8

Effectiveness of Alternative Management Strategies in Meeting Conservation Objectives

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This chapter evaluates how well various management strategies meet a variety of conservation objectives, summarizes their effectiveness in meeting objectives for rare or little-known (RLK) species, and proposes ways to combine strategies to meet overall conservation objectives. We address two broad categories of management strategies. *Species approaches* result in conservation actions focused on providing for individual species or groups of species with common needs or common ecological characteristics. Species approaches we consider here include those focused on managing for the viability of individual species, those that use surrogate species or groups of species, plus geographic approaches focused on species occurrences or ranges. *System approaches* focus conservation actions on providing for ecosystem composition, structure, or function. System approaches fall into two general categories: those that focus on managing to restore or maintain ecosystem composition and structure and those that focus on restoring or maintaining ecosystem function. These approaches are described in more detail in chapters 6 and 7. For this chapter, we analyzed approaches for which we could find studies or discussions illustrating how the approach might be used to meet either specific needs of a species or a group of species, or to meet more general biodiversity goals.

We evaluated each approach for relative effectiveness in meeting three general categories of conservation objectives: species diversity, genetic diversity, and ecosystem diversity (see chap. 2). *Species diversity* objectives included maintaining or restoring viable populations of (1) RLK species, (2) other species, and (3) other species in natural patterns of abundance and distribution. The objective of *genetic diversity* is to maintain or restore the natural genetic variation of species. *Ecosystem diversity* objectives included (1) providing for native ecosystem types and seral stages within their natural range of variation; (2) maintaining or restoring ecological processes such as disturbance regimes, trophic structures, nutrient cycling, and key functional roles of organisms; and (3) maintaining the capacity of landscapes to provide for resiliency of species in the face of long-term environmental change.

Our evaluation of the various approaches was complicated by a number of factors. Many of these approaches share some degree of overlap, making it difficult to place them in distinct categories. In some cases authors described and evaluated very similar approaches but gave them different names. In these situations, we discussed each author's work under the category where it seemed to fit best but also mentioned it under the category assigned to it by the author. In other papers, the management goals and evaluation criteria were unclear. For example, some papers described the use of a surrogate approach for developing a comprehensive ecosystem management strategy but did not clearly define the species goals for that strategy. Some focused on proximate rather than ultimate goals. For example, the likelihood that surrogate species measures would conserve other species was frequently shorthanded as "protection" of those other species and measured simply as the overlap of the surrogate's locations with locations of other species. This can be misleading because simple overlap with one or more locations of another species does not necessarily ensure adequate conservation measures for that species. We also found that different authors used different evaluation criteria for measuring the effectiveness of the same approaches. These complications were largely because the published research was intended to answer different questions than the ones that we were asking. As a consequence, we were often forced to make assumptions and interpretations beyond those given by the original authors.

We found that variations in the application of an approach could lead to different assessments of its utility. For example, a guild approach based on general species information from the literature might perform differently from one based on site-specific data. For some approaches, we were uncertain if the approach would be applied directly to RLK species or applied to other species with secondary inference to RLK species. For example, the focal species concept might be applied based on the needs of the rare species themselves. Alternatively, it might be applied to a broader array of species, in which case the evaluation becomes a determination of how well the conservation of that broader array of species provides for the rare species. In these cases, we described the assumptions that went into our evaluations.

We used four ranks to rate the effectiveness of each approach in meeting each of the conservation objectives (see table 8.1):

- A—likely to be effective. We assigned this rank for cases where a well-designed application of an approach would explicitly address the conservation objective in a way that would likely be effective in meeting it. For example, strategies that address the viability of individual species would likely be effective in providing for viability of those species.
- B—could be designed to be effective in some circumstances. We assigned this rating to approaches that would be effective in meeting a conservation objective when designed in a particular way but which might not be effective in other applications. For example, the biodiversity indicator approach would be effective in the conservation of rare species when applied directly to rare species and based on site-specific data. Other more generalized applications of this approach might not be effective in meeting this objective.
- C—effectiveness nearly completely dependent on other factors. We assigned this rating when the effectiveness of an approach would be more directly tied to circumstances rather than to the design of the approach itself. For example, the umbrella species approach, which focuses on species with large area requirements, could be effective in conserving rare species if there was significant co-occurrence between the selected umbrella and the rare species. In other circumstances, effectiveness would be low.
- D—unlikely to be effective. This rating was assigned where an

Table 8.1. *Relative effectiveness of various approaches in meeting species, genetic, and ecosystem diversity conservation objectives (see chap. 3)*

SPECIES OR SYSTEM OF APPROACH	CONSERVATION OBJECTIVE: SPECIES DIVERSITY — Maintain viable populations of: Rare and little-known species[1,2]	Other species	Natural patterns-abundance/distribution	GENETIC DIVERSITY: Maintain natural genetic variation[3]	ECOSYSTEM DIVERSITY — STRUCTURE: Maintain ecosystem types and seral stages within their RNV	PROCESSES: Disturbance regimes	Trophic structures	Nutrient cycling	Other processes	RESILIENCY: Maintain species in face of environmental change
Individual species population viability	A/D	C	C	B/C	C	C	C	C	C	C
Surrogate species										
Umbrella species	C	C	C	B/C	C	C	C	C	C	C
Focal species	B/C	B	B	B/C	B	B	B	B	B	B
Biodiversity indicator species	B/D	B	D	B/D	D	D	D	D	D	D
Flagship species	C	C	D	B/D	C	C	C	C	C	C
Guilds	D	C	C	C/C	D	D	D	D	D	D
Habitat assemblages	C	C	C	D/D	D	D	D	D	D	D
Geographically based approaches										
Locations of target species	B/C	C	C	B/C	D	D	D	D	D	D
Species hot spots	C/C	C	C	D	D	D	D	D	D	D
Reserves or protected areas	B/C	B	B	B/C	B	B	B	B	B	C
System structure/composition										
Natural range of variability	C	B	B	B	A	B	B	C	C	B
Key habitat conditions	C	C	C	C	C	C	C	C	C	C
Species with critical roles	C	C	C	C	C	C	C	C	C	C
System function										
Maintaining disturbance regimes	C	B	B	C	B	A	B	B	B	B
Maintaining other ecosystem functions	C	C	C	C	C	C	C	C	C	C

These rankings are based on using a well-designed example of the approach, and assume that the approach is used alone. Brief rank definitions are as follows: A—likely to be effective; B—could be designed to be effective in some circumstances; C—effectiveness will be nearly completely dependent on other factors; D—unlikely to be effective. See the text for further information on rankings.

[1]In some cases, the approach was assumed to apply directly to rare and little-known species. In other cases a more general application was assumed. See text for additional clarifications.

[2]Where two ranks are shown, the first applies to rare species and the second to little-known species.

[3]For species approaches two ranks are shown. The first applies to the target species of the approach and the second to the other species. In the case of surrogate approaches, the first rank is for the surrogate, and the scond is for the spcies it is intended to represent.

approach, by its nature, would not be effective in meeting a conservation objective. For example, development of individual species strategies based on the concepts of population viability analysis would not be effective if applied to little-known species as there would be inadequate information on which to base the strategies.

Where we felt a particular approach ranked differently for rare versus little-known species, we assigned a rank for each (e.g., A/B). In ranking species approaches for meeting genetic diversity objectives, we also used separate rankings when we felt the approach ranked differently for the species targeted by the approach versus other species. In each section, we briefly reiterate the major tenets of each approach and provide specific details of the examples of the application that we evaluated for the approach. Our intent was to use published, peer-reviewed papers wherever possible, but we also used reports by various agencies and nongovernmental organizations. In some cases we found no examples of application of the approach. In a few of these situations, we attempted to logically evaluate the likely effectiveness of the approach.

Conservation of Individual Species at Risk Based on Concepts of Population Viability

This approach entails developing a conservation strategy for a target species designed to sustain the species in a given geographic area. The most rigorous application of this approach involves incorporating population viability analyses (PVA) that test the likelihood of a species persisting under alternative strategies. Conservation strategies typically provide for conservation of the variety of habitats required for the species and its obligate symbionts (such as pollinators), including mutualist species. They may also provide for management of conditions and threats or stressors that might place a species at risk, such as management of human disturbance factors. The most rigorous approaches have an objective of maintaining the long-term evolutionary potential of the species. This is usually accomplished by maintaining the maximum range of conditions under which the species, including peripheral populations, is known to occur to maintain the species' ability to adapt to changing conditions.

Development of strategies for population viability may be based on detailed single-species models that incorporate quantitative data on species' ecology, demography, biotic interactions, and dispersal and colonization dynamics (Murphy and Noon 1992; USDA Forest Service 2000). These models can be used to explore relative population growth rates of the target species among various populations, in response to alternative management strategies, and in varying climatic conditions. Where the information for such models is lacking, strategies may be based on more general conservation principles (Ralls et al. 2002; Samson 2002), including the general life history characteristics of the species (Wu and Botkin 1980). As noted in chapter 6, application of PVA concepts assumes availability of substantial information about species status, distribution, and autecology, so by definition this approach would generally not be applicable to poorly known species.

Species Diversity Objectives

Some validation testing of PVAs has been completed (see chap. 6). However, the effectiveness of management strategies based on the concepts of population viability in meeting species diversity objectives has not been extensively tested. Such strategies have been implemented for a number of species, including grizzly bears (*Ursus arctos horribilis*) (U.S. Fish and Wildlife Service 1993), northern spotted owls (*Strix occidentalis caurina*) and other old-growth-associated species in the Pacific Northwest (USDA and USDI 1994), northern goshawks (*Accipiter gentilis*) (Reynolds et al. 1992), old-growth-associated species on the Tongass National Forest (USDA Forest Service 1997), red-cockaded woodpeckers (*Picoides borealis*) (Conner et al. 2001), and western prairie fringed orchids (*Platanthera praeclara*) (USDA Forest Service 2000). Because these strategies have all been implemented relatively recently, monitoring data are not yet adequate to provide definitive answers about long-term consequences. However, based on information collected to date, it seems reasonable that these strategies, as modified through time based on new information and conditions, will be successful in conserving their target species. In some cases, however, conditions that cannot be controlled at the scale at which the strategies are implemented (e.g., global warming, major shifts in distribution of competing species) may result in species extirpation/extinction despite the measures adopted through such strategies. For example, the success of the strategy for northern spotted owls is currently in question because of increasing competition from barred owls (*Strix varia*), which have recently moved into the range of the spotted owls (Kelly et al. 2003; Peterson and Robins 2003). Other species, such as the cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*) in Arizona, are already suffering from such severe habitat fragmentation that their long-term persistence is in doubt (Cartron and Finch 2000). Thus these strategies do not ensure species resiliency with all potential futures. They are expected to be successful dealing with the dominant stressors that are known at the time of their development, but not in cases where species and the ecosystems on which they depend are too severely degraded for recovery or where threats to the species cannot be controlled at the scale of the strategy.

We conclude that this approach would be effective (rank A) in maintaining or restoring viable populations of rare species where such species are actually the target of a strategy and information is available to develop the strategy. The information needed to conduct PVAs is often difficult to obtain, which can limit the effectiveness of PVA-based strategies. Sensitivity analysis may be used to bracket potential outcomes where information is highly uncertain. However, the approach is unlikely to be effective (rank D) for little-known species as the information necessary to implement the approach would, by definition, be lacking. (See table 8.1 for all rankings discussed in this and subsequent sections).

Effectiveness of this approach in providing for viability of nontarget species would be highly variable. There are situations where management for a single species could be detrimental to conditions needed to support other species. For example, use of a mechanical device to maintain cavities for red-cockaded woodpeckers may restrict the use of those cavities by Sherman's fox squirrel (*Sciurus niger shermani*), which has also declined significantly (Simberloff 1998). In other situations, target species of this approach may make effective umbrellas for other species and so provide conditions necessary to support viable populations of other species. In one of the best examples of this phenomenon, Thomas et al. (1993) assessed a conservation plan developed specifically for northern spotted owls. Spotted owls were prioritized for attention because they were listed under the Endangered Species Act and not because they were thought to be effective umbrellas. Thomas et al. concluded that conditions conducive to viable populations would be provided for more than half of all other vertebrate species associated with old-growth forests. We conclude that the use of this approach for target species at risk might be effective in providing for conservation of other species, but that this benefit will be incidental rather than the result of characteristics of the approach itself (rank C).

Genetic Diversity Objectives

Strategies aimed at maintaining population viability of individual species can be designed to maintain genetic diversity of the target species as well. Although data quantifying the genetic diversity of individuals in various populations rarely exist, by selecting sites for protection that encompass the diversity of circumstances where the species occurs, it is assumed that genetic diversity encompassed in populations within the planning area will also be retained. These principles were applied in developing the management guidelines for the western prairie fringed orchid on the Sheyenne National Grassland in southeastern North Dakota (USDA Forest Service 2000). In selecting populations deemed critical for the persistence of the species, consideration was given to connectivity of habitat and representation of populations on the periphery of the orchid's range on the planning area. Quantitative population viability analyses were conducted to assess the effectiveness of this level of protection on projected population growth rates of the orchid (Sieg et al. 2003). The success of these guidelines in maintaining viable populations (and hopefully genetic diversity) of the western prairie fringed orchid has yet to be verified by subsequent monitoring data. We conclude that guidelines that attempt to provide for viability of individual species have the potential of maintaining genetic variation of the target species if they are appropriately designed and implemented (rank B). Effectiveness of this strategy in providing for genetic diversity of nontarget species would be entirely dependent on other factors (rank C).

Ecosystem Diversity Objectives

In some situations, strategies developed to meet the needs of individual species may be based on management of overall ecosystem characteristics and thus be compatible with ecosystem management objectives. Where such species are widespread, their management may make a significant contribution to overall ecosystem management. For example, the management strategy for northern goshawks in forests of the southwestern United States (Reynolds et al. 1992) is based largely on the diverse habitat needs of species that serve as prey for goshawks. In this case, management for this wide array of habitats could result in landscapes that would fall both structurally and functionally within their natural range of variation, thus accomplishing ecosystem diversity objectives. However, there are other cases where management for an individual species could be antithetical to the accomplishment of ecosystem management objectives. For example, management guidelines for old-growth-associated vertebrate species in the Sierra Nevada Mountains of California called for higher levels of canopy closure than had been recommended for other ecosystem objectives (USDA Forest Service 2003). Also, in many cases the area affected by management for an individual species will simply be too small to have a significant impact on ecosystem diversity objectives. So we conclude that the use of this approach for target species at risk might be effective in providing for ecosystem diversity objectives, but that this benefit will be the result of fortunate circumstances rather than the characteristics of the approach itself (rank C).

Conservation of Surrogate Species

The following approaches, with the exception of habitat assemblages, use a single species to reflect the needs of a larger group of species. The habitat assemblages approach groups species together to represent their common habitat needs.

Umbrella Species

Umbrella species have generally been defined as species that use similar habitats as other sympatric species, and whose area of occupancy on the landscape physically encompasses the occurrence of other species (Wilcox 1984; Caro and O'Doherty 1999; Suter et al. 2002). Because of the large area requirement, the habitat needed for a viable population of an umbrella species may also provide for the habitat needs of sympatric species.

Umbrella species are used to specify the type and amount of habitat to be protected, but not necessarily specific locations (Berger 1997).

Species Diversity Objectives

A recent evaluation of applications of the umbrella species concept suggests that single-species umbrellas cannot ensure the conservation of all co-occurring species (Roberge and Angelstam 2004). Thomas et al. (1993) found that northern spotted owls served as an effective umbrella for about one-third of other vertebrate, invertebrate, and plant species associated with old-growth forests in the Pacific Northwest; a combination of spotted owls and marbled murrelets (*Brachyramphus marmoratus*) did better, lending protection to additional species. Suter et al. (2002) found that the grouse species Capercaillie (*Tetrao urogallus*) was an effective umbrella for other mountain bird species in the Swiss Prealps, but not for overall avian diversity. Rubinoff (2001) found that a bird associated with coastal sage scrub, the California gnatcatcher (*Polioptila californica*), served as a poor umbrella for three species of butterflies also found in this habitat, but it could be argued that the gnatcatcher was an inappropriate choice for an umbrella species because the butterflies apparently had larger area requirements. Martikainen et al. (1998) concluded that white-backed woodpeckers (*Dendrocopos leucotos*) might serve as an umbrella for the decayed wood habitat required by threatened, saproxylic beetles in Finland. Poiani et al. (2001) found that the use of greater prairie chickens (*Tympanuchus cupido pinnatus*) as an umbrella species provided identification of more "biologically important land" than two other conservation approaches. Rowland et al. (2005) reported that greater sage-grouse (*Centrocercus urophasianus*) would serve as a relatively effective umbrella for sagebrush obligates but not for other species that are associated with sagebrush but also use other habitat types. Variability in success of these tests of umbrella species can be attributed to the care with which the umbrellas were chosen, the characteristics of the landscapes in which the tests were conducted, and the response parameters chosen for the tests.

Effectiveness of the umbrella species approach in meeting objectives for RLK species received limited testing by Thomas et al. (1993). In old-growth forests of the Pacific Northwest, the use of northern spotted owls as umbrellas for rare species was judged to be inadequate. This was due in part to the fine-scale spatial pattern of rare species occurrences, which frequently occupied smaller and more isolated patches of old forest than those that were protected for northern spotted owls. This pattern might hold true in other areas, and the umbrella concept would provide for rare species only when the occurrences of the rare species happened to coincide with those of the umbrella species (rank C). The same condition is likely to hold true for little-known species. Also, because the umbrella species concept relies on species with large area requirements, it is unlikely that it could be tailored specifically to address RLK species.

Because umbrella species can be used to develop comprehensive conservation guidelines, we suspect that the concept might be moderately effective in providing for viability of some other species. The foregoing tests tend to demonstrate that effectiveness. However, this success would be limited to some subset of other species because umbrella species address only one dimension of limitation (i.e., largest area requirement). Consequently we assigned it rank C. In most cases, we expect that the more comprehensive focal species approach would be more effective.

Genetic Diversity Objectives

Under the umbrella species approach, management is directed at providing for viability of the identified umbrella species. Such management would deal with both the full range of the species in the planning area and appropriate connectivity of habitat across the area. Such management would be beneficial in providing for genetic variation of the umbrella species. As with the approach based on concepts of population viability of individual species, we assign the umbrella approach rank B for effectiveness in meeting genetic diversity objectives of the umbrella species itself. The umbrella approach would only be partially effective in providing for genetic diversity of other species, and such effectiveness would be coincidental rather than being based on the design of the approach (rank C).

Ecosystem Diversity Objectives

We found no published tests of the utility of the umbrella species concept in meeting ecosystem diversity objectives. However, because the umbrella species concept focuses on species with large area requirements, it could be effective in identifying large habitat areas for protection, and such areas might have the appropriate attributes to accomplish some level of ecosystem diversity objectives. Analysis done by FEMAT (1993) provides one working example. A conservation network designed around the needs of northern spotted owls was projected to be moderately successful in meeting the objective of maintaining an intact, interconnected, functioning old-growth ecosystem. Adding other umbrella species (e.g., marbled murrelets, salmon [*Oncorhynchus* spp.]) to the conservation design increased the likelihood of meeting ecosystem objectives. We expect that conservation designs based on multiple umbrella species would be more effective than single umbrella species in meeting ecosystem objectives. However, the likelihood that conservation efforts based on umbrella species would meet ecosystem diversity objectives is largely dependent on the characteristics of the species chosen as umbrellas (rank C). For example, species that still occur broadly across the landscape, and that are themselves dependent on a broad set of ecosystem characteristics, will be most likely to be effective in meeting ecosystem diversity objectives. Conservation designs based on the focal species concept, which identifies umbrellas for several different dimensions of species limitations, would likely be more effective in meeting ecosystem objectives than designs based on a single umbrella species.

Focal Species

The concept of focal species has been variously defined (chap. 6). For our evaluation, we accept the concept as defined by Lambeck (1997), who suggested that needs of all species could be represented by a set of species whose characteristics make them most sensitive to resource, area, or dispersal limitations.

Species Diversity Objectives

Several authors have used Lambeck's (1997) concepts to develop landscape designs for species conservation (Bani et al. 2002; Snaith and Beazley 2002). Watson et al. (2001) used the concept to develop spatially explicit conservation guidelines for woodland birds in southeastern Australia. They estimated that all woodland bird species would find suitable habitat in a landscape designed according to this set of guidelines. They cautioned that the guidelines might be inadequate since they were based on occupancy data for populations that might not have reached equilibrium in the test landscape, and recommended that their hypothesis be tested through adaptive management. They concluded that the focal species concept was useful for developing spatially explicit guidelines for bird species, but cautioned that they had not tested the concept for other taxa.

Effectiveness of the focal species approach in meeting objectives for RLK species has not been tested. (Kintsch and Urban's [2002] work, focused on rare plant species, is reviewed under the indicator species section despite their use of the term "focal species.") However, the species identified as focal using Lambeck's concept are likely to be those that occur less frequently on the landscape, simply because their occurrence is most limited by area, resources, or dispersal. Therefore, we conclude that application of the focal species concept to rare species could be used to design a landscape that would provide for viability of those species (rank B). This conclusion is based on the assumptions that (1) there is knowledge of the type, size, and distribution of habitats within which rare species occur; and (2) rare species occurrence is predictable based on these factors. Because this information would not be available for little-known species, the success of the focal species approach in meeting objectives for little-known species would be highly variable and difficult to assess or monitor (rank C).

Similarly, because the concept can be used to develop comprehensive and spatially explicit conservation guidelines, we suspect that it can be effectively applied to provide for viability of other species (rank B). We expect that cross-taxonomic sets of focal species would be more likely to accomplish this objective because it has been frequently demonstrated that surrogates from one taxon are not efficient surrogates for other taxa (Lawler et al. 2003). Also, if the selection and use of focal species were based on knowledge of natural patterns of abundance and distribution of species, the concept could be used to meet the objective of managing for species in such patterns (rank B).

Genetic Diversity Objectives

The focal species approach is intended to identify a subset of species that represent all factors that might significantly limit populations of all species and to establish a strategy that provides for viability of those species. A well-developed application of this approach would consider both the overall distribution of the focal species (at least in the area under consideration) and the connectivity of the landscape for them. As with strategies for viability of individual species, the strategies for viability of focal species would include provisions for the diversity of conditions under which the focal species occur. So we conclude that strategies that provide for viability of focal species could also provide for maintaining the genetic variation of those species (rank B). Further, such strategies would provide for genetic variation in some additional species for which the focal species act as surrogates. This is not likely to be the case for all other species, so we conclude that the focal species strategy would provide incidental benefits for genetic variation of other species (rank C).

Ecosystem Diversity Objectives

The focal species concept is designed to look broadly across species on a landscape and to identify factors that could be critical in limiting the distribution of those species. Because it is inherently based on concepts of species interactions throughout a landscape, it should be compatible with meeting both species and ecosystem needs within that landscape. For example, Raphael et al. (2001) proposed that 31 focal species could be used to design ecosystem management guidelines to meet the needs of a broader array of species of concern in the Interior Columbia River basin in the Pacific Northwest. However, several different forms of management could be used to implement guidelines developed under the focal species concept. For example, the size and distribution of habitat patches might be managed through a system of small reserves, or alternately through consideration of their occurrence over time in a dynamic landscape managed to mimic natural disturbance regimes. Since these two strategies could have very different effects on overall ecosystem diversity standards, we conclude that the focal species concept does not inherently meet ecosystem diversity objectives, even though it could be designed to meet such objectives under some circumstances (rank B).

Guild Surrogates

We discuss the use of a single guild member as a surrogate for other members of a guild in a later section (see "Conservation of Multiple-Species Groups—Guilds").

Management Indicator Species

"Management indicator species" (MIS) is a term used by the U.S. Department of Agriculture (USDA) Forest Service to describe a set of species used to judge the effects of management activities (Landres et al. 1988). Under 1982 regulations (*Federal Register,* Vol. 47, No. 190, September 30, 1982, 36 CFR Part 219) that implemented the National Forest Management Act, national forests were required to select a set of MIS, estimate the effects of proposed management alternatives on them, monitor changes in their populations, and relate those changes to changes in habitat. New regulations issued in 2005 (*Federal Register,* Vol. 70, No. 3, January 5, 2005, 36 CFR Part 219) no longer rely on the MIS concept, but national forests still operating under the 1982 regulations continue to use MIS. All MIS must be species that respond to management activities, and may include species of conservation concern; species with special habitat needs; species that are hunted, fished, or trapped; and species whose population changes may indicate the status of other species. Because there is broad latitude in the designation of MIS, any of the other surrogate concepts could be used to aid in their identification. Since the MIS requirement does not represent a unique surrogate approach, it is not possible to evaluate its effectiveness in meeting objectives.

Biodiversity Indicator Species

As described in chapter 6, biodiversity indicator species are used to identify locations of other species or of communities (Caro and O'Doherty 1999; Chase et al. 2000). Conservation of the biodiversity indicator may provide benefits for co-located species.

Species Diversity Objectives

Kintsch and Urban (2002) found common indicator plant species (that they termed focal) successful in predicting occurrences of rare species, with 62 to 100% of rare species locations predicted by the occurrence of the indicator species. Fleishman et al. (2000) identified two butterfly species whose protection would also protect sites of 97% of all other butterfly species found in the same area. Fleishman et al. (2001) identified sets of plant and butterfly species in California and Ohio whose protection would also protect a large proportion of sites for most other species within the same taxonomic groups. However, these species were not effective as cross-taxonomic indicators. (In both the 2000 and 2001 studies, Fleishman et al. used the term "umbrellas." However, since the species were used to indicate other species locations and not types and amounts of habitat, it seems that they better fit the definition of "biodiversity indicators.") In a study of 35 forest sites in Australia, Pharo et al. (1999) found positive correlations between fern species richness and bryophyte species richness and between overstory species richness and bryophyte species richness. In a study of reserves surrounding the city of Chicago, Panzer and Schwartz (1998) found that plant community richness, plant species richness, and plant genus richness explained significant levels of variation in the richness of insect species that were considered to require conservation attention. Chiarucci et al. (2005) investigated the use of vascular plant richness as surrogates for fungal species richness. Their analysis of data from 25 forest plots in Tuscany, Italy, suggested that vascular plants could not be used as surrogates to maximize fungal species diversity. Chase et al. (2000) tested the effectiveness of potential indicators for identifying areas of high species richness, or particular species composition within coastal sage scrub habitats. They found close associations between the presence of particular species and the composition of bird and small mammal communities but cautioned that additional data were needed to determine whether management for protection of the indicators would also result in protection of the associated species.

The foregoing results suggest that, in some situations, biodiversity indicators could be effectively used to identify locations of both rare species and sets of intra- and intertaxonomic species. However, the mix of positive and negative results reaffirms the need for local data in determining whether surrogacy is warranted. Whether managing for viability of the biodiversity indicators would also provide for viability of the other species would depend on the type of management used, the similarity of habitat needs between the indicator species and the species being indicated, and whether the extant populations of those species represented a viable population. However, it appears that the biodiversity indicator approach could be used to develop effective management direction for both rare species and other species (rank B). Since initial identification of biodiversity indicators requires substantial information on distribution of both target taxa and potential indicators, the approach would not be effective when applied to little-known species (rank D). Further, it is unlikely that this approach would provide for maintenance of other species in natural patterns of abundance and distribution (rank D). Since the approach focuses on existing locations of species, it would not provide information on the natural patterns of abundance and distribution.

Genetic Diversity Objectives

Both Kintsch and Urban (2002) and Fleishman et al. (2000, 2001) showed that biodiversity indicators could be used to locate a substantial portion of the occurrences of target taxa. Management of these sites for the target taxa should provide for significant retention of their genetic variability (rank B). There is no indication that this approach would be effective in maintaining the genetic variability of other, nontarget species (rank D).

Ecosystem Diversity Objectives

Biodiversity indicators are used to indicate the presence of individual rare species or of biodiversity hotspots. Management that would be applied to the locations is not specified by the approach but would presumably include some mixture of active management and reserving some sites from management. However, since this approach is targeted at the locations of individual species, or specified groups of species, it is unlikely to result in the accomplishment of overall ecosystem objectives (rank D).

Flagship Species

Flagship species are species of high public interest that are selected to rally conservation support. Caro and O'Doherty (1999) note that they are frequently large, and may also serve as umbrellas, but that there are no strict criteria for their selection. They are not based on an ecological concept, which distinguishes them from other surrogate approaches.

Species Diversity Objectives

To function as flagships, species must be reasonably well known to the public. Consequently, neither very rare species nor little-known species are likely to be selected as flagships, so the flagship concept is not intended to provide for viability of these species. Some coincidental benefits may accrue to the viability of RLK species (rank C). Although flagships may be large-bodied and have the characteristics of umbrella species, they are not intentionally selected to serve as surrogates for viability of other species, so benefits to those species are coincidental (rank C).

Genetic Diversity Objectives

Under the flagship species approach, management is directed at providing for viability of the identified flagship species. Such management would deal with both the full range of the species in the planning area and appropriate connectivity of habitat across the area. Such management could be beneficial in providing for genetic variation of the flagship species (rank B). However, because flagship species are selected with no strong ecological criteria, management for the flagships is unlikely to provide representation of the full range of ecological conditions in which other species occur. Thus this approach is likely to be ineffective in providing for genetic variability of species other than the flagship (rank D).

Ecosystem Diversity Objectives

Some flagships are large-bodied (Caro and O'Doherty 1999) and would likely have large area requirements. Management for such flagships could have a significant influence on overall ecosystem condition. However, many types of species could be designated as flagships and their management could take many forms, so effects on ecosystem objectives will be variable and coincidental rather than the result of intentional design (rank C).

Conservation of Multiple-Species Groups

Multiple-species approaches include management based on the requirements of species that are identified to be part of a guild or a habitat assemblage.

Guilds

As described in chapter 6, a guild is a group of species with common traits that may include behavior, diet, resource selection, and so forth. Most commonly, guilds are sets of species that use the same or similar resources for the same life function. Guilds have almost always been defined within a single taxonomic group (but see Roberts 1987 for an example of guilds containing birds and mammals).

We discuss two possible approaches. The guild surrogate approach is one in which one member of a guild is chosen to act as a surrogate for all other species in the guild. In the entire guild approach, the focus (e.g., monitoring) is on all members of a guild. Both approaches share common assumptions that the population trends of all members of the guild are closely correlated, and that changes in environmental conditions affect all members of the guild in a similar way. Most research on guilds has focused on tests of these assumptions, with the general finding that species within a guild demonstrate different responses to environmental conditions and changes in those conditions (see chap. 6) and thus violate guild assumptions. Block et al. (1986) concluded that management for an indicator species within a guild might not meet the needs of other guild members and that monitoring of either a guild indicator or of an entire guild might not reflect population fluctuations of individual species within a guild. As an alternative, Szaro (1986) proposed that "response" guilds be based on multiyear data of species' responses to environmental change by simply grouping together species that showed similar responses.

There has only been limited use of guilds to develop management direction. Federal managers have used guilds of cavity excavators to develop guidance for snags and down dead wood, but there has been little testing of the effectiveness of those guidelines (Bull et al. 1997).

Species Diversity Objectives

Use of the guild approach to provide for viable populations of species has not been widely explored. Tests of the guild approach have investigated the underlying assumptions or explored the utility of guilds as monitoring tools. Guilds have rarely been used in developing conservation strategies. Properly defined guilds could potentially be effective in developing conservation strategies, even if population trends of guild members are not closely correlated. In particular, the response guilds proposed by Szaro could be useful in the development of conservation strategies. However, this application of guilds requires significant data on population trends, and multiple guilds would probably be needed to provide for conservation of a broad array of species. Roberts (1987) provided a conceptual example of multiple guilds that could be used to represent key structural features of deciduous forest habitats. However, one shortcoming in the guild concept has been the failure to consider spatial needs of species. Guilds have focused primarily on needs of species within particular habitats, with little attention given to amounts or spatial arrangements of habitats. Thus the guild concept, in applications to date, has been weaker than either the umbrella or the focal species concepts in consideration of spatial needs of species. We conclude that the guild concept would be effective in providing for species viability only if species were not spatially limited, and we assign it rank C.

We did not find any reported attempts to develop guilds of RLK species, or to test the effectiveness of guilds developed for other species in providing for RLK species. Adapting the guild approach to RLK species would be difficult because (1) development of guilds requires significant knowledge of species' life histories (Block et al. 1986), and (2) guild indicators are most effective if they have large populations (Caro and O'Doherty 1999). We conclude that it is unlikely that the guild approach would be effective in the conservation of RLK species (rank D).

Genetic Diversity Objectives

The guild approach has been focused on requirements for specific habitats and not on the spatial distribution of populations. Thus, in application of the guild concept to date, it does not inherently maintain the variety of ecological conditions in which a species occurs. Consequently, benefits to genetic variability under the guild approach would be incidental and not a direct result of the guild approach itself (rank of C for both the guild indicator and the species that it represents within the guild).

Ecosystem Diversity Objectives

The utility of the guild approach for accomplishing ecosystem diversity objectives has not been demonstrated. Guilds constructed to represent key structural features of habitats, as proposed by Roberts (1987), might be used to develop conservation strategies to accomplish ecosystem objectives. However, as noted earlier, there has been little consideration of landscape issues in the identification of guilds. Thus guilds as defined to date would likely perform poorly in accomplishing ecosystem objectives (rank D).

Habitat Assemblages

This approach involves identifying sets of species that use common macrohabitats. The scale and detail of macrohabitat definition may vary considerably in different applications. This approach is widely used by resource managers to develop a basic classification of fauna within a management unit but is not well represented in the scientific literature. Two variants are possible. First, one or more indicators represent the larger group of species in the habitat group and second, the entire group of species (see "Entire Habitat Assemblages" in chap. 6) is the focus.

Species Diversity Objectives

Canterbury et al. (2000) tested correlations of the occurrences of bird species within four habitat groups: mature forest, shrubland, forest edge, and generalists, and by diet, foraging, and nesting guilds. Correlations of occurrences between individual species and the groups in which they were included were highest for habitat assemblages. Wisdom et al. (2000) used habitat groups to assess changes in habitat availability for species of concern in the Columbia River basin. They subsequently (Raphael et al. 2001) used indicators from each group to focus the assessment of potential management alternatives for federal lands in the basin. However, since these indicators were selected as focal species within each of the habitat groups, this was not an example of using habitat groups as a stand-alone approach. Wisdom et al. (2005) placed 40 species of conservation concern into five habitat groups in an assessment of Great Basin habitats and then used those groups to characterize habitat conditions within watersheds across the Great Basin.

The use of habitat assemblages as a stand-alone approach for conservation of species is likely to provide only coincidental benefit (rank C).

Use of macrohabitat groups does not take into consideration either the details of habitat use considered in the guild approach or the various types of spatial and other limitations considered in the umbrella and focal species approaches. Therefore, in developing management strategies, more detailed needs of individual species within each habitat group need to be considered. The groups themselves would only be useful for very coarse direction on maintaining macrohabitats within a landscape.

Genetic Diversity Objectives

Because the use of habitat assemblages as a stand-alone approach would not be effective in providing for viability of species, we conclude that it would also be unlikely to provide for genetic variability of species (rank D).

Ecosystem Diversity Objectives

We found no published reports of the utility of the habitat assemblages approach in meeting ecosystem diversity objectives. It is unlikely that the development of habitat groups as a stand-alone approach would achieve ecosystem diversity objectives. Identifying the habitat groups would only be a first step in the development of conservation strategies. Unless combined with another approach, it probably would be ineffective in achieving ecosystem diversity objectives (rank D).

Geographically Based Approaches

Geographically based approaches include (1) managing for locations of individual target species at risk, (2) delineating hot spots or concentration areas of rare species, and (3) establishing reserves or protected areas designed to conserve biodiversity. These geographic approaches are based on the assumption that appropriate management of the delineated areas will provide for conservation of the species, their biophysical environments, and/or the ecological system's characteristic processes (Flather et al. 1997; Lubchenco et al. 2003).

Locations of Target Species at Risk

Under this approach, documented locations of target species are protected and managed based on specific guidelines designed to sustain the species (see chap. 6). The difference between this approach and those described under "Conservation of Individual Species Based on Concepts of Population Viability" (chap. 6) is that it is most often based on presence of the species of interest, does not incorporate population estimates for known locations, does not attempt to quantify population viability of the target species, and does not generally provide for conservation of suitable but unoccupied areas or of habitat utilized for dispersal between the known locations.

Species Diversity Objectives

The effectiveness of this approach in sustaining viable populations of rare species has not been rigorously tested. This approach is the basis for the Survey and Manage program of the Northwest Forest Plan (Molina et al. 2006, also see chap. 4), as well as a number of Bureau of Land Management and Forest Service management programs intended to sustain sensitive species. Short-term monitoring data have verified continued occupation of known locations by target species in some regions but in most cases data span only a few years. We conclude that in cases where known locations represent quality habitat, and management guidelines are adequate for sustaining this habitat as well as ameliorating threats, this approach has the potential for sustaining the presence, but not necessarily the viability, of populations of the target species (see table 8.1, rank of B for rare species). This approach is less likely to provide for the persistence of viable populations of little-known species, as location data are usually incomplete and information required for quantifying habitat needs and developing management plans is not available (rank of C).

This strategy, when applied to RLK species, would not likely be effective in providing for population viability of other species. In one study, sites selected based on occurrence of rare species in five eastern U.S. states afforded some level of protection for 84% of all other species (Lawler et al. 2003). Based on these findings, species that share particular habitat requirements with the target species (springs, seeps, etc.) might be benefited. However, despite the co-occurrence of rare species with other species, sites protected for rare species would frequently be too small to provide significant benefit to many other species. For example, carnivores with large home ranges may not be protected well under this approach because known locations protected for rare species would be too small to encompass home ranges of the carnivores. We conclude that some benefits for other species might be realized, especially for those that co-occur with the target species and have similar habitat needs, but these benefits would not be the result of the inherent characteristics of the approach (rank of C).

Genetic Diversity Objectives

This approach can be tailored to some degree to retain genetic diversity of some target species (rank B), but contributions to genetic diversity of nontarget species would be dependent on other factors (rank C). The target species most likely to benefit are those for which quality location data are available and either all known locations are protected or, if only a subset will be protected, the goal of maximizing genetic diversity is used in identifying those locations to protect. An example of this approach was used on the Black Hills National Forest in selecting a subset of known locations of bloodroot (*Sanguinaria canadensis*) for monitoring and management (Hornbeck et al. 2003). The selected subset included sites that represented the variety of plant communities where the species occurred, and also considered geographic distribution as well as different types of threats. Such approaches that attempt to conserve genetic diversity represented in the area of interest may assist in meeting genetic diversity objectives of the target species, but whether benefits would also be realized for nontarget species is dependent on other factors.

Ecosystem Diversity Objectives

This approach is not designed to meet general ecosystem diversity objectives but might produce coincidental benefits. For example, managing for target locations of the Kirtland's warbler (*Dendroica kirtlandii*) would entail providing early successional jack pine (*Pinus banksiana*) forest (Probst and Weinrich 1993). If this seral stage were underrepresented relative to long-term structural diversity goals, increasing this community type might also help meet more general ecosystem diversity objectives. Further, using prescribed burning instead of cutting to provide early seral stage jack pine would provide some benefits along the lines of restoring disturbance regimes. However, in many situations, management for locations of target species would be ineffective in meeting ecosystem diversity objectives (rank D).

Species Hot Spots or Concentrations of Biodiversity

The concept of identifying hot spots (Myers 1989) has been used to delineate concentrations of total species richness or various subsets of species of conservation concern, such as endemics and various rare species (chap. 6).

Species Diversity Objectives

Approaches that identify and manage hot spots of species richness may be effective in maintaining the occurrence of rare species for which high-quality distribution data are available but may not assure the viability of these species. This approach is more likely to maintain this subset of species if co-occurrence among target species is high and location data of just target species (as opposed to the entire species pool) are used in identifying hot spots. For species that rarely co-occur with other species, protection of hot spots will not be effective in their conservation. Further, by designating only species-rich sites for protection, sites with fewer species would not be identified for protection. Failing to protect sites with fewer numbers of species may inadvertently result in an inadequate number and quality of sites to sustain some species (e.g., see Kareiva and Marvier 2003). Thus the effectiveness of this approach in maintaining viability of RLK species is strongly dependent on factors that are not accounted for in the approach (rank C).

Preserving species-rich hotspots is unlikely to preserve the overall species pool. Wide-ranging species such as carnivores or species associated with ephemeral habitats that shift on the landscape may not be inherently protected through delineation of species-rich areas. Benefits of this approach to the entire species pool will be dependent on a variety of factors not considered in the approach itself (rank C).

Genetic Diversity Objectives

Hot spot approaches are unlikely to provide for genetic diversity of component species (rank D) because focusing solely on species-rich sites may eliminate less rich sites that are important to protect to sustain genetic variability of the component species. The only exception would be for species whose locations coincide with the boundaries of the delineated hot spots, for which the hot spots represent the maximum geographic distribution of the species in the management area.

Ecosystem Diversity Objectives

Hot spot approaches, whether based solely on locations of RLK species or on the entire species pool, are not, by design, effective in meeting ecosystem diversity goals (rank D). Species-poor ecosystem and community types may be neglected, and species distributions and richness are poor surrogates for ecosystem processes (Conroy and Noon 1996). Sustaining both species-rich sites and those with only a few species may be important components of a landscape that has a capacity to sustain species in light of environmental changes.

Reserves or Other Protected Areas Designed to Conserve Biodiversity

The most sophisticated reserve designs seek to maximize efficiency; that is, contain the greatest number of biodiversity elements at the least cost; and consider complementarity, or the relative gain in conserving biodiversity elements as additional reserve units are added (chap. 6). Other important considerations in reserve designs include "representativeness," where a desired set of biodiversity elements are at least represented, as well as considerations of vulnerability, persistence, and replaceability of candidate sites.

Species Diversity Objectives

Reserve designs can be adapted to increase their effectiveness in meeting species diversity goals. For example, reserves can be designed to maximize the number of known locations of rare species and provide additional suitable habitat. Noss et al. (2002) described an algorithm for prioritizing sites to protect in the Greater Yellowstone Ecosystem. Their analysis showed that it was possible to protect all known locations of highly imperiled species by adding 43 "megasites" to the reserve. Such an approach would improve the likelihood that reserves would provide for viability of rare species (rank B).

The degree to which little known and other species would be protected in reserves would depend on a number of factors. Reserve designs that attempt to incorporate representation of all natural communities in an appropriate landscape configuration while also protecting locations of rare species could be effective in providing for other, nontarget species (rank B). However, even such designs could only provide coincidental benefits to little-known species (rank C).

Genetic Diversity Objectives

Reserve designs can be adapted to sustain genetic diversity of some species. Reserve designs that protect all known locations of imperiled species (e.g., Noss et al. 2002) or focus on protecting endemic species with restricted distributions (e.g., Ceballos et al. 1998) are more likely to sustain genetic diversity of the targeted species (rank B). The degree to which such approaches help meet genetic diversity goals of other species depends on how well the reserve design captures the extremes in the distribution of other species (rank C).

Ecosystem Diversity Objectives

Many existing reserves were not designed to be effective in meeting ecosystem diversity objectives. As pointed out in chapter 6, a number of existing reserves were designed around a single species or around scenic attractions or roadless areas. In recent years a broader set of biodiversity objectives have been proposed in developing reserve designs. Approaches that emphasize representativeness tend to be more effective in maintaining ecosystem types and seral stages and offer a better opportunity for maintaining more resilient landscapes. Noss et al. (2002) estimated that the addition of 15 "megasites" to the Greater Yellowstone Ecosystem would increase the representation of geoclimatic classes, which could potentially result in greater representation of ecosystem types and seral stages. Whether ecosystem types and processes would be sustained would depend on the degree to which disturbance regimes could be restored and maintained. Ideally, reserves could be designed to be large enough to maintain both the taxa and the ecological processes native to a bioregion over ecological time. This critical size was identified as the minimum dynamic area by Pickett and Thompson (1978). Reserves designed using these concepts could sustain ecological processes (rank B).

Maintaining System Structure and Composition

We classified approaches that focus on maintaining system structure and composition into two general categories: those based on an understanding of the range of natural variability (RNV), and those based on concepts other than RNV, including the use of key habitat conditions and managing for species that play critical ecological roles.

Range of Natural Variability

These approaches focus on maintaining the mix of ecosystems and seral stages across the landscape within the best approximation of a historic range of natural variability (RNV) (see chap. 7). It is frequently asserted that maintaining the mix of communities within RNV will provide for the current needs of associated species (Morgan et al. 1994). The approach assumes that adequate amounts of the ecosystem remain or can be restored and that threats such as introduction of exotic invasive species can be ameliorated.

Species Diversity Objectives

A variety of approaches that incorporate an understanding of RNV in restoring the mix of ecosystems and successional stages across the landscape are described in the literature. For the most part, these approaches have only recently been attempted, and therefore long-term data on their effectiveness in meeting species diversity objectives are limited.

Three management alternatives proposed for the Columbia River basin (USDA and USDI 2000) incorporated the concepts of RNV. Raphael et al. (2001) estimated the effects of these alternatives on 31 vertebrate species considered to be of conservation concern using a Bayesian belief network model. The model incorporated attributes of the quantity and quality of habitat for each species, including a composite measure of their departure from the historical range of variability. Their results suggested that all alternatives would improve the abundance and distribution of most forest-associated species but would provide few improvements for species associated with rangelands. Problems for rangeland species stemmed from a lack of available techniques to restore communities seriously affected by exotic plant invasion; such communities may be in an "altered state" whereby restoration of native plant communities may not be possible (Hemstrom et al. 2001).

Two proposed alternatives in the Sierra Nevada Forest Plan amendment were designed to promote ecosystem conditions expected under RNV. One alternative emphasized restoration of ecosystem conditions and processes within RNV under prevailing climate; another was designed to actively manage entire landscapes to establish and maintain a mosaic of forest conditions approximating patterns expected under RNV (USDA Forest Service 2003). Analyses indicated that neither of these alternatives ranked higher than other proposed alternatives for meeting plant and animal diversity objectives. Instead, the alternative that incorporated species-specific guidelines for conserving rare species was judged to rank higher in meeting species diversity objectives.

These examples suggest that, in some circumstances, approaches designed to maintain ecosystems and successional stages based on an understanding of RNV could be designed to provide for viability of many species in the species pool (rank B). However, to be successful in providing for viability, such approaches would have to consider RNV of macrohabitats (e.g., major vegetation types and successional stages and their arrangement on the landscape), microhabitats (e.g., snags and logs), special habitat features (e.g., seeps and springs), and human disturbances. For example, Litvaitis (2003) proposed that maintenance of "thicket-dependent" species in the northeastern United States will require more than simply maintaining pre-settlement levels of early successional habitat. Instead, for conservation efforts to be successful in maintaining this group of species, creative solutions that address other aspects such as high road densities, loss of special habitat features such as beaver dams, and habitat parcelization are needed. Such approaches may also provide habitat for some RLK species, but the degree to which viability for individual species is supported will be dependent on other factors such as the treatment of individual sites occupied by the species (rank C). Since the concept of RNV does not consider individual species locations, many RLK species sites might not be protected under such approaches.

Genetic Diversity Objectives

Approaches designed to retain ecosystem types and successional stages based on their RNV would likely provide for genetic diversity of many common species, especially in ecosystems that have not been greatly altered since settlement (rank B). Genetic diversity of some rare species may be retained, as well. But, for many RLK species, the success of such approaches in retaining genetic diversity would be dependent on other factors (rank C).

Ecosystem Diversity Objectives

Assuming that it is feasible to restore native ecosystem types and seral stages within RNV, such approaches have a high probability of meeting a number of ecosystem diversity objectives. One alternative of the Sierra Nevada Forest Plan amendment aims to establish and maintain a diversity of forest ages and structures over the landscape in a mosaic approximating patterns that would be expected under natural conditions, that is, conditions characterized by current and expected future climates, biota and natural processes (USDA Forest Service 2003). Ecosystems and ecological processes would be actively managed to maintain and restore them to desired conditions. Analyses indicated that some improvements in ecosystem diversity (i.e., providing for ecosystem types and seral stages within RNV) were achieved by this alternative. Verification of these projected results requires long-term monitoring, but the theoretical basis for accomplishing the objective for ecosystem types and seral stages within RNV is sound, assuming that it is possible to mimic natural community mosaics using available tools (rank A).

In regard to other ecosystem diversity objectives, if management were designed so that vegetation types and successional stages were created and maintained through the introduction of natural disturbance regimes, these approaches would be likely to achieve the objective of restoring disturbance regimes (rank B). It could also be assumed that by providing habitat for many species in the species pool, the restoration of trophic structures would be accomplished to some degree as well (rank B). The objectives of restoring nutrient cycles and key functional roles of organisms would be promoted by approaches that maintain ecosystem types and seral stages within RNV using natural disturbance regimes. However, since these functions may be partly dependent on individual species whose fate is uncertain under such approaches, we assigned rank C to the objectives of nutrient cycling and other processes. Finally, by providing for RNV of native ecosystems and successional stages, landscapes would likely retain a high level of resiliency in the face of long-term environmental changes (rank B). RNV-based approaches would be most successful in accomplishing these objectives if locations of various successional stages represented the entire geographic range available. We conclude that approaches that attempt to restore component ecosystem types and successional stages may have merit in meeting ecosystem diversity objectives, especially if resource managers can overcome political and legal constraints required to restore historic disturbances and consideration is given to maximizing the geographic range over which a given type occurs.

Diversity of Habitat Conditions

We evaluated two types of approaches that emphasize diversity of habitat conditions using concepts other than RNV: providing key habitat conditions, and managing for species that play critical ecological roles.

Key Habitat Conditions

This approach focuses on maintaining a mix of habitat conditions. The goal is not necessarily to provide these conditions based on RNV. Instead, the intent is to include the mix of habitat conditions, including their extremes, in an effort to provide habitat for a variety of species (Haufler et al. 2002; see chap. 7).

Species Diversity Objectives

A number of conservation plans incorporate the provision of key habitat conditions with the goal of sustaining species associated with this range in conditions. Examples include the residual cover guidelines proposed in the U.S. Forest Service's Northern Great Plains plan that are designed to provide a range of grazing intensities (USDA Forest Service 2001) and those proposed by Taft et al. (2002) for managing wetlands in California by providing the extreme ends of the water depth spectrum to provide habitat for both diving birds and shorebirds. We are not aware of any empirical tests of the effectiveness of these approaches in meeting species diversity objectives, but such approaches seem likely to provide for the persistence of species associated with the range of conditions provided. For rare species associated with the habitat conditions provided, their occurrence would be likely, but whether populations were viable would be dependent on other factors (rank C). Rare species dependent on entirely different key conditions would not be benefited. Benefits for little-known species would depend on the degree to which they were dependent on the conditions provided (rank C). Whether such approaches provided for the viability of other species or natural patterns of abundances of all native species would be dependent on other factors (rank C).

Genetic Diversity Objectives

Approaches designed to provide key habitat conditions might, in some applications, contribute to meeting genetic diversity objectives of some species (rank C). However, genetic benefits would usually be the result of factors that are not an inherent part of the approach such as whether these key conditions are geographically well distributed and consider the distribution of rare species. Benefits to little-known species would be dependent on their occurrence in, and dependence on, the habitat conditions provided in the approach.

Ecosystem Diversity Objectives

Approaches designed to provide key habitat conditions may contribute to meeting ecosystem diversity objectives, but such benefits are usually restricted to the ecosystems affected by the approach. For example, management guidelines proposed by Taft et al. (2002) that provide a range in water depth of wetlands would not, by design, provide for other ecosystem types and their successional stages. Similarly, such approaches may restore ecosystem processes to some degree in the affected ecosystem, but any benefits to other ecosystem types would not be inherent in the design. In summary, the effectiveness of approaches designed to provide key habitat conditions in meeting ecosystem diversity objectives depends on the approach being used, the diversity of resulting key conditions and affected ecosystems, and how widely the management guidelines are applied (rank C).

Species That Play Critical Ecological Roles

These approaches focus on restoring species that have large effects on community structure or ecosystem function that are disproportionate to their abundance, and that perform roles not performed by other species or processes (Power et al. 1996). Included in this group of species are *keystone species,* which have a large effect on species diversity and competition, and *ecosystem engineers* that modulate physical habitat.

Species Diversity Objectives

There is evidence that restoration of species with critical ecological roles helps meet overall species diversity objectives as well. For example, for the nine vertebrate species that depend on prairie dog (*Cynomys* spp.) colonies and 20 species that opportunistically use these habitats (Kotliar et al. 1999), maintenance of prairie dog colonies would be beneficial (Sharps and Uresk 1990; Mulhern and Knowles 1997). Other taxa, including nematodes (Ingham and Detling 1984) and birds (Agnew et al. 1986), may also benefit from maintenance of prairie dog colonies. However, the degree to which prairie dog colonies would provide for viable populations of both rare and common species would depend greatly on factors such as the number, size, and juxtaposition of the prairie dog colonies (Hof et al. 2002), as well as the effect of threats from other factors such as diseases and predation. Therefore, the benefit provided to other species by such approaches would depend on other factors (rank C).

Restoration of species with critical ecological roles may result in increases of overall species diversity. American bison (*Bison bison*) were reintroduced to a tallgrass prairie preserve in Kansas in 1987. Within a few years, increases in the abundances of forbs and an overall increase in plant species richness and diversity due to bison grazing and nongrazing activities were observed (Hartnett et al. 1996; Knapp et al. 1999). However, the degree to which the natural abundances and distributions of species could be restored through such an approach would be dependent on other factors (rank C).

Genetic Diversity Objectives

Reintroduction and maintenance of species with critical ecological roles may assist in retaining the natural genetic variation of both the introduced species and the associated species, but benefits would depend greatly on how well the species is established across the range of environmental conditions where the species naturally occurs (rank C).

Ecosystem Diversity Objectives

Restoration of species with critical ecological functions has the potential to meet some ecosystem diversity objectives, although effects along these lines are unlikely to be generalizable. Restoration and maintenance of prairie dog colonies can promote lower seral stage prairie habitat and assist in maintaining some ecosystem processes (Hansen and Gold 1977; Uresk and Bjugstad 1983; Knowles 1986). The degree to which the capacity of landscapes supporting prairie dog colonies would provide for diversity of species in the face of long-term environmental change would depend on a number of factors, including how well resulting colonies represent the maximum geographic range of the prairie dog.

We conclude that the degree to which ecosystem diversity objectives are met through the restoration and maintenance of a species with critical ecological function such as the prairie dog would depend largely on the characteristics of the species, the manner in which it affects ecosystem diversity, and how extensively it is reintroduced and maintained (rank C).

Maintaining System Processes and Functions

We evaluated two approaches that focus on maintaining system processes and functions. The first focuses on maintaining disturbance regimes, and the second focuses on maintaining other ecosystem functions.

Maintaining Disturbance Regimes

Maintaining disturbance regimes is considered an important aspect of maintaining the structure and function of many, if not most, ecosystems (see chap. 7). Many approaches that attempt to restore disturbance processes base management recommendations on an estimation of the range of natural variability of the disturbances under which the system evolved. This approach assumes that by restoring historic disturbance regimes (including frequency, intensity, timing, and spatial attributes), the functional and structural attributes will be restored as well. In reality, we found few examples where success in restoring all aspects of historic disturbances could be proclaimed.

Species Diversity Objectives

Conceptually, providing for disturbance regimes under which a given system evolved should provide a sound basis for sustaining associated species. In actuality, long-term studies that evaluate the effectiveness of disturbance-based approaches in maintaining species diversity are rare. Even for the well-studied Konza Prairie Research Natural Area in Kansas, where efforts to restore historic disturbances began in the 1970s (Hulbert 1973), there is uncertainty about the long-term effects on species diversity. Initial research was limited by burning treatments that encompassed only a few hundred hectares in only one season (Hulbert 1985). Despite recent increases in the scale of treatments and studies (Knapp et al. 1999), information is still limited by the small scale of treatments relative to historical scales and by the near absence of data on the response of some taxa.

The effectiveness of such strategies for meeting overall species diversity goals may be tied to how well historic disturbance regimes can be emulated. A high level of what Jordan et al. (2003) term "pyrodiversity," including varied fire regimes across landscapes and over many decades that include a range in fire intensities and severities and variable seasonality in accordance with natural rhythms, is expected to best enhance overall species diversity. Morrison et al. (1995) found that increasing the variability of the length of time between fires in sandstone communities in Australia was associated with an increase in species richness of both fire-tolerant and fire-sensitive species. In some situations it is possible that viable populations of some other species could be maintained by restoring and maintaining disturbance regimes, but this would not be guaranteed. Andersen et al. (2005) found that most taxa associated with tropical savannas in Australia were very resilient to fires, regardless of seasonality; yet riparian vegetation and associated stream biota, as well as small mammals, were mostly associated with unburned areas. Therefore, management designed to provide some less frequently burned areas might be required to maintain viable populations of fire-sensitive species. Parr and Andersen (2006) concluded that there is a need for more critical consideration of the levels of pyrodiversity needed to maintain diversity and greater attention to developing management guidelines for such approaches.

We conclude, therefore, that strategies that incorporate historic disturbance regimes have the potential to be designed to provide for viability of some species (rank B), and may lead to natural patterns of abundances (rank B). However, the degree to which such approaches result in viable populations of RLK species would depend on other factors (rank C), and viability of populations would not be guaranteed without viability assessments.

Genetic Diversity Objectives

Approaches designed to restore disturbance regimes based on their natural range of variation would potentially provide for genetic diversity of species that benefit from such disturbances. For rare species, some tailoring might be required to provide habitat conditions the species require across as broad a geographic area as possible. For little-known species, success in retaining genetic diversity would be dependent on other factors. Overall, we assign approaches designed to restore disturbance regimes a rank of C.

Ecosystem Diversity Objectives

As discussed in chapter 7, strategies aimed at restoring disturbance processes are fraught with a number of practical and logistical issues that would need to be overcome to meet other ecosystem diversity objectives. Accounting for the rarity of some ecosystems and the small size of remaining patches of many vegetation types are not trivial problems to overcome. For example, remaining patches need to be large enough to allow for disturbances to occur at an appropriate scale and intensity (Pickett and Thompson 1978). Restoring disturbance regimes would have a good chance of maintaining nutrient cycles, but the degree to which trophic structures and key functional roles of organisms are maintained would depend on the degree to which component species are restored. To the degree that restoring historic disturbances results in a heterogeneous landscape that spans the maximum geographic range available, such approaches have the potential to provide for resiliency in the face of long-term environmental changes.

We conclude that approaches that focus on restoring disturbance regimes could be designed to be effective in meeting some ecosystem diversity objectives in some circumstances (rank B). Especially in relatively intact ecosystems, restoration of disturbances has the potential to lead to restorations of species patterns and system processes.

Maintaining Other Ecosystem Processes

This section reviews other management strategies that seek to restore and maintain other ecosystem processes. We found only two examples where management strategies designed to restore key ecological functions were attempted. The first example was a functional groups approach proposed by the Forest Ecosystem Management Assessment Team (1993), whereby arthropods associated with late-successional forests in the Pacific Northwest were aggregated into 11 functional groups based on their ecological roles. The team then rated seven land management options as to their sufficiency in providing adequate habitat on federal lands to provide for well-distributed populations of the various functional groups. This approach focused on the functional aspects of the species and was necessitated by the fact that a great number of arthropods have not been identified, and distributional information was not adequate to conduct individual species viability assessments. The ultimate utility of this approach has not been tested.

The second example is the management strategy for northern goshawks in southwestern U.S. forests, which was based on a food web strategy, whereby the habitat needs of the primary prey species of the goshawk were used in developing management guidelines (Reynolds et al. 1992).

Species Diversity Objectives

Either of the approaches already described might provide for the occurrence of some RLK species but would not necessarily provide for the viability of those populations. Given that the functional groups proposed for late-successional forests in the Pacific Northwest encompass a variety of trophic levels (predators, herbivores, pollinators, and decomposers) as well as community types (aquatic, riparian, coarse wood, litter, understory, forest gap, canopy, and epizootic forest species), there is a potential that some subset of species in other taxa might be captured as well.

Because the goshawk management guidelines result in a high diversity of habitat conditions of southwestern forests, their implementation would be expected to provide for the occurrence of species associated with the resulting range of conditions. Whether the patterns of species occurrences that result from implementing the goshawk guidelines emulate their natural patterns depends on how well the habitat needs of these specific prey species represent natural habitat patterns in southwestern forests. The degree to which little-known species are accommodated by implementing these guidelines would be unknown. We conclude that approaches that attempt to provide for ecosystem functional attributes such as food webs or functional groups might provide habitat for rare, little-known, and common species, but benefits are not predictable (rank C).

Genetic Diversity Objectives

The degree to which approaches that focus on functional aspects of ecosystems such as functional groups of arthropods or food webs meet the objective of restoring or maintaining the natural genetic variation of species would depend on attributes other than the approach itself (rank C).

Ecosystem Diversity Objectives

The functional groups approach proposed for arthropods associated with late-successional forests in the Pacific Northwest would rank highly in regard to restoring key functional roles of arthropods, but whether this benefit extended to other ecosystem diversity objectives would depend on other factors. As discussed earlier, since the management guidelines for goshawks in southwestern U.S. forests result in a great variety of habitat conditions and are based on the subset of goshawk prey species, implementation of these guidelines has the potential of restoring some portion of the natural variation of native ecosystem types and seral stages.

We conclude that approaches that focus on restoring some functional aspect of ecosystems, such as functional roles of arthropods or food webs, have the potential to meet some ecosystem diversity objectives, especially related to those ecosystem structures and functions associated with the species or species groups that are featured in the approach. Ecosystem diversity attributes not addressed in the approach would not likely be provided, and therefore we assigned a rank of C for ecosystem processes. Whether or not landscapes with the capacity for resiliency of species in the face of long-term environmental change would result would depend on other factors (rank C).

Summary of Effectiveness in Conserving RLK

The primary focus of this book is conservation of RLK species. Successful conservation efforts must deal with both short-term and long-term sources of risk. In an attempt to consider all potential sources of risk, this chapter has taken a comprehensive view of conservation approaches and objectives. Some of those approaches tend to focus on short-term risks, such as protection of known species sites, while others incorporate longer-term risk and system resiliency. In this section we summarize success of the approaches in dealing with both short- and long-term risks associated with the conservation of RLK species.

Our evaluation of the various species-based and system-based approaches (see table 8.1) indicates that none is adequate to reliably meet all conservation objectives and thus meet both short- and long-term needs for conservation of RLK species. For most, effectiveness in meeting specific conservation goals depends on how they are implemented (ranks B and C). Some approaches are better designed for short-term conservation of RLK species. Others may perform well in the conservation of a broad array of more common species and habitats. Still others have their primary strength in addressing ecosystem-level objectives, including the long-term resiliency of those ecosystems.

To better understand underlying causes for the performance of the approaches, we examined how well each approach addresses seven of the elements that are key to species conservation (table 8.2). These are use of macrohabitats, use of fine-scale habitat features, spatial arrangement of habitat, habitat dynamics and resiliency, current species locations, biotic interactions of the species, species demographics, and species genetics. We rated the degree to which each approach addresses each of these elements (see table 8.2). An approach was rated 1 for an element if that element is a primary consideration of the approach and 2 if the element is a secondary consideration of the approach or addressed in at least some applications of the approach. A dash in the rating table indicates that the element is not addressed through the approach.

Ratings for table 8.2 were based on the descriptions of the conservation approaches presented in this chapter and information on those approaches from both this chapter and chapters 6 and 7. The ratings reflect an informed judgment about the elements of conservation that are addressed by each approach, but they are subjective and cannot represent nuances of every possible application of an approach.

As with the ratings for effectiveness of the various approaches (see table 8.1), the evaluation of species conservation elements (see table 8.2) was complicated by the fact that different approaches are targeted to different sets of species, or to overall systems rather than species. Consequently, the question of how the approaches address species-related elements takes on different meanings for different sets of approaches. For the individual species approaches, we evaluated how well the approach addresses the individual species under consideration. For the surrogate approaches, we evaluated how well the approach addresses the set of species being represented by the surrogate. For the geographic approaches, we evaluated how well the approach addresses the species or set of species targeted by the approach. For the system approaches, the term "habitat" was treated as a major vegetation type rather than habitat specific to a species.

Based on our evaluation of species conservation elements (table 8.2), the approach that comes closest to addressing all seven elements associated with species conservation is the development of conservation strategies for individual species based on concepts of species viability. Its long-term effectiveness may be limited, however, by lack of consideration of habitat dynamics. This shortcoming could be managed through an adaptive management approach, but other shortcomings such as the high cost, particularly when applied to many species, and lack of the necessary data, are more difficult to overcome.

Table 8.2. *The degree to which each approach addresses seven elements important to species conservation*

Approach	Macrohabitat	Fine-scale habitat features	Spatial habitat arrangement	Habitat dynamics and resiliency	Current species locations	Biotic interactions	Demographics	Genetics
Viability of individual species	Ratings reflect the individual species under consideration							
Strategy based on concepts of population viability	1	1	1	-	1	1	1	2
Surrogate species	Ratings reflect the set of species being represented by the surrogate							
Focal species	1	1	1	-	-	-	-	-
Umbrella species	1	-	2	-	-	-	-	-
Guilds	2	1	-	-	-	-	-	-
Habitat assemblages	1	-	-	-	-	-	-	-
Biodiversity indicator species	2	-	-	-	1	-	-	-
Flagship species	-	-	-	-	-	-	-	-
Geographic approaches	Ratings reflect the species that are the target of the technique							
Management for locations of target species	2	-	-	-	1	-	-	2
Hot spots	2	-	-	-	1	-	-	-
Reserves or protected areas	2	-	-	-	1	-	-	-

(continues)

Table 8.2. Continued

Approach	Macrohabitat	Fine-scale habitat features	Spatial habitat arrangement	Habitat dynamics and resiliency	Current species locations	Biotic interactions	Demographics	Genetics
Maintaining system structure and composition		Term "habitat" is interpreted as major vegetation type rather than habitat specific to a species						
Managing for RNV	1	2	2	1	-	-	-	-
Managing for diversity of habitats	1	2	2	2	-	-	-	-
Strongly interacting species	2	-	-	1	-	-	-	-
Maintaining system function		Term "habitat" is interpreted as major vegetation type rather than habitat specific to a species						
Maintaining disturbance regimes	2	2	2	1	-	-	-	-
Maintaining other ecosystem functions	-	-	-	2	-	-	-	-

Ratings are defined as follows: 1—the element is a primary consideration of the approach; 2—the element may be considered in some applications of the approach; dash—the element is not considered unless this approach is combined with another.

Elements of conservation are defined as follows:

Macrohabitats—species use of habitats mappable at fairly large-scale (e.g., 10 acre) resolution. Includes major vegetation types and structural stages. May also include specific topographic features and positions (e.g., cliffs or streamside zones).

Fine-scale habitat features—species use of habitat features that are not detectable in large-scale (e.g., 10 acre resolution) mapping. May include structural features such as logs or snags, or the presence of particular tree species that serve as habitat for some RLK species and are not predictable through knowledge of the major vegetation type.

Spatial habitat arrangement—reflects the species' spatial use of habitat, including habitat patch size, interpatch distances, juxtaposition of various habitats used by the species (e.g., breeding habitat, dispersal habitat, winter habitat), and so forth.

Habitat dynamics—deals with changes in habitat over time and ability of habitat to persist during disturbance and/or restore itself after disturbance.

Current species locations—sites that are currently occupied by populations of the species.

Demographics—vital population rates of the species and factors that influence those rates.

Genetics—genetic composition of the species' populations, and factors that influence that genetic composition.

Four of the surrogate approaches (focal species, umbrella species, guilds, and habitat assemblages) tend to focus on habitat use by the surrogate and the set of species represented by the surrogate. There is nothing inherent to these approaches that leads to consideration of the current locations or demographics of species or of habitat dynamics and system resiliency. The biodiversity indicator approach has its strength in denoting the locations of one or more species but does not address the other factors. The flagship approach does poorly in addressing any of the seven elements.

The system approaches tend to focus on habitats and dynamics of those habitats. Note however that under these approaches there is no knowledge or intentional manipulation of habitats associated with any particular species. Rather, they provide for the major compositional and structural components of vegetation that serve as habitat, and for the underlying processes that lend resiliency to systems. These approaches fail to explicitly consider species locations or demographics.

Conclusion

It is clear that no single approach acts as a comprehensive conservation strategy. This mirrors the findings of authors (Caro and O'Doherty 1999; Carignan and Villard 2002; Kintsch and Urban 2002; Kareiva and Marvier 2003; Hess et al. 2006) who have cited the need to combine approaches to provide for effective conservation. For example, RLK species that are small bodied, and therefore are expected to have small home ranges, might be most efficiently managed through approaches that focus on current species locations. Rare species for which habitat requirements are well understood and landscape configuration of habitat is important could be managed through the focal species approach. Species for which requirements and risks are complex and involve significant biotic interactions may need individual consideration that involves the concepts of population viability. Systems approaches may be needed in addition to species approaches to provide for overall function and resiliency of the ecosystem. Finally, it is important to remember that management strategies developed through any of these approaches are hypotheses that remain to be tested, and that validation of those hypotheses requires collection of local data.

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