem ecological science to land management. To facilitate this process, we propose a comprehensive set of standard procedures for implementing ecosystem management on public lands. These procedures incorporate our best contemporary understanding of population, community, and landscape dynamics to efficiently and systematically protect ecosystems and their constituent biodiversity.

Introduction

Management practices on federal lands have often harmed natural ecosystems, reducing not only biological diversity but even the resources-such as timber or grass production- for which the lands are primarily managed. For example, in many cases, fire suppression on national forests has changed the relative abundances of tree species, increased stand densities, or caused other structural and compositional changes that increase the probability of disease, fire, and loss of native species (Wagner and Kay, 1993; Anderson, H. M., 1994). Unwise grazing policies on Forest Service, Bureau of Land Management, and other federal lands contribute to the endangered or threatened status of many species, including Sonoran pronghorn (*Antilocapra americana sonoriensis*), Arizona willow (*Salix arizonica*), and desert tortoise (*Gopherus agassizii*) (National Wildlife Federation, 1994; USFWS, 1994a). The National Biological Service (1995) found that many U.S. natural ecosystems are seriously degraded or at risk of total loss. Many of these, such as Southern California coastal strand, Palouse prairie in the Northwest, and slash pine rockland in Florida have shrunk by more than 90 percent to become "critically endangered."

This unhappy state results from both scientific and institutional causes. Misundemanding of ecological principles has led to management decisions that were often inimical to biological diversity. For example, predators once were seen as negative influences to be removed (Anderson, S. H., 1995), whereas habitat edges were seen as universal benefits to be increased (Reid and Miller, 1989; Woodley et al., 1993). Nor has there been adequate appreciation that ecosystems are highly interconnected and that management decisions in one place may affect ecological conditions on other lands. A classic example is how logging can produce silt that harms the reproduction of salmon far downstream (Pringle and Aumen, 1993). These erroneous assumptions have helped agencies yield to political pressures to increase production of timber and other resources at the expense of ecosystem sustainability. For example, by overlooking the essential role that top predators play in maintaining healthy ecosystems, agencies have been able to rationalize activities that extirpate them. Likewise, their erroneous conclusion that edge habitat is universally beneficial allowed them to rationalize excessive timber harvesting.

Federal Land Management Agencies Have Been Slow to Adopt Conservation Science

Despite advances in ecology and conservation biology during the past 20 years that have refuted many ecological myths (Parker, 1993) and provided comprehensive tools for sound ecological management (Christensen, this volume), and even though agency scientists have been doing some of the best ecological work (e.g., on modeling viable population sizes, Ralls and Taylor, this volume), agencies have-been slow to base management policies on the new science, Scientists and conservation organizations have been educating, urging, and, in some cases, suing the agencies responsible for management to require them to collect adequate biological information and to act on it. For example, in 1992 the Sierra Club and other plaintiffs brought an unsuccessful suit against the U.S. Forest Service. when the agency refused to establish large blocks of mature forest that would be free of disturbances caused by logging, new roads, or wildlife openings. The suit complained that the Forest Service had rejected the proposal, and adopted a plan of ubiquitous fragmentation, without considering negative edge effects. island biogeography, and other concepts from conservation science (e.g., Noss. 1983; Meffe and Carroll. 1994).

Several factors have contributed to the historical unwillingness or inability of federal agencies to incorporate up-to-date conservation science in land management plans:

Misperceptions about the Quality of Conservation Science.

Resistance by the agencies is sometimes based on the incorrect conclusion that conservation science is too poorly developed to be dependable. People may draw this conclusion because they misunderstand the nature of science, mistaking scientific debate over particular points within the field for a generalized weakness (Pickett et al., 1994). For example, in the Sierra Club suit mentioned earlier, the judge concluded that the theory of island biogeography was too poorly substantiated to expect the Forest Service to use it in making decisions about how much habitat fragmentation to allow during timber production (Reynolds, 1994). He reached this conclusion partly because there is debate in the scientific literature over the degree to which the theory of island biogeography can explain patterns of species richness in habitat remnants, on mountain summits, and on other such terrestrial "islands" (Simberloff, this volume). The judge did not realize that scientific debate over the degree to which terrestrial habitat islands approximate real oceanic islands did not invalidate the basic conclusions, backed up by dozens of rigorous studies (e.g., White et al., 1990; As et al., 1992; Hansson, 1992a; Hansson, this volume), that small isolated habitat areas support fewer species than large ones, and that it is possible to make predictions about which species or groups of species will disappear first (e.g., Nott and Pimm, this volume). The inability of the theory to predict precisely how many species will disappear, given a particular logging pattern on a particular forest, in no way invalidates the general conclusion that fragmenting a contiguous forest, as was planned for the Chequamegon, will cause loss of biological diversity (Hansson et al., 1995).

Constituencies for Resource Use.

Arguably the most powerful force against incorporation of conservation science is pressure from resource-user groups. Historically, agencies have seen their primary responsibility to be the provision of sufficient resources for hunters. ranchers, and timber companies (Society of American Foresters, 1993), even if this comes at the cost of overstocking range lands and overcutting forests. Because conservation of biodiversity is a relatively new contender for agency concern and resources compared with traditional consumptive uses, there are frequently ideological, political, financial, or other constraints that predispose agencies to selectively interpret science.

Institutional Inertia.

Because the field of conservation biology is so new, with many of its primary tenets having been developed only within the past 20 years, it has not yet fully permeated government agencies (e.g., Hein, 1995). Conservation biology challenges individual agency professionals to think in new ways and asks the agencies themselves to develop and institutionalize new priorities.

Lack of Standardization.

No policy exists within and across agencies that sets standards for data sufficiency and types of studies required. Need exists for something analogous to the proposed interagency fire suppression policy (U.S. DOI and U.S. DOA, 1995) or the interagency standards for water quality assessment (Guru and Muir, 1994).

Lack of External Accountability.

American jurisprudence holds that courts will not substitute their judgment about how resources should be managed unless the ageny's decision is without rational basis. In the words of the judge in the Sierra Club case, "in areas of scientific uncertainty the agency's choice of methodology is entitled to considerable deference" (Reynolds, 1994). This legal principle, called "agency discretion," means that agencies may make resource management decisions even if they are contrary to generally accepted principles of conservation science.

New Opportunities Exist for Helping Federal Agencies Manage Lands More Responsibly

Despite the political pressures that encourage retrogressive action by the agencies, the imperiled state of many ecosystems on federal lands has forced the agencies to recognize that change is necessary. Federal and state agencies are trying to modify their approaches to natural resource management to ensure long-term sustainability of natural ecosystems and biological diversity. This period of reassessment offers scientists a unique opportunity to help agencies develop policies to use sound science in plans for sustainable use of natural ecosystems.

Many agency efforts to revise resource policies center around "ecosystem management." Ecosystem management generally implies turning away from single-use, single-species management, and turning toward management designed to ensure the health of ecosystems. The goal is to use natural resources in a sustainable way that does not threaten the integrity of the natural ecosystems that provide the resources. Ecosystem management and related issues are discussed in several chapters in this volume, including Barrett and Barrett, Christensen, Ewel, Gordon et al., Meyer, Thompson, and Wiens, among others. Also see Alverson et al. (1994); Noss and Cooperrider (1994); and Crow et al. (1994).

Ecosystem management demands a much broader vision than have historical management practices. It requires that managers

- widen their focus from a few species of economic or other value to all the species within the ecosystem;
- focus on understanding and preserving not only species per se but also the interactions between species that collectively maintain the ecosystem and provide ecosystem services (e.g., Meyer, this volume);
- enlarge the management time frame to include long-term ecosystem processes, such as cycles of forest fires and succession to old growth;
- widen the planning process to encompass entire ecosystems, communities. and populations, including portions extending off-site onto adjacent nonfederal lands;
- pursue solutions to threats that originate off-site, such as nonnative pests and pollution;
- accommodate the needs of nontraditional users of federal lands, including nonconsumptive users; and
- use adaptive management.

To effectively manage ecosystems and other elements of biological diversity that extend across management boundaries, managers of ecologically linked land units must cooperate in planning and implementation of management procedures. Joint planning will depend on collection of scientific data that are mutually compatible among land units.

Suggested Standard Procedures for Biodiversity Assessments

To assist in the development of acceptable scientific procedures, in this section we recommend standardized procedures that we consider essential to any management planning program[1]. The procedures are organized as four main activities:

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[1]This paper is the report of a workshop convened in July, 1994, by Defenders of Wildlife at the University of Wisconsin, Madison. Workshop attendees were conservation scientists and conservation law experts charged with developing a set of standard procedures that state and federal land managers could use to manage for biological diversity. The guidelines presented in this paper were developed at the workshop to help managers use up-to-date conservation science so that the impacts of timber harvesting, livestock grazing, and other types of resource extraction would not harm native ecosystems and species.

inventory and identification, evaluation of threats to diversity, management design, and monitoring and evaluating effects of management (Sections A, B, C, and D). Under these headings we identify and explain the importance of identifying communities and species at risk, choosing appropriate indicator species, measuring and mapping abundances, ranges, and other indicators of species and ecosystem health, calculating minimum viable population sizes for key species, calculating minimum dynamic areas for communities (defined later), and measuring edge effects. Agency procedures also should include methods for continued monitoring of ecosystem health so that short- and long-term negative impacts of management actions can be identified and rectified.

To be effective these procedures must be based on the best available science. Further, they should be standardized among agencies so that they can be consistently implemented across public lands. At present, agencies are frequently using divergent classification systems and data collection methods, as exemplified by the distinct ecosystem classification systems now being developed by the Forest Service and the Fish and Wildlife Service (CRS. 1994).

We realize that the standards offered below constitute an ambitious program. Because resources are limited, managers, scientists, and policy makers will have to jointly decide on which of the steps we recommend should receive highest priority. After priorities have been set, they should be reviewed regularly to make sure they are still appropriate given changing conditions and new information.

A. Inventory and Identification

As the first phase of their effort to assess the biotic status of their land base. managers[2] should assemble relevant and essential background information. Managers should

1. Prepare Maps of the Physical Environment.

Managers should prepare maps of topography, land forms, soils, climate and other factors that indicate the land's potential for supporting various types of biological communities. One important use of this information is to predict which kinds of natural vegetation could return to sites that are now substantially disturbed.

2. Prepare Maps of Biological Communities and Habitats.

Land managers need accurate and up-to-date information on the location and composition of the communities and habitats they oversee. Therefore

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[2]When we use the term "managers" in this general sense we mean managers in conjunction with scientists and others involved in gathering and analyzing data and carrying out management.

- For each biotic community, managers should compile comprehensive species lists for as many taxonomic groups as possible, incorporating data from herbaria, museums, state natural heritage databases, and other sources. Species lists should include not onlv the conspicuous tree and vertebrate groups but also herbaceous plants, cryptogams, invertebrates, and fungi.
- Communities and successional stages should be mapped to fine scale (e.g., 100-m resolution) and their ecological condition assessed. A finely detailed classification scheme should be used that can distinguish among communities and successional stages that differ significantly in species or structural composition.
- In cases where present vegetation does not reflect potential vegetation, for example where grazing has changed the plant species mix from that which occurred historically, both present and potential vegetation should be mapped.
- Data should be gathered for ecologically related land both inside and outside the management unit.
- Data on both the biotic community and the physical environment should be entered into Geographic Information Systems (GIS) capable of displaying them as electronic maps.
- Methods of identifying, classifying, formatting and mapping data should be standardized within and among agencies.

3. Identify Communities, Species and Populations Known to Be at Risk.

Managers should flag for special concern communities and species that may be imperiled in their planning area. These include

- communities recognized by the National Biological Service (Noss et al., 1995), heritage programs, other federal or state agencies, scientific bodies. or private conservation organizations (Grossman et al., 1994; Noss and Peters, 1995) as rare, substantially reduced in area, seriously degraded, or in imminent peril of substantial loss regionally or throughout their ranges;
- species recognized by heritage programs, state or federal agencies, or others as threatened, endangered, or otherwise of special concern, or known or suspected to be declining in abundance across a significant fraction of their range, or known to be suffering a loss of range; and
- communities or species known to decline in the presence of human activity; introduced species, toxics, or other threats present in the planning area. These include species sensitive to habitat fragmentation or edge effects.

Agencies should collect alI available data about these communities and species regarding their distribution, abundance, and responses to particular types of disturbance. In the case of species, assessment should include identification of specific habitat requirements. Where possible, distributions should be mapped.

4. Select, Inventory, and Monitor Indicator Species (ISs).

In addition to identifying species at risk, managers should identify other species that can serve as indicators of ecosystem structure and function and whose responses to changing conditions can be used to assess the success of management. Managers should include indicator species from all the following groups:

- species endemic to the area;
- species that require particular habitat or landscape features;
- species sensitive to environmental change;
- top carnivores or other species that require large blocks of habitat;
- keystone species that are known to have or suspected to have major influences on community structure or ecosystem function;
- species that are economically important, such as sport fish or game species;
- introduced species with substantial impact on natural communities; and
- species that exhibit metapopulation structure (e.g., Hanski, this volume; Wiens, this volume) or have ephemeral sub-populations that depend on disturbance (e.g., Hansson, this volume).

For these indicator species, agencies should collect and map where possible all available data regarding distribution, abundance, habitat needs, habitat specificity, and responses to particular types of disturbance.

5. Map the Hisorical Distributions and Characterize the Historical Compositions of Natural Communities.

Qualitative information and quantitative data should be gathered on distribution patterns from the pre-European settlement period both for the management unit and for ecologically related areas outside the unit. These data should be incorporated in GIS or otherwise mapped.

6. Characterize Current and Historical Disturbance Regimes.

Because disturbance regimes play a key role in determining patterns of biological diversity (Pickett and White, 1985; Huston, 1994), managers should identify and characterize patterns of disturbance from presettlement times to the present. As far as possible, information should include the frequency, intensity, areal extent, and distribution of each disturbance type. Current and recent anthropogenic disturbances, including grazing, timber harvest, and roads, should be characterized for comparison to the pre-European disturbance patterns that shaped the natural communities.

7. Determine How the Biological Communities Respond to Disturbances.

Managers should understand how disturbance patterns affect community structure and composition. For each major community type, managers should determine

- the immediate effects of the disturbances,
- the species composition and dynamics of communities that colonize after disturbance,
- the nature and composition of the intermediate successional communities that follow,
- the length of time necessary for "recovery" to old-growth conditions via succession,
- the predictability of successional sequences, and
- how disturbance size and intensity affect successional patterns.

Managers should pay particular attention to how indicator species and endangered and other "at risk" species respond to the type and intensity of both natural and anthropogenic disturbance, including rates and mechanisms of reestablishment.

8. Identify Area Needs and Edge Effects.

Managers need information on how habitat fragmentation and reduction in area affect the viability of natural communities. They should

- identify species and communities known to be sensitive to edge effects, limited habitat area, or genetic isolation. When data are not available for these species from the management area or its vicinity, managers should refer to published studies from other sites, particularly on closely related species.
- collect available data-on how species diversity changes with area for major community and habitat types. These data are necessary to assess-how decreases in acreage of a particular community may cause loss of species diversity within the community.

9. Identify Data Gaps and Priorities for Research.

Having compiled these data, managers should prepare a formal "Data Assessment Statement" describing the amount and quality of the data available to address preceding points 1 through 8. The statement should describe gaps in this basic knowledge and evaluate how this absence of information may limit a manager's ability to make informed land-planning decisions. Finally, the Data Assessment should identify high priorities for research based on both the significance of the gaps identified and on the relative costs of obtaining additional information. This research can be undertaken at the same time managers assess threats to diversity (Section B) and implement protective policies (Section C).

B. Evaluate Threats to Regional Diversity

Having assembled relevant information as described, managers should determine which immediate or potential long-term circumstances pose threats to natural ecosystems on their lands, and they should identify which communities, species, and other elements of native diversity have the most risk of being lost from the planning unit and from the region. In doing so, they should use the following analytical techniques, as well as their own judgment and expertise. The techniques described next fall into two categories --species and population approaches and community and landscape approaches (see Hansson, this volume). Both groups of techniques are required for a successful management program.

1. Species and Population Approaches

- Identify factors affecting viability and persistence of all indicator and "at risk" species. Managers (and scientific personnel) should use data collected in the inventory and identification phase (Section A) to identify factors affecting persistence of indicator species, endangered species and other species identified as being at risk (e.g., Ralls and Taylor, this volume; O'Brien, this volume). These factors include known or suspected biotic interactions, such as competition, disease, and predation, and associations with particular communities or habitats (e.g., Thompson, this volume).
- Estimate habitat needs for all species that are threatened, endangered. or otherwise at risk. Managers should attempt to predict minimal and optimal habitat requirements, taking into account known or suspected sensitivity to edge effects, area, and isolation effects. These factors should be analyzed both on the management unit and in surrounding, ecologically related areas.
- Perform quantitative and qualitative assessments of risk to vulnerable species. To minimize the probability of extinctions, managers should

identify which factors most influence long-term survival of endangered and other vulnerable species on their management units and adjacent areas. When sufficient data exist, agencies should use quantitative population viability analysis (PVA) to estimate the risk of local extinction for individual species. Where appropriate and feasible, such models should be spatially explicit (e.g., Possingham, this volume) and should be based on the best available data on habitat needs. demography, and other aspects of sustainable population dynamics. In many cases, such PVA models will result in estimates of how much habitat is necessary for survival (e.g., Noon, McKelvey, and Murphy, this volume). Where there are too few data for PVA analvsis, managers should identify threats and assess viability with less elaborate quantitative or qualitative population models. PVAs and or other methods should be used to assess how "at risk" species and indicator species are likely to respond to alternative management scenarios. These risk assessments should be routinely circulated for internal and external review and reevaluated every few years to incorporate improved data.

- Identify critical habitat for all threatened and endangered species present. To protect habitats that sustain rare and imperiled species and to meet the requirements of the Endangered Species Act, managers should use the data from inventory and identification, PVA, and the other risk analyses discussed to determine the minimum habitat necessary for long-term persistence of each endangered or other "at risk" species on the management unit or surrounding lands. These designations should include recommended management in and around critical habitat areas. Managers should also determine where the critical habitat needs of imperiled species overlap so they might be addressed simultaneously for maximum efficiency (National Research Council, 1995).

2. Community and Landscape Approaches

- Estimate the minimum dynamic area (MDA) for each major community type. Each community type historically developed partly in response to a particular disturbance regime. Thus the longleaf pine/wiregrass community developed and was sustained by frequent fires of a certain intensity and size. Conversely, eastern hardwood forests primarily developed where fires were relatively infrequent. Under modern conditions, two factors related to disturbance threaten the continued persistence of many community types. First, humans have changed many disturbance regimes, for example, increasing or decreasing fire frequency in different areas so that conditions no longer favor the original community. Second, many of the remaining areas of natural habitat are reduced in size and/or fragmented. As patches of a community type become smaller, they typically become less able to recover from unfavorable disturbance events. For example, a remnant of eastern deciduous forest may be so small that, after having been subjected to repeated large ties, no mature growth remains. Whatever second growth does develop will be burned again before it reaches maturity. Therefore, for each community type on their land, managers must identify and maintain contiguous patches that are large enough to ensure their long-term persistence. given the prevailing and possible future disturbance regimes.

How does a manager determine how large a patch is large enough? Unfortunately, we still lack a generally applicable method for determining how large an area is necessary to maintain a particular community type, given the prevailing disturbance regime. Nonetheless, progress is being made. In 1978 Pickett and Thompson first suggested theoretical guidelines for calculating such an area, which they named the minimum dynamic area. The first practical attempt to calulate MDA for a specific community was undertaken by Givnish, Menges, and Schweitzer (1988), who applied the MDA approach to managing fire-dominated "pine bush" landscapes critical for the conservation of the Karner Blue Butterfly. They concluded that areas of 2,000 acres or more were necessary to sustain populations of the butterfly and lupine, its food plant. This application was simplified, however, because burning was controlled and therefore the extent of disturbance and its frequency was not random.

High priority should be given to extending this work so that we can apply the MDA concept to communities that experience random disturbance. In the meantime, at least one practical conclusion can be made, namely that the size of an MDA must be large where disturbance events are either large or common. In cases where disturbance events are especially large or frequent, MDAs may be larger than typical management units (e.g., a USFS Ranger District), and so will require planning beyond typical jurisdictional boundaries.

Once an adequate MDA model has been developed, the steps taken to gather data and utilize the model should include

- choosing the community types to be modeled;
- characterizing the historical and contemporary disturbance regimes for each community type including frequencies. areas. and intensities of disturbance;
- assessing how each community type responds to the prevailing types of disturbance;
- estimating the minimal area needed to absorb the largest disturbance expected to occur within a 500- to 1,000-year period and still allow recovery: via adjacent-or-nearby sources of colonizers (MDA analysis); and

- identify communities at risk. Managers should identify communities that are at risk of losing species or ecological processes. Identification will depend on ecological research that illuminates how individual species respond to particular threats. including fire suppression. excessive timber harvesting, overgrazing, pests, pathogens, exotic species, and extirpation of commensal or prey species (Section A).

  For many community types, some assessment of risk can be developed bv characterizing the current disturbance regimes and comparing it with the natural historic regime. For example. when the ecological community depends on frequent fires for health, as does longleaf pine savanna, a decrease in fire frequency from historical levels puts some constituent species at risk of extirpation. To the degree possible. information on disturbance and community response should be used in an MDA-type analysis to reveal which major communities occur in areas smaller than their MDA.

- Perform a landscape element completeness (gap) analysis. As a complement to identifying communities at risk, managers should assess the degree to which habitats and communities historically typical of the region are represented in the regional landscape (Usher, 1986; National Research Council, 1993; Klijn and Udo de Haes, 1994). In particular. managers should identify communities or successional stages that have become scarce in the region or that are not currently being managed to ensure their long-term viabilty. A thorough analysis would include creating distribution maps of all communities, estimating minimum dynamic area for these communities to predict long-term persistence, exaninining known species-area relations, and dete rmining habitat needs for sensitive species. Managers should also examine the extent to which community types are protected within existing reserve lands, such as national parks, wilderness areas, and Research Natural Areas.

  The National Biological Service (NBS), in cooperation with over 30 states, has already applied gap analyses to map he location of major vegetation types, ranges of terrestrial vertebrates. and other biotic elements and to identify those that are not adequately protected by the existing network of public and private conservation areas or by other conservation mechanisms (Vickerman and Smith. 1995). This approach should be widened to incorporate information on plant community successional stages and distributional and habitat need data for other taxonomic groups (particularly rare or endemic species).

C. Management Design- Formulate Specific Management Options to Address Recognized Threats

Managers should use the information gathered in Section B to devise effective strategies to conserve native communities and the species and processes that maintain them. These efforts should occur via parallel paths, assessing both the viability of particular indicator species and the long-term sustainability of the communities in which they occur. Although the analyses performed in Sections A and B rest primarily on scientific expertise and judgment managers implementing the procedures outlined here must consider the wider set of issues surrounding multiple use. The procedures outlined here produce elements that can be integrated into the management alternatives required for long-term planning and the environmental impact process specified by the National Environmental Policy Act,

Priority for protection should be given to elements of biological diversity that are regionally, nationally, or globally rare and/or at risk of extinction. High-priority species, for example, would include those federally listed as threatened or endangered, whereas high-priority ecosystems would include those identified by the NBS (Noss et al., 1995) as "critically endanagered." Species or communities that are nationally or globally common and secure would receive lower priority for protection even if they happen to be rare on the planning unit. Thus, managers should avoid management that replaces old-growth forest with second growth even if second growth is less common than old growth on the planning unit. Managers should be aware that the local increase in species diversity that often occurs following habitat fragmentation usually detracts from rather than adds to biological diversity on regional or global scales.

1. Develop Species Recovery Plans.

Federal agencies are already under obligation to devise recovery plans that ameliorate threats to threatened and endangered species and allow populations to recover (USFWS, 1994b). The success of these plans depends on the adequacy of the biological data, making it critical that the best data possible be collected and assessed. Successful recovery plans also depend on whether adequate habitat can be provided to ensure viability of the species-for many species, such as the Sonoran pronghom (*Antilocapra americana sonoriensis*) (USFWS, 1994a) or the masked bobwhite *(Colinus virgianus ridgwayi*) (NWF. 1994), absence of suitable habitat is the greatest barrier to recovery.

2. Assess the Potential to Conserve or Restore Communities at Risk

Managers should determine what opportunities exist within and beyond their land base to conserve or restore habitat to ensure perpetuation of each community type at risk, Such an analysis would consider landscape context dynamic ecological processes, and the impacts of natural and human-induced disturbances, in addition to the physical suitability of potential restoration sites. An assessment should begin by asking

- "Is, or will this community type be threatened in the region because it lacks some successional stages in sufficient abundance?" If this is true, managers should assess the potential for providing more of the missing successional stages by using active or passive techniques of community restoration. This might be accomplished on the management unit alone or in conjunction with nearby owners.

- "Is, or will, this community type be threatened in the region because it exists on an area smaller than its required MDA?" If less than the necessary MDA exists, managers should assess the potential to provide more area for this community type by identifying lands suitable for the community type that are presently dominated by other vegetation. If the present dominant vegetation belongs to community types that are common on a regional basis, managers should explore the feasibility of using restoration techniques to replace this dominant vegetation with the rare communnity type.

3. Develop Specific Management Practices to Sustain Biodiversity

When species or communities are at risk of loss, managers should allocate sufficient area and make management changes to sustain those species and communities. Such management would likely incorporate planning decisions on the following two spatial scales.

- Regional scale.

Some communities and species that require extensive areas must be managed on the regional scale. Communities typically require large protected or managed areas if they historically developed in response to a regime of large disturbance events. Species requiring large areas include top carnivores and some other species with wide-ranging or otherwise dispersed populations. Large areas may be managed by

- letting natural disturbance regimes and other natural processes reassert themselves;
- generally letting natural regeneration of damaged communities occur rather than using active restoration techniques;
- allowing limited commodity production in some areas, provided evidence demonstrates that such activities will not threaten elements of diversity and provided that close monitoring occurs; and
- cooperating with other agencies and private land owners because the necessary large areas of habitat are likely to extend across management boundaries.

- Local scale.

Management can be successful on small areas provided that the desired communities and species- have attributes that allow them to persist in small areas. Such management can include:

- generally using more active management than for larger reserves (e.g., using prescribed burning to maintain small patches of prairie or pine barrens);
- often using active restoration;
- generally excluding extensive or intensive commodity production; and
- protecting small reserves under suitable programs such as Research Natural Areas and Wild and Scenic Rivers. Such reserves are often created to conserve specific species or communities at risk.

Management on both local and regional scales requires planning to maximize landscape connectivity. Specifically, isolated patches of habitat must be connected by corridors of habitat that allow native plant and animal species to disperse from one patch to another. This will allow migrants to exchange genes among populations and colonists to reestablish extirpated populations. In addition, species will be able to travel along corridors and colonize new areas, thereby shifting their ranges to adapt to changes in climate or in the disturbance regime. Corridors can often be placed along rivers to incorporate and protect aquatic communities.

D. Monitoring the Effects of Management on Diversity

To complete the procedures described above, managers must closely monitor the biotic resources they oversee. Such monitoring is vital for assessing population, community, and ecosystem trends and to evaluate how management affects the trends. Proper monitoring can warn of impending species loss, community degradation, and loss of ecosystem function so that midcourse corrections can be made in management (Landres et al., 1988; Goldsmith, 1991; Crow et al., 1994). A careful monitoring design can, in conjunction with different management treatments, act as an experiment to determine the effects of the treatments on biological diversity. For example, monitoring the abundance of native grasses and forbs on both heavily and lightly grazed plots provides information on the effects of grazing on grassland health.

Monitoring should have the following characteristics:

- Because resources are limited, managers should choose efficient and reliable indicators of biotic change and apply the best possible analytical techniques.
- Because accurate monitoring is particularly important for communities and species at risk, these should receive top priority.
- Monitoring should take place at several hierarchical scales to identify and diagnose new and emerging threats to diversity (Noss, 1990).
- Monitoring must be sustained over time to allow detection of slow or incremental change.

Because much has already been written about monitoring methods in the context of land management (e.g., Landres et al., 1988; Goldsmith, 1991; Crow et al., 1994) and because the NBS is currently developing guidelines applicable to all federal lands, we will not describe these techniques further.

Monitoring schemes should themselves be the subject of critical evaluation by the scientific community. We recommend that agencies publish their monitoring programs and distribute them for review. In addition, monitoring results should be systematically reviewed and regularly evaluated by scientists from academia, from local to federal levels of government, and from the private sector. It would be efficient to integrate these reviews and evaluations into the adaptive management cycle, with periodic updates of the activities described in Sections B, C. and D every 5 to 10 years.

Literature Cited

Alverson, W.S., W. Kuhlmann, and D.M. Waller. (1994) Wild forests: conservation biology and public policy. Island Press, Washington, DC.

Anderson, H.M. (1994) Reforming National-Forest Policy. Issues in Science and Technology 10:40-47.

Anderson, S. H. (1995) Traditional approaches and tools in natural resources management., in A new century for natural resources management (ed. R.L. Knight and S.F. Bates), Island Press, Washington, DC.

As, S. J. Bengtsson, and T. Eberhard. (1992) Archipelagoes and theories of insularity., in Ecological principles of nature conservation: applications in temperate and boreal environments (ed. L. Hansson), Elsevier Applied Science, New York.

Crow, T.R., A. Haney, and D.M. Waller. (1994) Report on the Scientific roundtable on Biological Diversity Convened by the Chequamegon and Nicolet National Forests. General Technical Report NC-166. North Central Forest Experiment Station, US Forest Service, St. Paul, MN.

Fleischner, T.L. (1994) Ecological costs of livestock grazing in western North America. Conservation Biology 8:629-644.

Givnish, T.J., E.S. Menges, and D.F. Schweitzer. (1988) Minimum area requirements for long-term conservation of the Albany Pine Bush and Karner blue butterfly: an assessment. Report to the City of Albany and the New York State Department of Environmental Conservation.

Grossman, D.H., K.L. Goodin, C.L. Reuss. (1994) Rare plant communities of the conterminous United States: an initial survey. The Nature Conservancy, Arlington, VA.

Gurtz, M.E., and T.A. Muir (eds.). (1994) Report of the interagency biological methods workshop. U.S. Geological Survey, Raleigh, NC.

Hansson, L. (ed.). (1992) Ecological principles of nature conservation: applications in temperate and boreal environments Elsevier Applied Science, New York.

Hansson, L., L. Fahrig, and G. Merriam (eds.). (1995) Mosaic landscapes and ecological processes. Chapman and Hall, New York.

Harrison, S., and L. Fahrig. (1995) Landscape pattern and population conservation., in Mosaic landscapes and ecological processes (ed. L. Hansson, L. Fahrig, and G. Merriam), Chapman and Hall, New York.

Hein, D. (1995) Traditional education in natural resources., in A new century for natural resources management (ed. R.L. Knight and S.F. Bates), island Press, Washington, DC.

Huston, M.A. (1994) Biological diversity: the coexistence of species in changing landscapes. Cambridge University Press, New York.

Klijn, F., and H.A. Udo de Haes. (1994) A hierarchical approach to ecosystems and its implications for ecoicgicai land classification, Landscape Ecology 9:89-104.

Lande, R. (1988) Genetics and demography in biological conservation; Science 241:1455-1460.

Mangel, M., and C. Tier. (1994) Four facts every conservation biologist should know about persistence. Ecology 75:607-614.

Meffe, G.K., and C.R. Carroll. (1994) Principles of conservation biology. Sinauer, Sunderland, Massachusetts.

Meine, C. (1995) The-oldest task in human history., in A new century for natural resources management (ed. R.L. Knight and

S.F. Bates), Island Press, Washington, DC.

Murcia, C. (1995) Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10:58-62.

National Research Council. (1993) Setting priorities for land conservation. National Research Council, Washington, DC.

---. (1995) Science and the endangered species act. National Academy of Sciences Press, Washington, DC.

National Wildlife Federation. (1994) Grazing to Extinction: Endangered, Threatened and Candidate Species Imperiled by Livestock Grazing on Western Public Lands: 8. National Wildlife Federation, Washington, DC.

Noss, R.F. (1983) A regional landscape approach to maintain diversity. BioScience 33:700-706.

Noss, R.F., and A.Y. Cooperrider. (1994) Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington, DC

Noss, R.F. and R. L. Peters. (1995) Endanagered ecosystems: a status report on America's vanishing habitat and wildlife.

Defenders of Wildlife, Washington, DC

Parker, V.T. (1993) Conservation issues in land management., in Interface between ecology and land development in California (ed. J.E. Keeley) Southern California Academy of Sciences, Los Angeles.

Pickett, S.T.A., 3. Kolasa, and C.G. Jones. (1994) Ecological understanding: the nature of theory and the theory of nature. Academic Press, San Diego.

Pickett, S.T.A., and P.S. White (eds.). (1985) The ecology of natural disturbance and patch dynamics. Academic Press, Orlando, FL.

Pringie, C.M., and N.G. Aumen. (1993) Current issues in freshwater conservation: introduction to a symposium. Journal of the North American Benthological Society 12:174-176.

Reid, W.V., and K.R. Miller. (1989) Keeping options alive: the scientific basic for conserving biodiversity. World Resources Institute, Washington, D.C.

Reynolds, J.W. 1994. Decision and Order: Sierra Club et al. v. Floyd J. Marita. Sierra Club V. Marita, 843 F. Supp. 15 (E.D. Wis. 1995), aff'd., 46 F.3d 606 (7th Cir. 1995).

Society of American Foresters. (1993) Task force report on sustaining long-term forest health and productivity. Society of American Foresters, Bethesda, Maryland.

US DOI and US DOA. 1995. Federal wildland fire management: policy & program review. U.S. Department of the Interior and U.S. Department of Agriculture, Washington, DC

US FWS. 1994a. Sonoran pronghorn recovery plan revision. U.S. Fish and Wildlife Service, Albuquerque, NM.

US FWS. 1984b. Recovery program: endangered and threatened species, 1994. Report to Congress. U.S. Fish and Wildlife Service, Washington, DC

Usher, M.B. (1986) Wildlife conservation evaluation: attributes, criteria and values., in Wildlife conservation evaluation (ed. M.B. Usher) Chapman and Hall, London.

Vickerman, S. and K.A. Smith. (1995). Recommendations for implementing gap analysis. Draft report for the national Biological Service.

Wagner, F.H., and C.E. Kay. (1993) "Natural" or "healthy" ecosystems: are U.S. national- parks providing them., in Humans as components of ecosystems: the ecology of subtle human effects and populated areas (ed. M.J. McDonnell and S.T.A. Pickett), Springer-Verlag, New York.

White, D.W., W. Worthen, and E.W. Stiles. (1990) Woodlands in a post-agricultural landscape in New Jersey. Bulletin of the Torrey Botanical Club 117:256-265.

Woodley, S., J. Kay, and G. Francis (eds.). (1993) Ecological integrity and the management of ecosystems. St. Lucie Press, Waterloo.

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