White paper on managing for species viability

Objective: Management of the National Forests to provide for diversity and viability of species has proven to be one of the most challenging requirements of the National Forest Management Act (NFMA) and its implementing regulations. In the initial development of Forest Plans, many different approaches were used to manage for and analyze viability, and administrative and legal challenges proliferated. Those initial plans are now being revised, many under the umbrella of bioregional assessments. Most of these revisions will follow requirements of the revised NFMA regulations issued in November 2000. Within the context of the bioregional assessments and Forest Plan revisions, the Forest Service is attempting to use more consistent and defensible approaches to both management for and assessment of species viability.

The objective of this paper is to provide background information for the development of Forest Service policy on the issue of viability. It provides initial recommendations on processes that could be used to address viability, and supplies scientific background for those recommendations. The intent of the paper is not to duplicate excellent technical reviews of population viability analysis that have been published in recent years, or to propose any new developments in the field of population viability analysis. The primary audience for the paper consists of two groups: the Forest Service policymakers who will finalize direction to address viability, and the biologists and other technical specialists who must implement that policy. We expect that the technical specialists who will implement direction for viability will require more detailed technical information than can be provided in this brief paper. A more detailed technical white paper, addressing specific analytical techniques, will be produced as a companion to this present effort.

While this paper focuses on the topic of viability, it is recognized that viability must be addressed as part of an overall approach to ecological sustainability. The revised NFMA regulations establish ecosystem diversity and species diversity as the two components of ecological sustainability, with species viability as the primary requirement for maintaining species diversity. Other facets of ecological sustainability will be addressed in other white papers, which must be considered in combination with this effort.

I. Introduction

The National Forest Management Act (NFMA) regulations revised in November 2000 require National Forests to "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" (36CFR219.20). This requirement for species viability is placed within the context of requirements for ecological sustainability and ecosystem diversity which state, in part, that "Plan decisions affecting ecosystem diversity 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 climatic period" (36CFR219.20). Thus the regulations require that a combination of ecosystem-based and species-based approaches be used in providing for ecological sustainability.

NFMA regulations (36CFR219.36) define a viable species as one "consisting of self-sustaining and interacting populations that are well distributed through the species' range. Self-sustaining populations are those that are sufficiently abundant and have sufficient diversity to display the array of life history strategies and forms to provide for their long-term persistence and adaptability over time." A species is described as being well-distributed "when individuals can interact with each other in the portion of the species' range that occurs within the plan area" (36 CFR219.20). The plan area may consist of one or more National Forests, and refers specifically to Forest Service lands within that area.

While the NFMA regulations include requirements for species viability, the Act does not use the term "viability". Rather, it directs that management of National Forests "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives." The regulation (36CFR219.19) reflects this language on multiple-use when it directs that "The first priority for stewardship of the national forests and grasslands is to maintain or restore ecological sustainability to provide a sustainable flow of uses, values, products, and services from these lands." Thus, requirements for ecosystem and species diversity, including species viability, are placed within the context of the overall goals for sustainability of National Forests. Sustainability is described as being "composed of interdependent ecological, social, and economic elements," and embodying "the principles of multiple-use and sustained-yield without impairment to the productivity of the land" (36 CFR 219.1).

Successful implementation of the species viability and diversity provisions of NFMA requires that the following be accomplished as part of Forest Planning:

- Identification of species in the planning area for which there may be risks that well-distributed populations will not be maintained, with the caveat that some species are naturally rare or not well-distributed
- Identification of risk factors and limiting factors for species-at-risk
- Identification of management approaches that would contribute to conservation of species-at-risk
- Construction of Forest Plan alternatives that represent a range of potential conservation approaches
- Assessment of projected effects of management actions on species-at-risk. Such assessments should 1) provide well-reasoned evaluation of the likelihood that habitat and other environmental conditions will allow maintenance of well-distributed populations; 2) consider a timeframe that is adequately long to allow the expression of management actions on populations; 3) consider effects of predominant risk factors pertinent to the species; 4) consider both cumulative effects and the contribution of National Forest management to species viability; 5) use currently-accepted scientific information; and 6) clearly portray uncertainty surrounding the assessment, including uncertainty due to gaps in knowledge.
- Thorough documentation in the EIS of the assessment process and the process used to select species for the assessment
- A description, in the Record of Decision, of the basis for judging that the proposed action satisfies the diversity and viability requirements. This must include discussion of and response to adverse opinions held by respected scientists.

II. Background

LEGAL AND POLICY INTERPRETATION

Components of the 1982 NFMA regulation have been difficult to interpret and have sparked controversy (Raphael and Marcot 1994). This is not surprising, as even the Committee of Scientists involved in drafting the initial regulation acknowledged that diversity was "one of the most perplexing issues dealt with in the draft regulations", and that "there remains a great deal of room for honest debate on the translation of policy into management planning requirements..." Several of these difficult points have been clarified through experience and legal interpretation, and that clarification is reflected in the revised regulation issued in November 2000. A discussion of those points follows and includes the resolution embodied in the revised regulation.

<u>What is an acceptable level of assurance of viability?</u>

The 1982 regulation defined a viable population as one for which the number and distribution of reproductive individuals would "insure its continued existence". However, because species and their environments are dynamic, it is not possible to insure that a species will persist indefinitely. Likewise, there is not a single, fixed size of a population above which a species is viable and below which it will become extinct (Boyce 1992). Consequently, viability is best expressed through varying levels of risk, and the level of assurance that a population will be maintained becomes a policy, legal, and technical issue.

Court decisions have found that the assurance of viability must be compatible with key multiple-use considerations. In ruling on the Northwest Forest Plan, the Ninth Circuit (Seattle Audubon Society v. Lyons, 871 F. Supp. 1291 (W.D. Wash. 1994)) stated that "the selection of an alternative with a higher likelihood of viability would preclude any multiple-use compromises contrary to the overall mandate of the NFMA". However, the Ninth Circuit has also made it clear that there is a substantive requirement to provide habitat that will maintain viability of species. In an earlier ruling in the northwest (Seattle Audubon Society v. Moseley, 798 F. Supp. 1473, 1484, and 1494 (W.D. Wash 1992)), the Ninth Circuit commented on a viability rating that had been made by an outside report on the Forest Service preferred alternative. Here, the court commented that "if the medium-low viability rating were admittedly the Forest Service's own rating, summary judgement under NFMA would be entered now...Whatever plan is adopted, it cannot be one which the agency knows or believes will probably cause the extirpation of other native vertebrate species from the planning area."

The revised NFMA regulations require that there be "high likelihood" that ecological conditions are capable of supporting viable populations over time (36 CFR219.20). This recognizes that, while continued existence cannot be insured, there must be some criterion for judging whether a plan adequately provides for viability. As noted by Shaffer et al. (in press), unambiguous criteria for acceptable levels of risk to viability have not yet been articulated. "High likelihood" is not intended to be a statistical measure, but instead expresses a level of belief that viability will be maintained. The finding of "high likelihood" should be based on ecological arguments, incorporating results of analysis and utilizing criteria such as representation, redundancy, and resiliency (Shaffer et al., in press).

Use of the term "ecological conditions" in the regulations is an acknowledgment that species requirements extend beyond vegetative or aquatic habitats. Ecological conditions are defined as including all components of the physical and biological environment that can affect species viability, including the abundance of habitats, roads and other structural developments, human uses, and invasive and exotic species (36CFR 219.36).

What is a well-distributed species?

Both the 1982 regulations and the 2000 revision require that conditions be provided to support species in a "well-distributed" pattern throughout the species range within the plan area. The term "well-distributed" refers to the geographic distribution of the species and its habitat, and the biological interactions allowed by that distribution. The concept of well-distributed must be based on the species' natural history and historical distribution, the potential distribution of its habitat, and recognition that habitat and population distribution is likely to be dynamic over time. It is most easily defined for broadly distributed species that occur across the landscape. For such species, a well-distributed pattern is one in which the species is either evenly distributed across the species range, or distributed in a pattern that allows dispersal of individuals or propagules among local populations that are distributed throughout the landscape. For other species, such as local endemics or those tied to naturally scarce or spatially disjunct habitats, a definition of well-distributed must be developed reflecting the inherent constraints on the distribution of the species. It should not be an expectation that management on National Forests would provide broadly- or evenly-distributed habitat for all species. Appropriate standards for species should be based on their life history requisites (home range size, dispersal capability, effect of habitat on dispersal, seasonal movements, etc.), historical distribution, potential habitat distribution and current condition. The 2000 revision of the NFMA regulations acknowledges that "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" (36CFR219.20). Appropriate application of the requirement that conditions be provided in a well-distributed pattern across the species' range also has the effect of providing for conservation of populations that are at the edge of the range, in addition to populations at the core of the range (Channell and Lomolino 2000; Lesica and Allendorf 1995).

What is an adequate level of analysis?

The courts have consistently ruled that the agencies have discretion in determining the appropriate level and form of analysis, as long as that analysis is logical, makes use of currently accepted science, and addresses any contrary views of respected scientists. In the decision on the Northwest Forest Plan [Seattle Audubon Society v. Lyons, 80 F. 3d 1401, 1404 (9th Cir. 1996)], the Ninth Circuit upheld Forest Service analysis and determination of viability saying, "the record demonstrates that the federal defendants considered the viability of plant and animal populations based on the current state of scientific knowledge. Because of the inherent flexibility of the NFMA, and because there is no showing that the federal defendants overlooked any relevant factors or made any clear errors of judgment, we conclude that their interpretation and application of the NFMA's viability regulation was reasonable." In a previous ruling in the Pacific Northwest, the Ninth Circuit had commented on the need for viability analysis (Seattle Audubon Society v. Moseley, 798 F. Supp. 1473, 1484, and 1494 (W.D. Wash 1992)), stating "The Forest Service argues that it should not be required to conduct a viability analysis as to every species. There is no such requirement. As in any administrative field, common sense and agency experience must be used." It added, "the court has repeatedly made clear that the agency is not required to make a study or develop standards and guidelines as to every species." In a ruling in Arkansas (Sierra Club v. Robertson, 784 F.Supp. 593 (W.D. Ark. 1991)), the court noted, "the agency's judgment in assessing issues requiring a high level of technical expertise, such as diversity, must therefore be accorded the considerable respect that matters within the agency's expertise deserve."

The NFMA regulations revised in November 2000 allow for the use of surrogate measures, including focal species and species groups, in the evaluation of viability. The use of surrogates is further described in section III of this paper. The regulations also establish expectations for levels of analysis in 36CFR 219.20: "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. 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."

RELATIONSHIP OF FOREST SERVICE VIABILITY EVALUATIONS TO POPULATION VIABILITY ANALYSIS (PVA)

Forest Service approaches to management for viable species have evolved at the same time as important advances were made in scientific applications of PVA (Beissinger and Westphal 1998; Boyce 1992; Emlen 1995; Lee and Rieman 1997; Menges 1991; Shaffer 1981; Shaffer and Samson 1985). While Forest Service approaches generally follow concepts described in the scientific literature, several key differences have emerged:

- Definitions of a viable population 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 NFMA 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 geographic distribution within which the species is projected to persist should be recognized explicitly in the evaluation.
- 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 evaluations.
- Discussions of PVA in the scientific literature generally refer to quantitative assessment of risk factors (Boyce 1992), with significant focus on demographic analyses (Beissinger and Westphal 1998; Menges 1991; Ralls et al. in press). Ralls et al. (in press) suggest that PVA be defined as "an analysis that uses data in an analytical or simulation model to calculate the risk of extinction or a closely related measure of population viability". However, Forest Service evaluations must frequently be done in support of management

decision-making when information is scarce and quantitative analysis is not feasible (Noon et al. 1999a; Rieman et al. 1993; Ruggiero et al. 1994). Such evaluations should nonetheless be structured as formal evaluations of available data and other information concerning a species (Boyce 1992; Noon et al. 1999a) with the objective of estimating the likelihood that it will persist into the future in a given distribution. Where information is weak, likelihood should not be considered as a statistical measure, but rather as an expression of the level of belief that viability will be maintained. These evaluations must be as credible and informative as possible, given the reality of scarce information, and may depend on techniques such as expert opinion panels and the application of general conservation principles.

To reflect the differences between Forest Service evaluations of viability and PVAs described in the scientific literature, we propose the term species viability evaluation (SVE) 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 (Ralls et al. in press).

III. Process for Incorporating Species Conservation and Viability into Forest Planning

This section describes a generalized process for addressing species viability in Forest Plans. It includes eight steps: 1) description of the ecological context, 2) identification of species-at-risk, 3) collection of information on species-at-risk, 4) identification of species group and focal species, 5) description of conservation approaches, 6) development of Forest Plan alternatives, 7) evaluation of effects on viability of the Forest Plan alternatives, and 8) monitoring. These steps are necessary to appropriately focus existing science on the issue of species conservation while complying with the provisions of both NFMA and the National Environmental Policy Act (NEPA). This should not be seen as a stand-alone process for addressing viability. Rather, the steps should be fully integrated into the overall Forest Planning process.

When possible, approaches to species viability for 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. 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 approach outlined in this paper. If any larger-scale assessments are available, they should be fully incorporated in the process. The importance of tiering analyses from one scale to another should be recognized. Larger-scale assessments provide the capability to deal with population level processes (dispersal, migration) for broadly-distributed species, but may have to employ crude estimates of habitat and other ecological conditions. Smaller-scale assessments, tiered to the larger-scale, provide the capability to deal with more detailed information on habitat and species occurrence.

In addition to coordination across administrative boundaries within the Forest Service, it is key to coordinate with other agencies, and to involve the scientific community and others who hold ecological knowledge (within the constraints of the Federal Advisory Committee Act). Coordination should include other federal land management agencies, federal regulatory agencies, American Indian tribes, state wildlife agencies and natural heritage programs. The scientific community, including Forest Service Research, university scientists, industry scientists, other agency scientists, and scientists from non-governmental organizations should be involved as fully as possible in all steps in the process in order to gain the benefit of scientific input and review.

Major components of each of the steps proposed for addressing viability are described below.

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 constraints of ecosystem dynamics (Dale et al. 2000, 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 (King 1997).

The ecological context for species management 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 regulations specify 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" (36CFR219.5(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.

Although ecosystems can be complex, Holling (1992) has postulated that each ecosystem is governed by small sets of processes that operate at particular spatial and temporal scales. At a spatial scale of tens to hundreds of miles and a temporal scale of decades to centuries, the structuring processes tend to be disturbance events such as fire and insect outbreaks. At larger spatial and temporal scales, geomorphological processes are the dominant structuring forces (Holling 1992). Thus, the key to describing ecological context in a simplified but meaningful way is to focus on the dominant processes that structure the ecosystem and to describe the relationship between these processes and the selected species (Risser 1995).

Research studies of disturbance-maintained systems indicate substantial variability in the frequency, intensity, and spatial pattern of most major disturbance processes. In fact, it appears that variability in these attributes is needed to maintain biodiversity, because some species may require a longer disturbance interval or lower intensity disturbance than the average found within the system in order to persist (Clark 1996). Thus, a description of the ecological context should also include the expected variability. The ecological insights developed from historical ecology (Swetnam et al. 1999) play an important role in understanding variability. An historical reconstruction of past ecological structure and disturbance regimes (e.g., assessment of historical range of variation) "informs us about what is possible within the context of certain locations and times, and places current conditions into this context" (Swetnam et al. 1999:1201). This knowledge provides insights into the potential causes of change and the ecological pathways that brought ecosystems to their current condition. Maybe more important, historical analysis can suggest whether current conditions are anomalous and provide an understanding of the frequency, intensity, and interaction among dominant disturbance processes that influence the ecosystems we manage.

Knowledge gained through assessments of historical range of variability does not provide a target condition, but an understanding of past variation in pattern and disturbance processes that can provide a basis for predicting future variability (Swetnam et al. 1999). It may not be appropriate or possible to recreate the historical range of variability due to long-term changes in land use patterns and climate (Landres et al. 1999). For example, historical conditions based on a "presettlement" period likely extend into the warmer climatic period known as the Little Ice Age that occurred from roughly AD 1400-1900 (Millar and Woolfenden 1999). Recognizing the limitations of applying historical assessments, the NFMA planning regulations specify that an assessment be done of the range of variability that would be expected under the current climatic regime (36CFR219.20(a)). The regulations require that this assessment address, at a minimum, major vegetation types, water resources, soil resources, air resources, and focal species that are selected to provide insights to the larger ecological system. Focal species could include keystones (e.g., beaver), ecological indicators (e.g., aquatic macro-invertebrates), and indicators of ecological processes (e.g., aspen and other fire dependent species). In addition to assessment of these characteristics of the system, the regulations direct that there be assessment of the principle ecological processes that have shaped the ecosystem during the current climatic period including the distribution, intensity, frequency, and magnitude of those processes. The regulations generally require that areas be managed to maintain them or move them towards a state where ecological conditions fall within the range of variability that would be expected under the current climatic regime. However, they permit areas to be managed outside of the expected range of variability when it is not practical to restore ecological conditions within this range, or when doing so would result in conditions that are ecologically, socially or economically unacceptable (36CFR219.20(b)).

An understanding of ecosystem processes can serve not only as ecological context, but can also suggest a system-based strategy for maintaining appropriate ecological conditions that contribute to viability of species (Bisson et al. 1997; Hunter et al. 1989). Many species are at risk due to changes in ecological processes that have affected vegetation composition and structure and altered species interactions (Knopf and Samson 1997; Wilcove 1999). In the Columbia Basin, Wisdom et al. (2000) assessed change from historical to current times in availability of habitat for selected vertebrate species. They concluded that habitat had declined significantly for species-at-risk, and that the greatest declines had occurred in fire-maintained, late-seral ponderosa pine forests. Saab and Dudley (1998) projected effects on cavity-nesting birds in ponderosa pine forests based on changes in fire regimes from historical conditions. Management strategies that are based on such information and provide for maintenance of ecosystem conditions and ecological processes within the expected range of variability contribute to maintaining viability of species.

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 plant and animal 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. Overall ecosystem management direction likely provides appropriate conditions for maintenance of these species. 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.” 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 in the future under provisions of possible Forest Plan alternatives. 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 with species experts to determine 1) if any species on the list is clearly secure within the planning area and therefore does not require further formal consideration and 2) if there are additional species not on the list that are locally at risk and which should be considered in detail in the plan. Risk classification systems, such as that developed by the International Union for the Conservation of Nature (IUCN) (Hilton-Taylor 2000; Mace and Collar 1995; Mace and Lande 1991), may be useful in developing the final list of species-at-risk. Note that many species, especially plants, are intrinsically rare and, where their populations are demonstrably secure despite their rarity, may not need explicit conservation attention. Use of the classifications for plants is also complicated by the diversity of breeding systems present in plant species. The number and distribution of populations that contribute to viability on a landscape level is highly dependent on the breeding system (Huenneke 1991). The reviews that determine the final list of species-at-risk should be carefully documented.

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 trends
- Abundance, including trends
- Demographic characteristics
- Population trend
- Diversity – phenotypic, genetic, and ecological
- Habitat requirements at appropriate spatial scales

- Habitat amount, distribution and trends
- Other life history traits, including reproductive system, dispersal mode and capability, and seasonal movement patterns
- Ecological function
- Key biological interactions
- Limiting factors/Risk factors

Reviews of factors that can influence viability are found in Allendorf et al. 1997; Emlen 1995, Gilpin and Soule (1986); Holthausen et al. (1999); Lee and Rieman 1997; Marcot (1994), Menges (1991); and Noon et al. (1999a).

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.

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, where species-at-risk number in the hundreds, it will be infeasible to consider all of them in detail in the planning process. In these cases, credible processes may be used to identify a 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. 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.

Grouping by degree of risk

Species can be ranked by their risk to extinction using a combination of internationally and. nationally accepted ranking systems, each designed to assess extinction 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 the entire range of a species at a global scale, but these ranks can also help guide national and regional evaluations. Nationally, the federal standard for ranking species by degree of risk was set by the Endangered Species Act of 1973 (P.L. 94-359) that established two categories: Endangered and Threatened. In addition to the ESA risk categories, The Nature Conservancy 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; Master 1991). The Nature Conservancy 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 USFWS assessment for that species (Groves et al. 2000; Stein et al. 2000). An example of grouping species by risk levels is found in the Northern Great Plains Science Assessment (Samson et al. 1999), where all species selected for the viability assessment were placed into three categories of decreasing imperilment. The first category included federally listed species, the second included candidates for federal listing and a combination of global and state ranks assigned by the Nature Conservancy, and the third category included species considered to be at risk by two or more federal, state, provincial, or other organizations.

The most obvious advantage in grouping species by risk level is the potential to focus attention and resources on species in most immediate need of management attention (Mace and Lande 1991). In the context of conducting effects analysis, grouping by degree of risk provides a framework to focus effects analysis on those species for which management actions may result in the most significant consequences -- a significant trend toward extinction or a trend toward recovery. However, grouping by degree of risk fails to reduce the task of conducting effects analysis aside from prioritizing analysis efforts. Species in high-risk categories are not likely to have strong ecological similarities, and examining the effects of management on one species is unlikely to provide strong insights into the specific effects on other species in the same risk category. Therefore, grouping species by degree of risk alone is unlikely to represent a sufficient grouping strategy to facilitate the process of evaluating management alternatives.

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, changes in ecological processes, 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 (Caughley 1994; Caughley and Sinclair 1994; Diamond 1989; Pimm et al. 1988; Wilcove et al. 1998). 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.

The categories of risk factors can be used to organize an effects analysis, and to propose particular management alternatives that directly alter the perceived threat. As such, risk factor groupings can provide a framework for the efficient development of effective mitigation measures. Presumably, many species in a risk category would respond to the perceived risk in a similar way, facilitating the evaluation of effects. However, this assumption will not be universal and some species placed in a common category by risk factor will respond in divergent ways.

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. Five ways to group species ecologically are discussed here: 1) habitat associations; 2) guilds; 3) ecological function; 4) body size/home range size; and, 5) 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 made 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) and the Northern Great Plains Assessment (Samson et al. 1999).

Guilds

Guilds are groups of species that share one or more life history characteristics. MacArthur and MacArthur (1961) classified groups of forest birds by the canopy characteristics occupied by each species. Root (1967) coined the term “guild” to identify groups of species with similar feeding ecology. A major criticism of the guild concept is that although guild members share life history characteristics, they may respond to environmental changes in distinctly different ways and therefore the guild cannot be used to predict how individual guild members may respond (Morrison et al. 1992, Marcot et al. 1994). Guilds may, however, provide a useful way to further subdivide groups based on habitat associations. An example is provided in Wall (1999).

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. Note that the objective here becomes the maintenance of functionality of groups, and not necessarily the maintenance of conditions for individual species. Grouping by ecological function may be the best approach for taxa with many poorly known (or unknown) species, and resulting groups also serve to assess the functioning of important ecosystem processes. An example of grouping arthropods by ecological function is found in the Forest Ecosystem Management Assessment Team report (Thomas et al. 1993b).

Body size and home range size
A number of ecologists have shown a relationship between body size or weight and home range size (McNab 1963, Harestad and Bunnell 1979, Holling 1992). This relationship may be useful for evaluating how species perceive habitats at different spatial scales. Body size/home range size can be used in conjunction with habitat associations to provide further refinement of groups using similar habitats but at different scales. An application of these combined approaches was used in Ontario to select indicator species for habitat types and structural stages at three spatial scales (McLaren et al. 1998).

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 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).

<u>Identification of focal species</u>
It may be helpful to select individual focal species that would represent the needs of the groups of species-at-risk identified in the previous steps. Regulations implementing the National Forest Management Act suggest that focal species may be used in developing management strategies, evaluating 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). A 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 the process presented here is to select focal species that best represent the composite ecological requirements of species-at-risk.

- First, identify species groups associated with specific forest types and structures (e.g., late-successional, single-story ponderosa pine) or analogous groups associated with grasslands, shrub lands, or aquatic systems. Processes such as hierarchical cluster analysis will be of assistance in developing appropriate habitat-based groups (Wisdom et al. 2000).

- For each of the species in the group, array the following additional information:
    - Fine-scale habitats used (e.g., snags)
    - Home range and dispersal capability
    - Additional ecological requirements (e.g., lack of human disturbance)
    - Range
- Based on this information, select one or more species that best represent the full array of ecological requirements for all species in each of the habitat-based groups. 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, within that same habitat group, 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 and diverse set of focal species may be needed to provide insight into 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. Focal species may also be used as system indicators (e.g., keystones and other indicators of ecological processes) rather than as representatives of species-at-risk. This use of focal species was discussed in the section on ecological context. Finally, focal species may also be identified to represent the ecological requirements of species that are not identified as being at risk. Such focal species could be used in the design of overall ecosystem management strategies, and in the demonstration that appropriate ecological conditions are being provided for all species.

DEVELOP CONSERVATION APPROACHES

Once species-at-risk, species groups, and focal species are identified, approaches to their conservation should be developed (Noss and Cooperrider 1994). For species-at-risk, conservation approaches should focus on the key risk factors, and provide options (where available) to change those conditions in order to maintain the viability of that species (or group of species) (Hilderbrand and Kershner 2000; Lee et al. 1997; Wisdom et al. 2000). Conservation approaches should be designed to mitigate or eliminate both short-term and long-term risks to species. Existing conservation strategies and agreements may be sources for conservation approaches. At this stage in the process, conservation approaches are not management direction. When alternatives are developed, the conservation approaches should serve as the basis for forestwide standards and guidelines and management area direction. The alternatives assessed in the Forest Planning process may differ in the way that they incorporate the conservation approaches. Conservation approaches only become management direction after a record of decision is issued for a Forest Plan.

To the extent possible, conservation approaches should take into account the needs of a species 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. Under some circumstances, it also may be legitimate to use various approaches in order to test their effectiveness. 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 appropriate levels of consistency, approaches are best developed at the ecoregional or bioregional scale. Ecologists and species experts within the scientific community should be involved in the formulation or review of conservation approaches. The development of conservation approaches can be made more manageable by grouping species as described in the previous step, and/or by the use of focal species.

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 (Hunter 1990). That is, some part of the overall conditions required by species may be provided through overall ecosystem management direction, while other conditions may require species-specific direction. Understanding the ecological context for species-at-risk provides information needed to design overall ecosystem management direction that will contribute to viability. Severe modification of ecosystem processes and patterns places many species-at-risk. The development of conservation approaches should begin with this understanding of the ecosystem conditions that have placed species-at-risk, and should initially emphasize broad approaches for management of ecosystems that are designed to restore those processes and patterns. Such approaches 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 will usually be necessary to consider several of these strategies when species conservation approaches are being developed. It will be most helpful 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. Species-specific direction for such features, or for other non-habitat factors, should be developed to supplement broad-scale management as necessary. 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. It should be emphasized that species-specific direction should generally be compatible with overall ecosystem management direction. For example, a focus on seeps and bogs may be key to providing appropriate conditions for some wetland species. But, maintenance of those features is also dependent on overall direction for maintaining soil and hydrologic conditions.

Conservation approaches should address all levels of biological organization appropriate to the species. This may include demes, local populations, metapopulations, and the entire species (Rieman and McIntyre 1993; Wiens 1996). At the deme or local population scale, the emphasis should be on maintaining conditions to support collections of individuals and population function. At the scale of a metapopulation (or other spatially-structured collection of populations), the emphasis should be on maintaining populations and interactions among them. At the scale of the entire species range, the emphasis should be on maintenance of the geographic extent of the species through appropriate population and metapopulation function. Conservation of populations on the periphery of a species range should have the same priority as conservation of core populations (Channell and Lomolino 2000; Lesica and Allendorf 1995).

Menges (1991) notes the importance of multiple scales of biological organization in maintaining overall viability of plant species. An excellent review of the importance of metapopulation structure to the maintenance of viability is provided by Gilpin (1987), and is also summarized by Rieman and McIntyre (1993) and Rohlf (1991). The existence of many populations is especially critical for plant species that inhabit patches in a shifting mosaic of habitats. Multiple populations also serve as a source of colonists and thus as a hedge against environmental stochasticity. And, metapopulation dynamics are likely to become increasingly important as habitat areas become fragmented. Thus, the maintenance of metapopulation structure will be more likely to allow the species to withstand adverse land management effects (as well as future stochastic habitat changes). The maintenance of this "distribution viability" should also serve as a good surrogate for maintaining less easily observed features that also affect the viability of plant species, such as genetic variation patterns, pollinator relationships, seed dispersal patterns, and gene flow within and among populations. An example of a metapopulation framework for addressing viability of a plant species is provided in the species management guidelines for western prairie fringed orchids (Platanthera praeclara) on the Sheyenne National Grassland (USDA Forest Service 1999).

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 maintaining 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.

Alternatives may differ in both the overall ecosystem management direction that is applied, and the species-specific direction that is incorporated. Note that differences in overall ecosystem management direction may result in different sets of species needs that must be addressed through species-specific direction. To facilitate the process of alternative development, it may be helpful to clearly describe the elements of habitat that must be considered for each species, and then array the conservation approaches from higher to lower likelihood of successfully providing for each element.

ASSESS EFFECTS OF ALTERNATIVES

This may be the most difficult step in addressing species viability in Forest Plans. In most situations, we lack much of the basic information needed to assess effects on species viability. However, NEPA and NFMA require that effects on species viability be disclosed. The framework within which the evaluation is done is also critical. Guidelines for the framework of the Species Viability Evaluation follow:

- Evaluation of effects should be framed as a risk and uncertainty assessment (Cleaves 1994), rather than a simplistic determination of viable/not viable.
- The evaluation must include assessment of both short-term and long-term risks. The timeframe over which long-term risks are projected should be determined based both on biology of the species (e.g., generation time, response time to changed conditions, recolonization capability) and on the time needed for the overall ecosystem to respond to proposed management. Assessment over such a timeframe is important to a full understanding of the long-term effects of management on ecosystems and species, but it must be understood that confidence in the accuracy of projections decreases rapidly as the timeframe of projections increases.
- The spatial scale of the evaluation should reflect the scale at which biological populations of the species operate (Ruggiero et al. 1994). Addressing viability at the correct spatial scale may require the use of broad-scale assessments as described in the revised NFMA regulations (36CFR219.5).
- In addition to the projected future, the analysis should also address the current condition and, where possible, the historical condition of the species.
- The evaluation must consider both conditions that will be provided on National Forests, and cumulative effects of all land ownerships and of actions outside of National Forests.
- The obligation under the NFMA regulations is to provide for ecological conditions on National Forests that would allow for the species continued existence, well-distributed in the plan area. The plan area is defined as National Forest lands. Thus, the evaluation must include an assessment of the likelihood that appropriate conditions for the species are to be provided on National Forest lands, even if conditions outside of National Forests place the species-at-risk and threaten population processes of the species.
- For most species, the only practical quantitative analysis is assessment of habitat conditions. It is, however, essential that we make a connection from habitat conditions to population consequences, even if this connection can only be established through ecological inference.
- The assessment of conditions that are “well-distributed” must be based on the species natural history and historical distribution, the potential distribution of its habitat, and recognition that habitat and population distribution is likely to be dynamic over time.
- Basic requirements for the evaluation are that it be logical, consistent, consider all relevant information, and disclose both risks and levels of uncertainty. It is important to document all sources of uncertainty, including uncertainty due to environmental stochasticity.

- Peer review of assessments contributes to their rigor and credibility.

Viability evaluations may actually be used at several points in the Forest planning process. An initial evaluation may set the stage for the development of conservation approaches. Such an evaluation would help identify the key risk factors to be addressed through conservation actions. Evaluations may also be used iteratively in the development of alternatives. Here, the evaluations would help determine what suites of conservation approaches would provide for varying levels of risk to viability. Finally, evaluations must be completed for the final set of alternatives brought forward in a Forest Plan effort. Also, the processes of identifying conservation approaches, developing alternatives, and evaluating viability may be iterative. The results of viability evaluations may suggest the need for a refined set of alternatives that would then require additional evaluation. The need for such iteration should be taken into account when timelines for planning are established.

Techniques for evaluating viability

In most situations, the information needed to complete a truly quantitative population viability analysis (PVA) is lacking (Lee and Rieman 1997; Noon et al. 1999a; Ruggiero et al. 1994). Even where substantial information is available, analysis can be complicated by year-to-year variability in species population size and demographics (Beissinger and Westphal 1998), especially in migratory species or plants that have long-lived seed banks. An additional complication for analysis of viability of Forest Plan alternatives is the need to make future projections of the implications of management. Current conditions of habitat, and species response to habitat, will likely be altered by proposed management. Predicting species response to those altered conditions requires knowledge of the relationship of species population dynamics to varying habitat conditions. Such information is only rarely available.

Despite these complications, a variety of techniques have been successfully used to evaluate viability within the context of the NFMA regulations. These range from simple qualitative evaluations to complex simulation models that require demographic information. Evaluation techniques are discussed below in three major classes: evaluations relying only on habitat information, evaluations based on current population status and characteristics, and evaluations combining habitat and population information. In practice, many evaluations combine two or more of the techniques discussed below. When it is feasible to conduct several different types of evaluations of a species, the combined results of those evaluations may provide greater insights than would be gained from a single evaluation.

Evaluations relying only on habitat information

In the face of missing information, one alternative is to use inventories and projections of the amount and distribution of suitable habitat as a surrogate for species viability evaluation. This method relies on three primary assumptions: (1) that attributes of suitable habitat are known well enough to identify areas that meet the life requisites of the species; (2) that the amount, condition or quality of suitable habitat is correlated with fitness (Gawler et al. 1987; Van Horne 1983; Wilcove et al. 1998); and (3) that habitat is limiting so that changes in amount of suitable habitat are correlated with changes in population status. Viability assessments based on habitat inventories and projections are useful to the degree that these assumptions are met, but testing the assumptions may not be possible. After all, if data were available to test fully the assumptions, one could proceed with more sophisticated assessment procedures.

Evaluation relying solely on habitat has a major shortcoming: actual populations, including their current status and dynamics, are not explicitly considered. Such an evaluation may be useful to demonstrate broadly that a species status is likely to decline, improve, or remain unchanged. However, habitat evaluation as a stand alone technique should not be relied upon to make critical determinations in high-risk situations. Habitat modeling can be combined with other techniques, such as expert panels or demographic assessments, to provide a more rigorous analysis.

Evaluations based on population status and characteristics

Demographic characteristics. The most powerful information on current population status is derived from estimates of vital rates. Such vital rate information may be derived from capture-recapture (Pollock et al. 1990) or other demographic studies and can include estimates of age-specific survival and fecundity, immigration, emigration and trends over time in these parameters (Lebreton et al. 1992). This information can be used to estimate overall rates of population increase or decrease (Caswell 1989; McDonald and Caswell 1993; Morris et al. 1999; Rieman and McIntyre 1993; Silvertown et al. 1993).

Although demographic information can be compelling, its limitations must also be recognized. First among these is the expense of collecting the data and the need to collect data over a period of years to allow the analysis of trends and to estimate variance in vital rates. Because of the expense of data collection, it is unlikely that reliable demographic data will ever be collected for many species. The second limitation is the need to restrict interpretations of demographic data to both the geographic area and the time period within which the data were collected. Demographic characteristics can be used to project future population status only if an assumption is made that rates either remain constant over that future time, or change in some specified way. The final limitation on the use of demographic data is the potential for bias in the estimates of survival and reproductive rates and of the overall rate of population increase (Caswell 1989; Raphael et al. 1996). Knowledge of these potential biases should be used to temper conclusions drawn from demographic analyses.

Population trend based on census and presence/absence data. Population count data and presence/absence data can be used to estimate population trend over time. An excellent summary of literature on this subject and techniques for conducting these analyses was recently published by the Nature Conservancy (Morris et al. 1999). Such an analysis is subject to some of the same limitations as is analysis of demographic rate information. Morris et al. (1999) recommend that a minimum of seven years of data be used in estimating population trend. As with the use of demographic rates to estimate population trend, the resulting trend is specific to the time period and geographic area within which the data were collected, and projections of future population status can be made only under an assumption that trends either remain constant or change in some specified way. Estimates of trend based on census and presence/absence data may be very useful measures of the relative health of two or more populations and thus provide useful information for making decisions concerning those populations (Morris et al. 1999).

Genetic considerations. Knowledge of genetic variation ought to contribute to PVA. For example, isolation of populations can result in restriction of gene flow and loss of genetic variation with increased risk of inbreeding depression and genetic drift, which may increase risk of extinction (Nelson and Soule 1987; Barrett and Kohn 1991; Frankel and Soulé 1981). We do not know, however, how much and what type of genetic variation is most important to preserve (Landweber and Dobson 1999), and efforts to date to incorporate genetics in PVAs completed for land-management decisions have not been fruitful.

Evaluations combining habitat and population information

Expert opinion assessments. Because quantitative PVAs have important shortcomings (Beissinger and Westphal 1998), and the data needed to conduct them are scarce, management decisions have often depended on information provided by qualitative assessments. Although these assessments have been criticized for lack of scientific rigor (Boyce 1992; Ruggiero and McKelvey 2000), they often carry significant weight in management decision-making. Because we lack quantitative information on many species, expert opinion is likely to be a frequently used technique. Therefore, it is important to discuss ways that such assessments can be made as credible and informative as possible given the reality of scarce information.

Expert opinion, gathered from panels of experts in a carefully structured process, has been used in several large-scale viability assessments (Lehmkuhl et al. 1997; Shaw 1999; Thomas et al. 1993a;Thomas et al. 1993b). Guidelines for the use of such panels have been described by Cleaves (1994). Among the points emphasized by Cleaves were 1) the value of careful definition of the viability outcome scale used in the expert judgment process; 2) the need for careful management of the assessment process to minimize bias (task, motivational, and cognitive); 3) the importance of separating the assessment process from the determination of "acceptable" risk; and 4) the need to fully explain the assessment to decision-makers so that it is not misinterpreted during the process of option selection.

Several additional practices may improve the credibility and utility of expert judgments. First, breaking the judgment into component parts has several advantages. Experts are likely to have a clearer understanding of individual components; reviewers can better understand the basis for judgments; and individual components are more easily tested through later monitoring efforts. Second, requiring experts to provide documentation that supports their judgment would improve credibility of the judgment and understanding of the basis for it. Third, combining expert opinion with other techniques should improve the quality of judgments. For example, if thorough demographic and habitat analyses are used as input to expert judgment processes, the quality of the resulting judgments is likely to be high. Finally, monitoring designed to validate judgments would greatly improve credibility, and the ability to improve judgments over time. As emphasized by Ruggiero and McKelvey (2000), the collection of new information to fill knowledge gaps is critical in situations where the scarcity of information necessitated the use of expert opinion as an evaluation technique.

The use of expert opinion assessment may also help solve another dilemma--deciding which species should be the subject of PVA. An initial assessment, addressing the broadest possible array of taxa, could be used to determine those species for which more detailed analysis is appropriate. Species whose habitats and populations were considered secure in the expert opinion assessment would require little additional attention, allowing the use of more time and resources to deal with those species for which experts expressed higher levels of risk to viability. This would be particularly helpful in large-scale assessments for areas where there has been no thorough review of the status of a broad array of species.

Incidence functions. Incidence functions may be a useful technique for assessing viability of species whose habitat requirements are well known and for which habitat is patchily distributed across the landscape. Incidence functions are based on the tendency for occupancy of habitat patches to increase with size of the patch and proximity to other patches, and to decrease as patch size declines and/or isolation of patches decreases. Incidence functions can be estimated from data on the presence/absence of a species in habitat patches of varying size and isolation (Herkert 1994). Where such functions are available, they can then be used to estimate the likelihood of occupancy of single or multiple patches over time (Hanski 1994). An implicit assumption in this approach is that occupancy rates of patches of a given size will remain constant over time. This assumption may not be valid in landscapes that undergo significant change.

Bayesian belief networks. Bayesian belief networks (BBNs) are a form of influence diagram (Oliver and Smith 1990) that can be used to depict the causal relationships among factors that influence the outcome of some parameter of interest. BBNs have been applied to a variety of problems in ecology and forest management (Haas 1991; Haas et al. 1994; Lee and Rieman 1997; Olson et al. 1990). BBNs have several characteristics that make them useful in assessing species viability (Marcot et al. In press): 1) they require the user to clearly display the factors that are major influences on species viability, and interactions among those factors; 2) they combine categorical and continuous variables; 3) they allow the combination of empirical data with expert judgment (Heckerman et al. 1994); 4) they express predicted outcomes as likelihoods; and 5) they can be used to structure a monitoring program in a way that compares the likelihood of competing hypotheses and continually updates models based on new information. While BBNs frequently make use of expert opinion, they have several advantages over expert opinion assessments as described above. First, they make the use of expert opinion explicit so that reviewers and critics can understand the underlying basis for judgments. Second, by combining expert opinion with empirical data, and structuring them into models, they provide for repeatability of assessments. This is especially useful for iterative analysis of possible management alternatives. Examples of BBN models being used to test the effects of management alternatives on wildlife and fish species can be found in Raphael et al. (In press) and Rieman et al. (In press).

Simulation models. As noted above, demographic information must be linked to habitat information to produce an analysis that is useful for projecting viability into the future under a Forest Plan. One way to make this link is through the use of simulation models (Akçakaya et al. 1995; Holthausen et al. 1995; Lefkovitch 1965; Raphael et al. 1994). The simulation models that are most germane to management questions are those that link population attributes (size, birth, and death rates) to habitat conditions, and thus base future population performance on projected future habitat conditions (e.g., Akçakaya 1992, McKelvey et al. 1993).

Simulation models using the relationship of demographic performance to habitat can yield a number of different measures of risk, defined as the likelihood of population extinction by some specified time under various management scenarios. Such measures include quasi-extinction probabilities (chance of a population decline below a specified level), time to extinction, and likelihood of extinction within a fixed time. Spatially-explicit models can be used to estimate the likelihood of maintaining the distribution of species across a landscape. In virtually all cases, there will not be full knowledge of the relationships of demographic rates to habitat. In these cases, simulation models can be used to test sensitivity of model results to various assumptions about the relationships of demographics and habitat (Holthausen et al. 1995).

Although simulation models can be very useful, and may be one of the only methods to evaluate population response to large-scale land management actions, users must understand the limitations of the models and the effort necessary to build and test them. Results are dependent on the structure of the model, the assumptions used to parameterize the model, and the input data (including the representation of the land management action being evaluated) (Beissinger and Westphal 1998). Despite these cautions, Brook et al. (2000) found PVA predictions to be surprisingly accurate in a retrospective test that used five of the most commonly available PVA software packages. Brook at al. (2000) noted that these findings did not necessarily apply to plants. A summary of the challenges and approaches specific to plant population viability modeling is provided by Menges (2000).

<u>Use of species viability evaluations in decision-making</u>

Determination of whether alternatives meet the NFMA standard of “high likelihood” is made through the decision-making processes. This determination should be based on all information that is brought forward in the Species Viability Evaluation. Determinations that integrate the results from multiple techniques are generally more robust than those dependent on a single technique. The determination may apply to a single Forest or to a group of Forests that are included within the same planning effort, and should take into account the historical, current, and projected future conditions for a species. It should tier to any determinations or assessments made at broader scales. The determination 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. Uncertainty associated with the determination should be explicitly recognized, and adaptive management measures that will be employed to deal with uncertainty over time should be described.

MONITORING

There is significant uncertainty involved in the processes of managing for and evaluating species viability (Beissinger and Westphal 1998; Raphael and Marcot 1994; Ruggiero et al. 1994). This uncertainty is due both to simple lack of knowledge, and to unpredictability of ecological systems. Because of these high levels of uncertainty, it is critical to implement an effective monitoring and adaptive management program.

The revised planning regulations require monitoring and evaluation of focal species and species-at-risk (36CFR219.11). The primary emphasis is on monitoring the status and trends of ecological conditions known or suspected to support these species. Actual population monitoring is appropriate for some species, especially where risk to viability is high and population characteristics cannot be reliably inferred from ecological conditions. The overall intent of monitoring related to viability is to focus on those areas of uncertainty for which new information could prompt important changes in management.

The most useful monitoring information provides insights into relations between management actions and selected species or their habitats (Noon et al. 1999b). However, collecting information on cause and effect is often impractical due to our lack of knowledge about a species, the difficulty in monitoring it, its rarity, or the long lag time between activities and biological responses (Montgomery 1995). Therefore, the establishment of monitoring objectives for species-at-risk must take into account the state of current knowledge about the species, its rarity, detectability, level of risk, the strength of association between habitat conditions and population dynamics, and the expected lag time between disturbances and biological responses. For poorly known species the primary objective may simply be to determine its status in the plan area (does it occur, and if so, in what habitats). For very rare species, the primary objective may be to detect change in status over time. For many species, however, it is possible to monitor change in habitat and to explore causal relations by simultaneously monitoring stressors (Noon et al. 1999b) or effectors (USDA Forest Service 2000) that influence habitat condition. For a few species, causal relations between population dynamics and stressors or effectors can be explored. Specific considerations for monitoring plant species are discussed in Elzinga et al. (1998).

A primary requirement of successful monitoring is selecting the right indicators (Noss and Cooperrider 1994, Noon et al. 1999b). It may not be necessary to monitor a host of habitat attributes or population parameters. Much can be gained by monitoring one or two carefully chosen indicators that are fairly easy to measure or observe, particularly if these indicators are responsive to changes in stressors that are monitored over the same period of time (Ziemer 1998, Noon et al. 1999b).

The following are monitoring objectives related to species viability. For each objective, there is discussion of species characteristics that would lead to that choice of monitoring objective, and suggested categories of indicators are given. The first three objectives are aimed at determining status and change of ecological conditions or selected species characteristics, whereas the last two objectives explore causal relationships. One or more of these objectives would apply to each species being monitored.

- <u>Determine whether ecological conditions for selected species are consistent with plan direction.</u> The primary indicators to be monitored are the abundance, spatial distribution, and quality of habitat. Monitoring of ecological conditions will be most meaningful for species whose population dynamics are believed to be responsive to changes in ecological conditions. Monitoring of ecological conditions is less useful when there is a poor correlation between ecological conditions and population dynamics, particularly when habitat is abundant but the species is more restricted. This is often true for rare plants, and consequently it is necessary to monitor their abundance or spatial distribution rather than ecological conditions. Also, monitoring of ecological conditions is not particularly meaningful for species with poorly understood environmental requirements.

- <u>Determine whether the status of selected species is in keeping with plan direction.</u> The primary indicators of species' status are abundance, spatial distribution, and/or demographic characteristics such as age-specific survival or reproductive output. Direct monitoring of status may be most appropriate for species with the following characteristics:

- Federally listed species for which recovery plans specify population monitoring
- Federally listed species without recovery plans, but for which population monitoring is considered important
- Species for which population changes are not strongly linked to habitat and therefore population information is needed
- Species for which identified changes in abundance, spatial distribution, or any demographic parameter would trigger a review of management

The last category includes species with low numbers that must be closely monitored to determine whether a management activity must be altered, or if direct intervention is necessary (population augmentation, reintroduction). This category also includes species that may be abundant, but whose populations appear to respond to management activities. Monitoring of these species may serve as an indicator of change in ecological conditions for a larger functional group of species (Committee of Scientists 1999). This category could include species besides those considered to be at risk; for example, populations of exotic or pest species could be monitored if changes in their populations would trigger a review of management.

- <u>Determine whether there are unexpected changes in habitats or populations for species that were not identified to be of concern during the planning process.</u> One area of uncertainty is whether or not all species that ought to be of concern were identified in the planning process. Ecological modeling suggests that some common, competitively dominant species may be at risk from even moderate habitat loss in patchy landscapes (Kareiva and Wennergren 1995; Tilman et al. 1994). Addressing this area of uncertainty requires implementation of a broad based monitoring effort that extends beyond the species-at-risk identified in the Forest Plan. Monitoring the presence/absence of a suite of species using a grid sampling design may be an effective way to accomplish this objective (USDA Forest Service 2000). A grid design with a starting point that varies randomly from year to year may reduce problems associated with impacts to permanent plots (Guerrant 1998).

- <u>Investigate assumptions made about effects of management on ecological conditions for species-at-risk.</u> A forest can explore causal relationships between management actions and ecological conditions by monitoring selected indicators on replicated management treatments and untreated control areas (Walters and Holling 1990). Such monitoring will be most useful for species for which habitat relationships are fairly clear, but the effects of management on habitat are uncertain. For example, the need for snags to support cavity-dependent species is well established, but whether a certain vegetation treatment is achieving the desired snag density over time may be unknown and therefore worth monitoring.

- <u>Investigate assumptions about the effects of management on species populations.</u> This objective requires the greatest effort to achieve, is only realistic to attain for a few species, and is best accomplished in cooperation with the research community. Primary indicators are the abundance, spatial distribution, and/or demographic characteristics of a species. Targeted species should be those for which the link between management action and species' status is uncertain. For example, a forest may choose to monitor the abundance or simply the presence of a species in response to tree thinning if the direction and/or magnitude of the response are unknown. Other selected species might be those affected by human disturbance or non-habitat factors. As with the previous objective, a rigorous sampling design of replicated treatments and controls can be used for certain monitoring questions, but information can also be gained by examining correlations between the status of primary stressors and population levels over the same time period. In the thinning example, a forest might monitor species' abundance on several thinned and unthinned areas, or it might investigate a correlative relationship over time between total acres thinned and the abundance of the species.

Monitoring is not complete until the results are analyzed in the context of adaptive management. Examples of techniques that could be used to analyze population data are found in Thompson et al. (1998) and Morris et al. (1999). Monitoring data may also be used to increase understanding of species habitat relationships (Carroll et al. 1999).

The primary purpose of monitoring species-at-risk and their habitats is to determine whether management actions need to be modified. Threshold values of each indicator should be established that would trigger a review of management (Committee of Scientists 1999). For most indicators, a precise threshold value is not realistic, and it may be more meaningful to specify a range of expected values that reflects the dynamic nature of ecosystems (Noon et al. 1999b). For some indicators, the threshold may be expressed as a magnitude of change rather than a specific value or range of values. Regardless of the degree of precision, the process of establishing threshold values is a good check on the usefulness of the indicators: are they measurable, sensitive to change and able to provide the kind of information needed for adaptive management. In addition to triggering reviews of management practices, thresholds may also be used to trigger reviews of the monitoring program itself, focusing on the effectiveness and appropriateness of monitoring methodology. It may also be appropriate to review management in situations where objectives are being achieved, but monitoring reveals that there is little relationship between management actions and the accomplishment of objectives.

IV. Forest Plan Documentation

Considerations for species viability, including identification of species-at-risk, identification of risk factors, description of management approaches that contribute to their conservation, use of species groups and focal species, evaluation of the effects of alternatives, and description of proposed monitoring, must be fully incorporated into Forest Plans. Information on species and viability should appear in the following sections of the Forest Plan.

- Analysis of the Management Situation. The species-at-risk should be identified and discussed as part of the current management situation. This provides an opportunity to disclose the species that will need to be addressed in the planning process, basic habitat relationships and other environmental needs of those species, species status, threats to viability, relationship of species to ecosystem processes, and methods that were used to group species and identify focal species.

- Goals and Objectives. Maintaining species viability should be stated as a Forest Goal and also incorporated into the broader goals of ecosystem diversity and ecological sustainability. Objective statements should be based on identified conservation approaches and other species information.

- Forestwide Standards and Guidelines. Standards and guidelines provide an obvious opportunity to display specific language for providing appropriate ecological conditions for species-at-risk. Conservation approaches developed by a regional or bioregional viability team could provide consistency across forests in the wording of standards and guidelines for species-at-risk, where such consistency is warranted by ecological conditions and risk factors.

- Plan Alternatives. Maintaining species viability 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 maintaining viable populations, and the risks of species extirpations. Alternatives may differ in both the overall ecosystem management direction that is applied, and additional direction that is incorporated to provide for species needs.

- Management Area Direction. Provisions for species-at-risk should be included in the direction for specific management allocations.

- EIS: Affected Environment. The full list of species-at-risk should be included in the Affected Environment chapter of the EIS. The chapter should highlight some of the same features as the Analysis of the Management Situation, discussed above.

- EIS: Effects and Consequences. This section contains the Species Viability Evaluations. Effects specific to National Forests, and cumulative effects, must both be disclosed. Effects should be projected over an appropriately long period of time, address a meaningful portion of the species range, and be framed as a risk assessment rather than a simple determination of viable/not viable.

- Monitoring Plan. The monitoring section of the Forest Plan should display how species viability will be monitored, and feedback processes that will be used to improve management based on monitoring results.

VI. Summary

It is extremely important that considerations for species viability be incorporated throughout the Forest Planning process, rather than simply being a reactive analysis at the end of the process. This can be accomplished through setting an appropriate ecological context for the plan, identifying all species-at-risk, collection of information on those species and the ecosystems on which they depend, and construction of alternatives featuring an appropriate range of conservation measures. Evaluation of viability, which has been the primary focus of many former efforts, then becomes a check on how well the objective for viability has been met. Many options are available for conducting these evaluations, but the choice of technique for most species will be severely constrained by limited availability of data. As a consequence, high levels of uncertainty will be associated with findings about species viability. This necessitates substantial focus on the collection of information through monitoring programs, and on the potential need for frequent changes in management direction to respond to that new information.

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