ECOLOGICAL SUSTAINABILITY

INTRODUCTION

Over the last half-century, ecologists have learned much about how ecosystems contribute to the fulfillment of human life. Most obviously, ecosystems provide many of the goods that are harvested and traded in the human economy -- food, fiber, timber, forage, biomass fuels, and many pharmaceuticals (Daily 1997a). Ecosystems also provide indirect benefits to humans through their impacts on nutrient flux and cycling, mitigation of flood and drought, and maintenance of biodiversity, all of which feedback in important ways on the production of ecosystem goods that humans directly derive from ecosystems (Chapin et al. 1996). Finally, ecosystems also provide less tangible, but equally important, benefits in the form of recreational, spiritual, and intellectual stimulation (Postel and Carpenter 1997). Despite widespread public awareness of the direct benefits that humans derive from ecosystems, the full magnitude of benefits attributable to ecosystems is woefully underappreciated by the public (Daily 1997b).

The public's failure to recognize these benefits increases the likelihood that natural resources will be managed and developed in a manner that leads to ecosystem degradation. Such resource development, in conjunction with increasing human populations and land use intensification, can stress ecosystems to a point where their ability to provide the aforementioned benefits is compromised (Rapport et al. 1985). Concern that the human enterprise may jeopardize the viability of ecosystems (Vitousek et al. 1997) is the motivation behind a natural resource management paradigm shift that is now focusing on long-term sustainability of ecosystems as the measure of responsible stewardship of natural resources (Lubchenco et al. 1991).

Because the notion of ecological sustainability has a strong intuitive appeal, there are few who would criticize a natural resource management strategy that seeks to restore and maintain the composition, structure, and function of ecosystems so that future generations can derive the same ecosystem services that current generations enjoy (Johnson 1993). Despite widespread acceptance of the goals implied by ecological sustainability, there is little agreement and much contention surrounding how to implement ecological sustainability in a resource management context. Some have argued that sustainability is neither a realistic goal nor a useful concept (Ludwig et al. 1993), while others have argued that it is the only strategy leading to a viable long-term pattern of human resource use (Dale et al. 2000).

There are many factors that have contributed to these varied opinions on the utility of ecological sustainability as a guide to resource management. First, and most fundamentally, is the absence of a clear definition (Pajak 2000). Certainly, ecological sustainability has been defined as a *general concept* that is easily understood. Sustainability has been defined as "the capacity of an area to provide the present generation with the needed direct, indirect, and spiritual benefits humans derive from ecosystems" (USDA Forest Service 2000). Applied to natural ecosystems, this definition implies that: (1) management will not degrade those systems being utilized (Lubchenco et al. 1991), and (2) the current generation of humans will leave an equitable share of resources for future generations (Meyer and Helfman 1993). However, a much more precise definition is required if the concept of ecological sustainability is to move from simple statements of conviction to operational resource management.

Second, the basic principles upon which to base operational definitions of sustainability have not been articulated (Chapin et al. 1996). In the absence of an agreed upon set of basic constructs, definitions to guide implementation will continue to be vague, elusive, and untested. Third, the spatial and temporal variability of ecosystems does not support a single implementation approach for ecological sustainability (Committee of Scientists 1999). Consequently, the differences among sustainable management case studies (e.g., differences in ecological attributes measured, or differences in interpretation) has been used, perhaps inappropriately, as evidence for an ill-defined management paradigm. Finally, although lists of potential indicators of ecological sustainability are beginning to emerge (Coulombe 1995, Pajak 2000, Committee to Evaluate Indicators for Monitoring Aquatic and Terrestrial Environments 2000), most lack clarity and consensus (Fluharty 2000).

The primary objective of this report is to provide a clearer understanding of what ecological sustainability means and how the concept could potentially be implemented as a resource management paradigm for natural resources through the National Forest System planning process. This objective will be addressed by synthesizing information on a number of topics. First, we will review what the new planning rule specifically requires with respect to ecological sustainability. The new planning rule defines ecological sustainability as "[t]he maintenance or restoration of the composition, structure, and processes of ecosystems including the diversity of plant and animal communities and the productive capacity or ecological system" (USDA Forest Service 2000: 67580). This definition implies that there are two primary components to ecological sustainability -- ecosystem diversity and species diversity. Our review of ecological sustainability is organized around these two components

Secondly, we will review the recent published literature on ecological sustainability and provide an overview of the varying perspectives of what it means to manage natural resources in an ecologically sustainable manner**.** This second section will attempt to distill a set of key principles of sustainable management for both ecosystem diversity and species diversity components that could help guide the agency's forest planning process and management of natural resources. We also will examine some potential techniques and methods that could be used to assess and monitor whether the goals of ecological sustainability are being met by resource management on National Forests. Because ecological sustainability is a concept that encompasses many aspects of human development, resource management, and ecological response, it will be difficult to monitor directly. For this reason, evaluations of whether a particular ecosystem is being managed in a sustainable manner are often couched in the concept of indicators (Coulombe 1995), which ostensibly represent key measurable attributes that reflect ecosystem properties that are too difficult or costly to monitor directly (Noss 1990). An important contribution of this second section will be to propose broad classes of candidate indicators that could be used to gauge whether ecosystems occurring on National Forests are trending toward or away from conditions considered to be sustainable. Cases studies that have attempted to couch resource management under the rubric of ecological sustainability will be cited to provide examples of the methods and indicators that have been used recently to address ecological sustainability.

A final section will review key planning steps that the Agency must take to incorporate ecological sustainability in the planning process in an adaptive framework. It is important for resource planners to treat the management direction as a hypothesis that we are managing resources in a sustainable manner that is tested through monitoring. The process of developing management direction, revision of management direction and monitoring is key to placing ecological sustainability in an adaptive management framework.

Although this desk guide is focusing on ecological sustainability, we fully recognize that setting goals for sustainability will necessarily be a process of integration of ecological, social, and economic components of ecosystems (Pajak 2000). A separate desk guide is being developed for social and economic sustainability and the integration of these components will be accomplished through collaborative planning efforts at local and regional scales as indicated in other parts of the planning rule.

PLANNING RULE REQUIREMENTS

The maintenance and restoration of ecological sustainability is the first priority for the management of national forests and grasslands so these lands can contribute to economic and social sustainability by providing a sustainable flow of uses, values, products and services (219.2). The benefits sought from these lands depend upon long-term ecological sustainability and planning will be based of the temporal and spatial scales necessary for sustainability.

Ecological sustainability is defined as the maintenance or restoration of the composition, structure, and processes of ecosystems including the diversity of plant and animal communities and the productive capacity of ecological systems (219.36). Ecosystem diversity and species diversity are components of ecological sustainability [219.20 (a)].

Ecosystem Diversity

Characteristics of ecosystem diversity focus on major vegetation types and success ional stages (probable occurrences under the current climate window); water resources including the diversity, abundance, distribution and dynamics of aquatic and riparian systems; soil resources as indicated by productivity; abiotic and biotic properties, and soil loss and compaction; and air resources. Another requirement is the identification of Focal Species [219.20 (1) (i) (A-E). Focal species are surrogate measures used in the evaluation of ecological sustainability and trend provide insights to the larger ecological system to which it belongs. Characteristics of species diversity center on the number, distribution, and geographic ranges of plant and animal species and species-at-risk [219.20 (ii)]. Species-at-risk and focal species must be identified for the plan area.

To achieve ecological sustainability, the responsible official must ensure that Forest plans provide for maintenance or restoration of ecosystems at appropriate spatial and temporal scales determined by the responsible official. Identification and consideration of issues [219.4 (2)], the development of information and analysis of the information and evaluation of ecological sustainability (219.20), and monitoring [219.11 (1)] are central to achieve ecological sustainability

Evaluations of ecological sustainability must be conducted at the scope and scale determined by the responsible official to be appropriate to the planning decision [219.20 (2)]. These evaluations must describe the current status of ecosystem diversity and species diversity, risks to ecological sustainability, cumulative effects of human and natural disturbances, and the contribution of National Forest System lands to the ecological sustainability of all lands within the area of analysis.

Evaluations of ecosystem diversity must include, as appropriate, information about focal species, biological and physical properties of the ecosystem, a description of the principal ecological processes characteristic to the analysis area, and may include both an evaluation of the feasibility of maintaining natural ecological processes as a tool to contribute to ecological sustainability and a description of the effects of human activities on ecosystem diversity [219.20 (2) (i) (A-D)]. The current values of these characteristics should be compared to the expected range of variability to develop insights about the current status of ecosystem diversity [219.20 (2) (i) (E)]. An evaluation of both the effects of air quality on ecological systems including current and foreseeable future Forest Service water uses contribute to ecological sustainability [219.20 (2) (i) (F-G)]. Identification of reference landscapes provides for the evaluation of the effects of land management actions [219.20 (2) (i) (G)].

The responsible individual must use information developed under 219.20 (a) when making plan decisions that affect ecological sustainability [219.20 (b)]. Such plan decisions must provide for maintenance or restoration of the characteristics of ecosystem composition and structure within the range of variability that would be expected to occur under natural disturbance regimes of the current climate period with the exceptions when the ecosystem composition and structure are currently within the expected range of variability [(219.20 (b) (i)], cannot be practicably defined [(219.20 (b) (iii)] and either is not practicable to make measurable progress toward conditions within the expected range of variability or is ecologically, socially or economically unacceptable [(219.20 (b) (iv)]. The responsible official must use independently peer-reviewed scientific methods if other than the expected range of variability to maintain or restore ecosystem diversity (219.22 - 219.25).

Species Diversity

Evaluations of species diversity must include, as appropriate, assessments of the risks to species viability and the identification of ecological conditions needed to maintain species viability over time [219.20 (2) (ii)]. Evaluations are based on the viability of each species listed under the Endangered Species Act as threatened, endangered, candidate, and proposed species must be assessed [219.20 (2) (ii) (A)]. Individual species assessments must be used for these species. For all other species, including other species-at-risk and those species for which there is little information, a variety of approaches may be used, including individual species assessments and assessments of focal species or other indicators used as surrogates in the evaluation of ecological conditions needed to maintain species viability [219.20 (2) (ii) (B)].

Except as provided in paragraph [219.20 (2) (A)], species or habitat groups rather than individual species may be appropriate to maintain species viability. In analyzing viability, the extent of information available about species, their habitats, the dynamic nature of ecosystems and the ecological conditions needed to support them must be identified [219.20 (2) (ii) (C). Species assessments may rely on general conservation principles and expert opinion. When detailed information on species habitat relationships, demographics, genetics, and risk factors is available, that information should be considered [219.20 (2) (ii) (D)].

Plan decisions affecting species diversity must provide for ecological conditions that the responsible official determines provide a high likelihood that those conditions are capable of supporting over time the viability of native and desired non-native species well distributed throughout their ranges within the plan area [(219.20 (2) (i)]. A species is well distributed when individuals can interact with each other in the portion of the species range that occurs within the plan area.

When a plan area occupies the entire range of a species, these decisions must provide for ecological conditions capable of supporting viability of the species and its component populations throughout that range. When a plan area encompasses one or more naturally disjunct and self-sustaining populations of a species, these decisions must provide ecological conditions capable of supporting over time viability of each population. When a plan area encompasses only a part of a population, these decisions must provide ecological conditions capable of supporting viability of that population well distributed throughout its range within the plan area.

In addition, when conditions outside the authority of the agency prevent the agency from providing ecological conditions that provide a high likelihood of viability, plan decisions must provide for ecological conditions well distributed throughout the species range within the plan area to contribute to viability of that species [219.20 (2) (ii)]. Where species are inherently rare or not naturally well distributed in the plan area, plan decisions should not contribute to the extirpation of the species from the plan area and must provide for ecological conditions to maintain these species considering their natural distribution and abundance [219.20 (2) (iii)]. Where environmental conditions needed to support a species have been so degraded that it is technically infeasible to restore ecological conditions that would provide a high likelihood of supporting viability, plan decisions must provide for ecological conditions to contribute to supporting over time viability to the degree practicable [219.20 (2) (iv)].

Plan decisions must provide for implementing actions in conservation agreements with the Fish and Wildlife Service or the National Marine Fisheries Service that provide a basis for not needing to list a species [219.20 (3) (i)]. In some situations, conditions or events beyond the control or authority of the agency may limit the Forest Service's ability to prevent the need for federal listing. Plan decisions should reflect the unique opportunities that National Forest System lands provide to contribute to recovery of listed species.

Plan decisions involving species listed under the Endangered Species Act must include, at the scale determined by the responsible official to be appropriate to the plan decision, reasonable and prudent measures and associated terms and conditions contained in final biological opinions issued under 50 CFR Part 402. The plan decision documents must provide a rationale for adoption or rejection of discretionary conservation recommendations contained in final biological opinions [219.20 (3) (ii)].

Monitoring

Each plan according to 219.11 must contain a practicable, effective, and efficient monitoring strategy to evaluate sustainability in the plan area (219.19 - 219.21). The strategy must require monitoring of appropriate plan decisions and characteristics of sustainability. The plan monitoring strategy for the monitoring and evaluation of must require monitoring of both ecosystem diversity [219.11 (1) (i)] and species diversity [219.11 (1) (ii)].

Monitoring for ecosystem diversity is to evaluate the status and trend of selected physical and biological characteristics of ecosystem diversity [219.11 (1) (i)]. The plan monitoring strategy must document the reasons for selection of characteristics to be monitored, monitoring objectives, methodology, and designate critical values that will prompt reviews of plan decisions.

Monitoring for species diversity is to evaluate focal species and species-at-risk [219.11 (1) (ii)]. The status and trends of ecological conditions known or suspected to support focal species and selected species-at-risk must be monitored. The plan monitoring strategy must document the reasons for the selection of species-at-risk for which ecological conditions are to be monitored, including the degree of risk to the species, the factors that put the species at risk, and the strength of association between ecological conditions and population dynamics [219.11 (1) (ii) (A)]. In addition to monitoring of ecological conditions, the plan monitoring strategy may require population monitoring for some focal species and some species-at-risk [219.11 (1) (ii) (B)]. This monitoring may be accomplished by a variety of methods including population occurrence and presence/absence data, sampling population characteristics, using population indices to track relative population trends, or inferring population status from ecological conditions.

A decision by the responsible official to monitor populations and the responsible official’s choice of methodologies for monitoring selected focal species and selected species-at-risk may be based upon factors that include, but are not limited to, the degree of risk to the species, the degree to which a species’ life history characteristics lend themselves to monitoring, the reasons that a species is included in the list of focal species or species-at-risk, and the strength of association between ecological conditions and population dynamics.

Monitoring of population trend is often appropriate in those cases where risk to species viability is high and population characteristics cannot be reliably inferred from ecological conditions. The reasons for selection of species, monitoring objectives, and methodologies must be documented as part of the plan monitoring strategy. Critical values that will prompt reviews of plan decisions must be designated in the monitoring strategy [219.11 (1) (ii) (C)]. Unless required by the monitoring strategy, monitoring, monitoring methods may change to reflect new information without plan amendment or revision ([219.11 (2) (c)].

As a part of the plan monitoring strategy, the responsible official must evaluate the effectiveness of selected characteristics of ecosystem diversity and species diversity in providing reliable information regarding ecological sustainability. The intent of this requirement is most likely "effectiveness" monitoring although the requirement suggests an evaluation of the selected characteristics of ecosystem diversity and species diversity.

PROCESSES FOR SPECIES DIVERSITY, ECOSYSTEM DIVERSITY, AND PLANNING

We present five steps for species diversity and ecosystem diversity that will help guide the agency's forest planning process to achieve the principles of ecological sustainability. Following that are four key planning steps that the agency must take to incorporate both ecosystem diversity and species diversity in the planning process in an adaptive framework.
Both species diversity and viability and ecosystem diversity are preceded by brief reviews to provide further clarification.

Species diversity

Forest Service approaches to management for viable populations have evolved at the same time as important advances were made in scientific applications of population viability analysis (PVA) (Shepard et al. 1997, Lee and Rieman 1997, Allendorf et al. 1997, Beissinger and Westphal 1998, Holthausen et al. 1999, Menges 2000, National Marine Fisheries Service 2000, Beissenger and McCullough in press). While Forest Service approaches generally follow concepts described in the scientific literature, the following key differences have emerged.

First, definitions of population viability in the scientific literature have generally focused on the probability of population persistence for a biologically meaningful period of time. For example, Shaffer (1981) defined a minimum viable population as "the smallest isolated population having a 99% chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental, and genetic stochasticity, and natural catastrophes." The role of PVA then is to provide an assessment of the likelihood of species persistence to some specified point in time. However, since National Forest Management Act (NFMA) (1976) regulations require that habitat be provided to support well-distributed populations, it is not adequate in Forest Service evaluations to simply project species persistence until some point in time. We also need to know the area and distribution within which the species persists. Thus, the area and distribution within which the species persists should be recognized explicitly in the evaluation.

Second, most scientific applications of PVA attempt to address all risk factors and other influences that can affect viability of species. However, because the NFMA regulations focus on ecological conditions on National Forests within the planning area, Forest Service evaluations must partition the effects of ecological conditions on National Forests from other effects. This need to separate out the effects of National Forest management creates additional challenges for Forest Service viability evaluations.

Third, discussions of PVA in the scientific literature generally refer to quantitative assessment of risk factors (Boyce 1992), with significant focus on demographic analyses (Beissenger and McCullough in press). However, Forest Service evaluations must frequently be done in support of management decision-making when information is scarce and quantitative analysis is not feasible (Rieman et al. 1993, Ruggiero et al. 1994, Noon et al. 1999a, Samson in press). Such evaluations should nonetheless be structured as formal evaluations of available data and other information concerning a population with the objective of estimating the likelihood that it will persist into the future in a given distribution. These evaluations must be as credible and informative as possible, given the reality of scarce information, and may depend on techniques such as the use of scientific panels and reliance on general conservation principles.

To reflect the differences between Forest Service evaluations of viability and PVAs described in the scientific literature, the term Species Viability Evaluation (SVE) is proposed for the evaluations done in support of Forest Planning. Use of the term PVA should be reserved for those analyses that actually meet criteria described in the literature (Beissenger and Westphal 1998). Reed et al. (in press) and Ralls et al. (in press) have proposed that the term PVA be used for analyses that use data in an analytical or simulation model to calculate a measure of persistence.

Species diversity is defined by the number, kinds, density and distribution of species that occur in a given ecosystem. Species diversity is sustained only when the individual species characteristic of an ecosystem persist (Committee of Scientists 1999). Successful management for species diversity requires implementation of a generalized process for addressing species viability in Forest Plans. Successful implementation of the species diversity requires the following five steps.

1. Understanding the overall context of ecological conditions for the plan area.

2. Identification of species in the planning area for which there may be risks that well-distributed populations will not be maintained.

3. Collection of information for species at risk, including risk factors.

4. Identification of any surrogates (e.g., focal species, species groups) that will be used in evaluation of and management for species at risk

5. Identification of management approaches that would contribute to conservation of species at risk.

When possible, management for viability of broadly-distributed species should be coordinated at the bioregional or Forest Service regional level. Coordination at that scale will facilitate the development of consistent approaches and documentation, and may occur as part of a broad-scale assessment as described in the planning rule (36 CFR 219.5). However, it is recognized that some Forest Plan revisions will precede Regional coordination efforts. In such cases, Forests should attempt to coordinate with adjoining Forests, and incorporate as fully as possible the elements of the process described here. If any larger-scale assessments are available, they should be fully incorporated in the process.

In addition to coordination within the Forest Service, it is key to coordinate with other agencies, and to involve the scientific community (within the constraints of the Federal Advisory Committee Act). Coordination should include other federal land management agencies, federal regulatory agencies, state wildlife agencies and natural heritage programs. The scientific community, including scientists from Forest Service Research, conservation organizations, university scientists, industry scientists, and other agency scientists, should be involved as fully as possible in all steps in the process in order to gain the benefit of scientific input and review (see 36 CFR 219.22 through 219.25).

Major components the steps required for species diversity are described below. This general description of the process is followed by a more detailed discussion of techniques that have been used to assess effects on viability.

1. Describe the ecological context

An understanding of ecological systems over a range of spatial and temporal scales provides a critical foundation for management of species. The importance of understanding the ecological context for land management planning has become clear as agency practices and policies evolve to implement ecosystem management (Grumbine 1997). Recent reviews of land management planning suggest that sustainable resource conditions can only be achieved within the context of ecosystem dynamics (Aber et al 2000). We cannot manage systems toward unsustainable conditions and expect species within those systems to enjoy a high probability of persistence. Because species persistence depends on the state of ecological systems, an understanding of system dynamics, pattern, and process provides critical insights into the design of conservation approaches and sustainable resource management. Hierarchy theory highlights the importance of understanding the contextual framework that broad-scale processes establish for more fine scale elements (Wu and Louchs 1995).

The ecological context for species diversity at the National Forest or multi-Forest level should be described within a broad-scale assessment for the bioregion that contains the National Forest lands. The planning rule specifies that a broad-scale assessment should provide “findings and conclusions that describe historic conditions, current status, and future trends of ecological, social, and/or economic conditions, their relationship to sustainability, and the principal factors contributing to those conditions and trends” [(219.5(a)(1)(i)]. The ecological context should include both the causal processes and the resulting patterns, emphasizing the interactions among disturbance processes in creating pattern.

2. Identify species at risk

Forest Plan documentation must demonstrate that management direction will provide ecological conditions such that there is high likelihood that those conditions are capable of supporting viability of all native and desired non-native animal and plant species. For many species (those that are common, associated with readily-available habitats, and for which there are no significant threats), such demonstration should be relatively straight-forward. More extensive documentation, and increased conservation emphasis, will be necessary for a subset of species that are documented or suspected to be at risk within the Forest Plan area. As a first step in addressing species viability, the list of species believed to be at risk in the planning area must be identified. The revised NFMA regulations define species at risk as “Federally listed endangered, threatened, candidate, and proposed species and other species for which loss of viability, including reduction in distribution or abundance, is a concern within the plan area.” This definition includes species that are considered to be at risk at a large spatial scale (e.g., the entire range of the species), and species that are considered to be at risk at the scale of a single National Forest. Since the requirement is to provide for species viability over time, the identification of species-at-risk should include presently secure species that may be placed at risk under existing management direction. Species include any taxa in the plant and animal kingdom that have been formally described in the peer-reviewed literature.

A 2-step process can be used to identify species at risk. The first step is identification of species that are federally- or state-listed, on the Forest Service sensitive species list, or recognized by other organizations, such as the Nature Conservancy, as being at risk. The second step is review of this list using a science team (Samson et al. 1999) or with species experts (Suring et al. 1993) to determine if any species on the list is clearly secure within the planning area and therefore does not require further formal consideration or if there are additional species not on the list that are locally at risk and which should be considered in detail in the plan. Note that many species, especially plants, are intrinsically rare and, where their populations are demonstrably secure, may not need explicit conservation attention despite their rarity. These reviews should be carefully documented as they determine which species will and will not be considered in detail in the planning process.

3. Collect information

Existing information on species at risk should be collected and summarized. This should include information from a variety of sources, including information from the literature, local information on occurrence and population status, and information gathered from local species experts. The following types of information should be considered.

- Current taxonomy
- Distribution, including historical and current trends
- Abundance, including historical and current trends
- Demographics and population trend
- Diversity – phenotypic, genetic, and ecological
- Habitat requirements at appropriate spatial scales
- Habitat amount, distribution and trends
- Ecological function
- Key biological interactions
- Limiting factors/Risk factors

This step emphasizes the collection and summarization of existing information. However, one of the key points in this step should be the identification of critical information that is currently lacking. Collection of that information through monitoring programs should become a high priority.

4. Develop species groups/focal species

It's important to identify all species-at-risk in the plan area, and to gather basic information on them. However, in most cases it will be infeasible to consider all species-at-risk in detail in the planning process. Consequently, credible processes must be used to identify a manageable subset of species that will be used to focus species conservation measures and analysis in the plan. The revised NFMA regulations allow and encourage the use of surrogate species and species groups in the evaluation of viability for species at risk in some but not all situations. The regulation specifies that functional, taxonomic, or habitat based groups of species may all be used. In addition, grouping based on type and degree of risk may be useful. Provisions for the use of individual surrogate species are adopted under the term "focal" species. The regulation clarifies that focal species used in the evaluation of viability represent ecological conditions that provide for viability, and that it is not expected that the population dynamics of a focal species would directly represent the population dynamics of another species. This distinguishes the focal species concept from the concept of management indicator species (MIS) in the 1982 regulations. The 1982 regulation stipulated that MIS would be selected to indicate population dynamics of other species. This concept was widely criticized (Landres et al. 1988) because field studies demonstrated that species using the environment in very similar ways could experience markedly different population trends.

Development of species groups based on risk and on ecological characteristics is discussed below. That discussion is followed by a description of a process by which focal species might be identified. This description emphasizes the selection of focal species to represent ecological conditions needed to support species-at-risk. Other focal species may also be selected as broader system indicators (see section on Ecological Context).

Grouping based on risk. Grouping can be organized around the concept of risk, where categories are determined either by degree of risk or factors limiting the abundance and distribution of species. Below we briefly describe approaches to grouping species by risk level and risk factors and discuss the advantages and disadvantages of doing so.

<u>Grouping by degree of risk</u>. Species can be ranked by degree of risk using a combination of internationally and. nationally accepted ranking systems, each designed to assess degree of risk at a different scale. Globally, the standard for grouping species by degree of risk was established nearly 30 years ago by the International Union for the Conservation of Nature (IUCN) and has been used to set conservation priorities worldwide. The IUCN criteria are most appropriately applied to an entire species at a global scale, but these ranks can help guide national and regional evaluations. Nationally, the federal standard for ranking species by degree of risk was set by the Endangered Species Act (1973) that established two categories: Endangered and Threatened. In addition to the ESA risk categories, The Nature Conservancy (TNC) and Partners in Flight have each developed systems for ranking by risk level below the federal categories of Endangered and Threatened (Carter et al. 2000). TNC system recognizes the need to assess extinction risk at different spatial scales and thus assigns each species a global, national, and state rank, tiering to the IUCN and U.S. Fish and Wildlife Service assessment for that species. An example of grouping species by risk levels is found in the Northern Great Plains Science Assessment

(Samson et al. 1999).

Grouping by risk factors. Examination of the causes of species endangerment and extinction demonstrates that a limited number of general factors contribute to the majority of species conservation problems. Habitat loss or change, effects of introduced predators or diseases, effects of poorly regulated harvest, effects of competition with introduced species, and the effects of environmental contaminants, together or individually, contribute to a significant proportion of extinctions and population declines (Wilcove et al. 1998, 1999). A closer look at conservation of species in a particular geographic region will reveal a more specific list of threats to species persistence. The dominant risk factors or threats to species persistence can be used as an organizing framework to group species for effects analysis.

Grouping based on ecological characteristics. Grouping species on the basis of one or more ecological factors provides a strong foundation for developing conservation strategies for species at risk, because the conservation strategies can then be ordered around ecological principles. Ecological groupings also make sense for evaluating the effects of planning alternatives. Four ways to group species ecologically are by habitat associations, ecological function, body size/home range size, and categories of limitation.

Habitat associations. The concepts of community types, plant association, and seral (or structural) stages provided by plant ecologists form a foundation for grouping terrestrial species by similarity of habitats. Seral/structural stages as well as vegetation types should be used when grouping species by habitat, because the viability of some species may be dependent on a particular stage that is underrepresented or in poor ecological condition. By using seral/structural stages to define species groups, conservation strategies and the analysis of effects can be more specific. Short and Burnham (1982) illustrated a variety of clustering techniques to form groups of species to facilitate understanding of the composite environmental requirements of large sets of vertebrate species. Wisdom et al. (2000) used hierarchical cluster analysis to group species at risk within the Columbia Basin. Similar grouping approaches have been used to cluster fish communities (Lee et al. 1997). Other examples of grouping by habitat association are contained in the Southern Appalachian Assessment (SAMAB 1996), the Northern Great Plains Assessment (Samson et al. 1999), and the Tongass National Forest Plan revision (Suring et al. 1993, USDA 1997).

Ecological function. Ecological function as a basis for grouping species was described by Marcot et al. (1997). Resulting groups may be used in the development of conservation approaches, with the objective of maintaining ecological functions by providing for the composite needs of species that perform each function. Grouping by ecological function may be the best approach for taxa with many poorly known (or unknown) species. An example of grouping arthropods by ecological function is found in the Forest Ecosystem Management Assessment Team report (Thomas et al. 1993).

Body size/home range size. Numerous ecologists have recognized the importance of body size groupings, e.g, Schmid el al. (2000), Garcia (2000), and Norris (1998) among others. This relationship may be useful for evaluating how species perceive habitats at different spatial scales (Holling 1992). Body size is considered a useful predictor of the size of habitat patches needed to maintain populations (Smallwood 2000). Body size groups may serve as a useful way to group species that perceive habitats at similar spatial scales. For example, in the Northern Region, Redmond and Hart (in prep and following Smallwood 2000) have proposed grouping species into four categories based on size and mobility: large, wide-ranging species, intermediate species, small yet mobile species, and small sedentary species. Habitat requirements would then be presented at four spatial scales pertinent to these species groups. Vertebrate body size grouping are also particularly important in predicting consequences of broad-scale events such as global warming (Thompson et al. 1998a) and for landscape processes such as fire (Wilsey 1996).

Categories of limitation. Species can also be grouped according to the primary limitations that have contributed to their decline. Lambeck (1997) proposed four categories for grouping species: area-limited, resource-limited, dispersal-limited, and process-limited. Lambeck (1997) suggested that the area-limited group could be further divided according to major habitat types. This group may also be subdivided by using by using body size/home range size as an indicator of dispersal limitation. The resource-limited group can be subdivided by categories of key resources (caves, snags), and the process-limited group can be divided into types of processes (fire, hydrologic processes).

It may be helpful to select individual focal species that would represent the needs of the groups of species identified in the previous steps. Regulations implementing the National Forest Management Act suggest that focal species may be used in developing management strategies, assessing viability of species, and developing monitoring plans. It is also worth noting that the regulations do not require that all species be represented by focal species. It also allows for the use of individual species assessments where appropriate, and for the use of the groups themselves as an analytical entity where that is most helpful. One process for identifying focal species follows. This process assumes that species are being classified and treated according to their ecological requirements, and that the process is being carried out at the scale of a Forest plan or at a bioregional scale. Note that the objective of this process is to select focal species that best represent the composite ecological requirements of species at risk. Additional focal species may be selected to provide other insights to the larger ecological system.

Based on the above information, select one or more species that best represent the full array of ecological requirements for all species in the habitat-based group. It is recommended that species with the most demanding requirements be selected here. If their needs are met, then needs of other species within the habitat group should also be met. Several species may have to be selected to fully represent the requirements of all species within the habitat-based group. For example, if some species within the habitat-based group use snags, then a species with the most demanding or limiting snag requirements should be selected as a focal species. Similarly, it may be appropriate to select the species with the largest home range, and the species with the most limited dispersal capability as focal species.

If focal species are selected in this way, we can legitimately defend them as being representative of the ecological requirements of the larger group of species. Note however, that even where species have very similar ecological requirements, it is not an expectation that their population dynamics would parallel each other. Note also that this process requires the use of a great deal of detailed information on species habitat requirements, and that a relatively large set of focal species may be needed to fully represent the requirements of all species.

The above process emphasizes the selection of focal species through grouping of species-at-risk. It is also possible in some cases that ecological requirements of species-at-risk could be represented by focal species that are not themselves species-at-risk. For example, ecological requirements of predators that are identified to be at risk could be at least partially represented by common prey species selected as focal species.

5. Develop conservation approaches for species at risk

Once species at risk, species groups, and focal species are identified, approaches to their conservation should be developed (Noss and Cooperrider 1994). Conservation approaches should focus on the key conditions that have caused the species to be at risk, and provide options (where available) to change those conditions in order to maintain the viability of that species or group of species (Foin et al. 1998). Existing conservation strategies and agreements or recovery plans may be sources for conservation approaches. Conservation approaches are not management direction. When alternatives are developed, they may serve as the basis for forestwide standards or guidelines, for direction for specific management areas, and/or for land allocations. They also may remain outside of the Forest Plan direction and simply be used as a gauge for evaluating the effects of the alternatives in the Environmental Impact statement (EIS).

To the extent possible, conservation approaches should take into account species needs across its entire range or the portion of its range where it is considered at risk. Approaches should generally be consistent across the range of the species, although ecological differences across the range may require different approaches in some cases. Conservation approaches should also generally be consistent for species that have nearly identical reasons for their viability concern. For example, the conservation approaches considered for narrowly endemic plants limited to a few known occurrences should be consistent, even though each plant may occur on only one forest. To achieve consistency, approaches are best developed at the ecoregional or bioregional scale. Ecologists and species experts should be involved in the formulation or review of conservation approaches. The development of conservation approaches can be made more manageable by clustering species as described in the previous step.

Development of conservation approaches may also be aided by consideration of both broad management practices that provide for overall ecosystem composition and function, and specific practices directed at the needs of individual species. The two general approaches in the conservation of natural resources are the coarse filter and fine filter (Baydack et al. 1999). The coarse filter is a strategy to conserve the majority of species based on providing an appropriate mix of ecological communities across the planning area, rather than focusing on the needs of specific species (Haufler 1999). The fine filter is a strategy based on the needs of individual species or groups of species. A major part of the overall conditions required by a species or species groups may be provided through overall ecosystem management direction, while other conditions may require species-specific direction. Broad approaches for management of ecosystems may include strategies such as designation of reserves, management of ecosystem elements and processes within the historical range of variation, or emulation of natural disturbance processes in the design of management activities. Since Forest Planning involves the development of alternatives, it is necessary to consider several of these strategies when species conservation approaches are being developed. It is necessary to first state the species needs in terms of broad-scale habitats and processes that support viability, before describing possible approaches for achieving those conditions.

The viability of many species is only partially addressed through broad direction for management of ecosystems, either because the causes for concern are not related to habitat, or because those approaches do not adequately address certain fine scale habitat components and features such as leks, caves, seeps, bogs, spawning sites and raptor nest sites that are essential for viability. For most species, it is likely that management for such specific features will be needed in addition to broad-scale management for ecosystems. This does not imply, however, that a separate approach is needed for each individual species. Development of common approaches for species groups should be feasible.

Ecosystem Diversity

Ecosystem diversity is the structure (from patch sizes and distributions to seral stages), composition (both plant and animals) and the ecological processes native to a landscape. Ecosystem diversity arises from diversity in abiotic and biotic components and ecological processes that vary over space and time (Huston 1994). Ecosystems are open complex systems that in reality have no physical boundaries and are constantly changing. History plays a strong role in the ecosystems we see today through the long-term effects of geological and climate change and evolution and the shorter-term effects of climate change, disturbance, and succession and migration of organisms. Ecosystems are complex, linked, adaptive systems but linkages can be weak or strong and responses to change in one component can be spatially and temporally lagged (Wu and Loucks 1997).

There is general agreement on the major attributes of ecosystem diversity that must be considered in analysis of ecological sustainability. Various groups and organizations have developed indicators. The most well known are probably the Criteria and Indicators of sustainable forest management that originated from the Montreal Process (http://www.mpci.org/meetings/santiago). Although designed for assessing sustainability at national scales, many of these, such as area of successional stages, are suitable for application in management of National Forests and Grasslands. However, additional indicators may be necessary to characterize the particular diversity of ecosystem at regional and landscape scales The Montreal Process indicators can form an upper level framework within which additional indicators may be used. Indicators should focus on those biotic, and occasionally abiotic, features of the environment over which the agency has management authority and control.

The Planning Rule states that a foundation (standards) must be established before other social and economic uses are considered. According to the Planning Rule, decisions must provide for vegetation types that fall within the range of natural variation. The concept of natural range of variability specifies the spatial and temporal patterns of ecosystem structure, composition and processes that is expected under the current climatic period.

The following steps provide an approach for implementing the range of natural variation concept. The approach is based primarily on characteristics of terrestrial and aquatic systems and their dynamics which are important features in their own right and can serve as surrogates for more obscure ecosystem processes, structures and species.

1. Use a hierarchical ecosystem classification framework to develop the framework of an ecosystem diversity strategy.

2. Characterize current terrestrial and aquatic patterns to provide assessment of current ecosystem conditions.

3. Characterize the natural disturbance regimes of terrestrial and aquatic ecosystems at multiples scales of a region under the current climatic period (reference period).

4. Develop expected/desired distributions of terrestrial and aquatic patterns to approximate that range and assess how current conditions compare with expected/desired range variability.

5. Project future conditions under current and alternative management policies to establish expected trends against which to evaluate changes detected through monitoring.

1. Use a hierarchical ecosystem classification framework to develop the building blocks of an ecosystem diversity strategy.

Hierarchical ecosystem classifications enable the development of maps that portray ecologically important patterns of ecosystem components including climate, geomorphology, soils, hydrology, vegetation types and biotic regions. Such classifications are typically spatially and ecologically hierarchical. Many different ecological classifications have been proposed (Grossman et al. 1999). For example, ECOMAP, a national ecoregional classification (Avers et al. 1994), is based on climatic patterns at broad scales and landform and plant associations at local scales.

Current approaches to ecosystem classification have limitations (Grossman et al. 1999). First, no comprehensive system currently exists that is accepted for all agencies and ownerships although a tentative the process to develop a national vegetation classification is nearing completion (Ecological Society of America 2000). Second, the existing systems that emphasize vegetation are not well integrated with aquatic systems or taxonomic hierarchies (Nudds 1999). Third, ecosystem classifications are typically based on abiotic factors such as climate, landform, soils or potential vegetation (the late successional communities that would develop in an area) which may predict primary productivity and late successional vegetation but say nothing about current vegetation and landscape patterns which can have a strong control on ecosystem processes and species diversity. Despite these deficiencies such classifications can still be used as the basis of ecosystem diversity if they are viewed as first approximations that will be refined as the science develops (Palik et al. 2000, Poini et al. 2000).

Regional scale classifications that identify provinces and subregions with relatively similar ecological potential may be the best starting place for ecosystem evaluation, since landscape and local level classifications may not exist for many regions. Major units should be identified in regional assessments and used as strata for evaluating the distribution of other ecological conditions (e.g. seral stage distributions or species occurrences. Wherever possible the area included in such analysis should also include non-federal lands since ecosystem process and species do not recognize jurisdictional boundaries. At landscape scales and finer scales, classifications of ecosystems are based on geology, landforms, topography, local climate, soil, and various plant association groupings. At these scales individual management features, such as wetlands, small watersheds, dune systems and ecological land units with characteristic soils, topography and late successional vegetation can be identified. These landscape and local units can serve as the framework of ecosystem planning at forest and district levels.

2. Characterize current terrestrial and aquatic patterns to evaluate current ecosystem conditions

Classifications based on abiotic factors or potential vegetation states do not provide information about current ecosystem conditions. Information is needed about the current state of vegetation, which in most cases is in some stage of development following recent disturbances or those of the more distant past. Changes in vegetation composition and structure following disturbance can be classified into general stand developmental and seral stages (Knopf 1996, Spies 1997, Haufler et al. 1999). Developmental stages are the structural changes that occur following disturbance and seral stages are the sequence of compositional/structural plant communities that occur within particular environments or ecosystem types. While no universal classification system exists there is broad agreement on the general sequence of stages, although the number of different stages recognized is open to debate. In many cases, vegetation changes following disturbance follow multiple pathways toward dominance by late successional species and structure (Laubhan and Fredrickson 1997, Spies 1997, Knapp et al. 1999). Despite the complexity of vegetation change following disturbance it is generally accepted in the forest system literature that seral or developmental stages and landscape patterns can be described using a relative small set of classes (e.g. 6-20) (Waring and Running 1998) and fewer in (e.g., 3-4) grassland (Knopf and Samson 1997) and other systems (Knick and Rotenberry 1998).

A hierarchical approach can be used to step down from broad seral classes (e.g. open/shrub or old-growth) to individual structure such as large trees and snags. Some have proposed that indices or other metrics of forest development be used to capture the structural variability that occurs during stand development (Spies and Franklin 1988). A hierarchical approach may also be used in grassland (Steinauer and Collins 1996), desert (Yool 1998), arctic (Walker and Walker 1991), riverine (Ward 1998, Montgomery 1999) and other communities. For analyses of landscape mosaics, developmental and seral stages can be used to define upland patches along with other landscape features such as roads and human activity areas such as campgrounds and cities.

3. Characterize the natural disturbance regimes of terrestrial and aquatic ecosystems of a region under the current climatic period.

Descriptions of the disturbance regimes of an area is one prerequisite for describing the Range of Natural Variation (RNV). In addition, Wilcove and Chen (1998) note the suppression of natural disturbances, particularly fire, and invasive species are two key factors that threaten the persistence of about 60% of the Threatened and Endangered species in the United States. Maintaining natural disturbance regimes is important to slow the invasion of alien and exotic species (Stylinski and Allen 1999) and, on the other hand, invasive species and a significant and negative impacts on natural disturbance regimes (Mack and D'Antinio 1998, Albert et al. 2000).

An immense literature exists that describes natural disturbance regimes. Examples of such literature includethat for the shrubsteppe (Knick and Rotenberry 1997); river and riparian systems (Bush and Smith 1995, Tabacchi et al. 1998, Townsend and Rley 1999, Montgomery 1999), deciduous forests (Abrams and Orwig 1996, Batek et al. 1999, Mladenoff 1999, Cook 2000, Copenheaver et al. 2000), prairie (Hatnett et al. 1997, Vinton and Collins 1997), and coniferous forests (Baker 1994, Mast et al. 1998) among other systems (Parsons et al. 1999). General references include Lorimer (1985), Samson and Knopf (1997), and Engstrom et al. (1999).

Where feasible the description of disturbance regimes should be placed within an ecosystem classification framework. However, it should be recognized that ecosystem classifications based on climate and geomorphology or potential vegetation are not necessarily useful at predicting disturbances disturbance regimes which typically are sensitive to current vegetation and often have a strong stochastic component in their behavior. General, descriptions of disturbance regime are better suited for regions, provinces, and landscapes. Variability in disturbance history and behavior at finer scales may be too large to be characterized with distinctive disturbance regimes, although there are many exceptions to this generalization.

The changes in species composition and live and dead vegetation structure that occur following disturbances have important implications to biological diversity and ecosystem function. Successional changes typically refer to the compositional changes that occur with time following disturbance. In many ecosystems these can be characterized by a change from highly mobile species that arrive immediately after a disturbance to less mobile species that arrive later. Frequently, the later arriving species are more competitive for resources (e.g. shade tolerant plants) and exclude the early arriving individuals. Consequently, landscapes with a diversity of times since disturbance will probably have greater species diversity than landscapes with low diversity of times since disturbance. In other landscapes, species composition may not change much from shortly after a disturbance to a long time after a disturbance. In those cases, the destroyed species resprout or reinvade the disturbed areas from nearby source areas.

Although succession may not include species compositional change, it always involves structural changes. Stand development involves accumulation of biomass in live and dead plant parts. This structural development is the part of RNV upon which other plant and animal organisms find shelter, food and other resources. Consequently, landscapes that lack a diversity of stand developmental stages will be deficient in organisms that are sensitive to individual structures (e.g. snags) or structural stages (e.g. grasslands, old-growth forests). Structural stages are to a certain degree insensitive to species composition. For example, old-growth stages characterized by relatively large trees and accumulations of dead wood are common to many different forest types (Spies and Franklin 1998). For many animals, the exact species composition of a successional stage may be less important than the general lifeform (conifer vs harwood). However, there are many exceptions where animal species track the occurrence of individual plant species, particularly invertebrates.

Descriptions of the historic animal communities is important to understanding the natural range and structure in species composition for a region and is second consideration for describing the RNV. Species composition for a region responds to a variety of abiotic and biotic factors operating at multiple spatial scales. For example, FAUNMAP is an electronic database of the Pleistocene and Holocene distributions of mammal species in the United States. FAUNAMAP has been used to compare climate/ long-term versus human impacts on the American pronghorn and to identify primary habitat (Paster et al. 2000). Use of historic vertebrate composition information has proved useful in determining if fish populations are extirpated (Grogan and Boreman 1998), determine the magnitude of change in vertebrate communities for a particular ecosystem or biome (Bogan 1997), and in developing both species and ecosystem-level conservation approaches (Samson et al. 1999). Species due play an important role in the extent and composition of major ecosystems. One example is the shift of the shortgrass prairie and mixed prairie transition to the west (over 200 miles) as the large, herbivorous bison were removed from the Great Plains in the mid- to late 19th century.

Water, carbon and nutrient cycling are important processes in ecosystem function and diversity (See Lugo et al. 1999 for more information). Nitrogen cycling is especially important because of the role of nitrogen plays in photosynthesis and tissue development and because nitrogen is limiting in many ecosystems. Most nitrogen that is available to plants comes from stocks of nitrogen contained within soil organic matter and live and dead plant tissues. In other words, nitrogen for plant growth must come from recycled sources from within the ecosystem. Process that tie up nitrogen in unavailable forms, or cause the loss of nitrogen from soils can have a strong impact on productivity. Hence management of ecosystems must take into account how disturbance and species composition—plant and animal-- influence nitrogen availability especially in those ecosystems where nitrogen is limiting. Disturbances can have both negative and positive influences on nitrogen availability.

Establishing the disturbance regime of an area will require identification of a climatic period of reference. The native ecosystems of a region are adapted to variations in the macroclimate of an area that have occurred in past centuries and millennia. Climate variability provides a reference framework for developing goals for ecosystem diversity. Climate controls disturbance regimes, productivity, and species ranges, and many of the species and ecosystems that humans currently value are adapted to the variability that has occurred in the past and may continue into the future. For each region or subregion a climatic period that represents a reference climatic regime should be identified.

The current climatic period can be thought of as an interval of time, or moving window of time that includes the present day but goes back some centuries or millennia to encompass the decadal and multi-decadal cycles and variation in climate that occur in most regions. The period should also be at least several times the life spans of the dominant plant species or several times the length of seral sequences that follow catastrophic disturbances. As an example, the Interior Columbia Basin Ecosystem Management Project estimated that the current climatic period emerged 2,700 years ago and that the present-day plant communities have been in equilibrium with their climate for the last 2,000 years (Committee of Scientists 1999). Other regions will have different climatic histories and different degrees of vegetation-climate equilibrium. Other examples include Peng and Apps (1999), Swetnam and Delecourt (1998) and Delcourt and Delcourt (1998).

The use of a reference climatic period does not imply that current vegetation and ecosystems are adapted to the current climate. Nor does it imply that climate change will not occur in the future. In many regions of North America it is well documented that some species ranges and ecosystem types are still changing in response to post glacial climate warming (Delcourt and Delcourt 2000). Where these ecological trends are known they must be incorporated into expectations for ecosystem diversity in a region. Similarly, projected changes in climate over the next century could result in completely new climatic regimes. While considerable uncertainty exists regarding the magnitude and direction of changes regional climates in the future it is clear that changes will occur and will affect ecosystem processes and diversity (IPCC 2000). This uncertainty makes the task of ecosystem conservation and planning a very difficult process. It will be important for the responsible officials to use an adaptive management framework in conserving ecosystem diversity. Identification of the current climatic reference period and expectations for species and ecosystems that are responding to past changes or possible response to future changes should be done with assistance from paleoecologists, climate change scientists and other ecologists.

Other key ecological processes should be identified and described to the extent practical. Ecosystems are complex and characterized by a large number of processes, including erosion and nutrient cycling, food web interactions, succession and migration (Lugo et al. 1999). It is not possible to quantify and measure all of these processes across the range of ecosystem types. It is more reasonable to expect that these processes could be generally characterized for major ecosystem types at province and coarser scales. Such characterizations would include general descriptions of these processes and identifications of processes that are particularly limiting to ecosystem functioning or particularly sensitive to human activities and impacts. Some of these processes or surrogates of them (e.g. productivity, carbon storage, and succession) can be measured in regional inventory and monitoring grids.

The role of humans should be described from three different perspectives. First, human activities that have played important roles in shaping ecosystems that we may now find desirable should be identified (Bonnicksen 1999), e.g. native American burning that helped maintain open understories in many forest types. Second, information should be compiled about historical, contemporary, and future impacts of humans on native ecosystems that have undesirable consequences. (e.g. fire suppression, logging, introduction and spread of exotic plant and animal species, and road building). To the extent possible, anthropogenic stressors on ecosystem function and diversity should be identified in an ecological framework (Noon et al. 1999b). This information can provide a basis for planning actions as well as targeting monitoring efforts. I was following. Third, substantial loss of native habitat around public lands may preclude management for all seral stages with the focus on a smaller set of seral stages required by one or more rare species (Samson et al. 1997).

4. Develop expected/desired distributions of vegetation stages and/or types to approximate that range and assess how current conditions compare with expected/desired range variability.

If general characteristics disturbance regimes (e.g. type, frequency, size, and severity) are known (or can be estimated) then it is possible to develop expected and/or desired seral stage or age class distributions that would occur in a region in the absence of disturbance suppression (Cassagrandi and Rinaldi 1999, Wimberly et al. 2000). This process is probably best begun at regional and provincial scales where disturbance regimes are typically best known. For small landscapes and sites where the range of variation in successional stages may be too wide (e.g. 0-100% old-growth or early successional forests) to be of much guidance. This occurs because individual sites will typically experience considerable variability relative to large landscapes or regions where aggregate dynamics are slower and more restricted. The concept of historical range of variability can be used to help set the range of proportions of different seral stages that would potentially occur in the current climatic period (Parsons et al. 1999).

The actual range of variation can be estimated using computer models (Gill and McCarthy 1998, Wimberly et al. 2000) or can be estimated by science teams (Samson et al. 1999) that rely on general principles of landscape ecology. No accepted standard exists for the magnitude of variation that constitutes an "acceptable range."

If current conditions fall outside of key indicators then actions could be undertaken to move the distribution toward range or to increase or decrease seral stages whose proportions are near the high or low end of the historical range. Active and/or passive management practices such as thinning, regeneration harvesting, prescribed burning, grazing and no-management zones may be used to achieve desired results. In some ecosystems, "unusually large fires would probably hasten the restoration of landscape structure, while small prescribed fires will not restore the landscape but instead will produce further alteration (Baker 1994:763). In other cases, delay in returning the natural process with that expected for the natural disturbance regimes will create habitat for many species (Madden et al. 1999), including endangered species (James et al. 1997). And, in other landscape, establishing patters and frequencies characteristic to a particularly landscape may not be recommended in terms of conservation (Reeves et al. 1995) or impossible due to other constraints (Samson et al. 1997).

Within landscapes, disturbance regimes and seral stage distributions can be distributed by local ecological landscape units so that a diversity of stand development x environment x landscape pattern (patch size, connectivity etc.) combinations are provided for (see Cissel et al. 1999 and Haufler et. al. 1999). Landscape-scale allocations of desired distributions derived from the regional scale analysis will be made on the basis of current ecosystem or landscape conditions, and other decision making criteria such management of threatened and endangered species, environmental laws and economic and social values. Developing desired seral stage distributions across landscapes based on disturbance histories and ecosystem patterns can be an intensive effort. Until we gain more experience with this approach it may be best to develop stand development or seral stage distributions that apply to mid-sized landscapes or watersheds and let current conditions and other factors determine spatial distributions within those units.

Applying range of variability to species, particularly for plants, is more problematic than applying it to communities, seral stages, and stand development stages (Collins 2000). These ecological entities are relatively less sensitive to variations in abundance and occurrence of individual species. Applying the RNV to individual species is problematic from at least three perspectives: First, we typically know little about variation in abundance and distribution of species during he current climatic period. Second, species ranges are dynamic and some slow-moving species are not in equilibrium with current climatic conditions (Delcourt and Delcourt 1999). Ranges in mobile species may also be dynamic in response to biotic interactions (disease, predators, etc.) and changes in overall landscape structure. Third, future climate changes will probably affect species on an individual basis so that some species may react relatively rapidly while others may be relatively insensitive to climatic changes. Consequently, setting goals for individual species relative to expected variation under the current climatic regime should be done cautiously. We can, however, characterize composition relative to historic conditions by recognizing extirpations/extintions and the introduction of exotics/non-natives. The best approach might be to discuss range of variability of species in terms of variation in their habitat conditions, with the recognition that may be unrealistic to set goals for individual species in terms of historical range of variability.

Within ecosystem diversity, focal Species are to serve has species-level indicators of ecosystem status and as surrogate measure of species diversity (Simberloff 1998). Focal species are intended to provide another window or perspective on ecosystem conditions. They should not be viewed as indicators of whole ecosystems but as parts of some larger system that can be used to gain insights about the whole system. Focal species can be selected based on ecological criteria including: keystone species (Flieshman et al. 2000), umbrella species (Koltiar 2000) and link species (species that play important roles in transfer of matter and energy) (Jones et al. 1994), game species (species that are important to human communities or other species with high interest (Linnell et al. 2000).

5. Project future conditions under current and alternative management policies to establish expected trends against which to evaluate changes detected through monitoring.

To the extent feasible expected trends in ecosystem/landscapes should be simulated at landscape to regional scales and potential effects on key ecological and socio-economic components evaluated (Lugo et al. 1999). Several examples exist of how to conduct landscape modeling in support of ecosystem management objectives (Maddox et al. 1999, Mladenoff and Baker 1999, Spies et al. In press). No single modeling system can work for all situations and objectives and sets of models will need to be used or new models developed. Model projections can be used to compare alternative policies and plans as well as to establish trend lines against which to evaluate changes detected in monitoring.

PLANNING

The are four remaining steps necessary to appropriately focus existing science on the issue of conserving species diversity and ecosystem diversity while complying with the provisions of both the NFMA planning rule and the National Environmental Policy Act (NEPA) are discussed below.

6. Incorporate Conservation Approaches into Forest Plan Alternatives

Maintaining species viability is a legal requirement and therefore must be a goal of every Forest Plan alternative. However, not every alternative will achieve the goal of viability with the same level of certainty. Alternatives will differ in the likelihood of providing ecological conditions to viable populations, and the risks of species extirpations. In a similar fashion, alternatives will differ in the degree to which they accomplish other goals. In Forest Plan revisions, the effects of the current plan serve as the basis for deciding how much change is needed.

There are many ways to reach ecosystem diversity goals including both active and passive management methods. Using concepts from disturbance ecology and landscape ecology, managers can apply or allow disturbances at frequencies, severities and spatial patterns that direct terrestrial and aquatic systems toward the development of alternatives. In some cases this will involve traditional or novel silvicultural practices to manipulate vegetation such as regeneration cutting, thinning, prescribed fire, and grazing while in other cases it may simply involve allowing relatively natural landscapes to develop without active management. Restoration of stand structures, landscape patterns and processes will be required in many landscapes that have had a long history of human influences that have moved them outside the range of conditions expected under disturbance regimes of the current climate. In some cases roads may be removed or modified to reduce their effects on watershed and ecological processes. It will probably not be desirable to reproduce the full range of natural disturbance regimes of an area. For example, large intense fires though part of natural variation, may not be practical or necessarily ecologically desirable in some landscapes. Management practices to remove or slow the spread of exotic species should be considered in each situation.

7. Assess Effects of Alternatives

Construction of alternatives that represent a range of potential conservation assessments should provide well-reasoned evaluation of the high likelihood that habitat and other environmental conditions will allow maintenance of well-distributed viable populations and desired distributions of vegetation stages. Ensure the timeframe is adequately long to allow the expression of management actions on populations and desired distributions of vegetation stages. Consider both the effects of predominant risk factors pertinent to the species and desired distributions of vegetation stage the cumulative effects that reflect surrounding landscapes. Use currently accepted scientific information (Smallwood et al. 2000) and clearly portrays uncertainty surrounding the assessment, including uncertainty due to gaps in knowledge. Independent peer review of assessments contributes to their rigor and credibility.

8. Documentation in the EIS and Record of Decision

Thorough documentation of the assessment process is required in the EIS that accompanies a Forest or Grassland Plan. In the Record of Decision, there must be a description of the basis for judging that the proposed action satisfies both the species diversity and viability and ecosystem diversity requirements. Considerations for species viability should include identification of species-at-risk and risk factors and the description of management approaches that contribute to species at risk conservation, the use of species groups and focal species, the evaluation of the effects of alternatives, and for the proposed monitoring.

Determination of whether the proposed actions meet the regulation's standard of "high likelihood" for species viability is made through the decision-making processes and should reflect results from multiple techniques versus use of a single technique. Determinations may apply to a single Forest or to a group of Forests that are included within the same planning effort. and should tier to any determinations or assessments made at broader scales. Determinations should discuss specific features of the proposed action that affect the likelihood of providing for viability, including any trade-offs made to meet other goals or because of budget constraints.

Considerations for ecosystem diversity should include the identification of the hierarchical classification scheme and the characterization of current and projected future vegetative conditions, natural disturbance regimes under the current climatic period (reference period), expected/desired distributions of vegetation stages and/or types, use of focal species, evaluation of the effects of alternatives, and a description of proposed monitoring.

9 Monitoring

Monitoring and adaptive management are essential elements of sustaining species diversity and ecosystem diversity. Because of these high levels of uncertainty, it is critical to implement an effective monitoring (Thompson et al. 1998b) and adaptive management program (Nudds 1999). Simple surrogates of diversity and processes must be developed. Sound monitoring programs must be based on a scientifically defendable conceptual model that helps identify questions and indicators.

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