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Managing for Featured, Threatened, Endangered, and Sensitive Species and Unique Habitats for Ecosystem Sustainability

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ABSTRACT

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The traditional approach to wildlife management has focused on single species—historically game species and more recently threatened and endangered species. Several newer approaches to managing for multiple species and biological diversity include managing coarse filters, ecological indicator species, indicator guilds, and use of species-habitat matrices. These and other modeling approaches each have strong points as well as weak points, which include conflicts among objectives for species with disparate needs. We present three case examples of integrating management for single species with management for multiple species and ecosystems. These examples are: managing elk habitat in the Blue Mountains of eastern Oregon; managing for sustainable native fish faunas in eastern Oregon and Washington; and managing plant and animal species closely associated with old-growth forests in the Pacific Northwest. Each case illustrates a unique set of considerations and ecological conditions. Successful integration of species and ecosystem management depends on clearly defining objectives at several scales of time and space, and not violating the three most basic principles of ecosystem management: maintaining or restoring biodiversity, maintaining long-term site productivity, and maintaining sustainable use of renewable resources.

Keywords: Wildlife habitat, fish habitat, biodiversity, eastside, threatened species, endangered species, sensitive species, management indicator species, species planning.

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INTRODUCTION

Biological diversity has been described as the variety of life and its processes (Keystone Center 1991). Managing for biological diversity on lands administered by USDA Forest Service includes species management. Species-specific management of plants and animals is a traditional approach focusing both on amount, distribution, and quality of habitat, as well as key environmental factors such as food, cover, and water (Leopold 1933). The single-species orientation has included managing a sustainable, harvestable surplus of fish and wildlife game species; maintaining habitat for featured species and management indicator species; protecting sensitive and State-designated rare species; and recovery of Federally designated threatened and endangered species.

In recent years, however, other aspects of biological diversity have been recognized as natural resources worth conserving (Hansen and others 1991, SAF 1991). These include unique, scarce, and declining habitats, such as old-growth forests and riparian vegetation not disturbed by human activities, and entire plant and animal communities and ecosystems. Traditional approaches, however, which focus on individual species and their habitats might inadequately provide for these new management objectives (Noss 1991, Thomas and others 1993).

As a result, a new management paradigm has emerged within the USDA Forest Service, focusing now as much on biological diversity and ecological processes as on individual species. Within this context of ecosystem management, three main themes are appearing: maintaining and restoring biological diversity (including conserving species, populations, genomes, and communities); maintaining long-term site productivity; and maintaining long-term sustainability of use of renewable natural resources. These three themes collectively encompass and surpass (but should not supersede) the traditional species focus for management. Conflicts in site-specific management objectives have arisen in early attempts to merge these broader goals with those of the traditional species-specific approach.

In this paper, we discuss some of the recent methods proposed for species management within the larger context of ecosystem management of biological diversity. We explore some potential conflicts and propose resolutions. Next, we present three case studies of integrating species-specific management objectives into an ecosystem framework. We conclude with general recommendations for integrating the species focus with broader ecosystem management objectives. This paper focuses on managing biological resources; economic and other resources will require additional consideration.

METHODS FOR INTEGRATING SPECIES AND ECOSYSTEM MANAGEMENT

The challenge forest managers face today is to manage threatened, endangered, indicator, featured, game, and sensitive species in a context that also conserves biological diversity, site productivity, and sustainability of resource use. In this section, we discuss some of the proposed approaches: coarse-filter and fine-filter species management, ecological indicator species, indicator guilds, and use of species-habitat matrices.

Coarse-Filter and Fine-Filter Species Management

Coarse-filter species management (Hunter 1990, 1991; The Nature Conservancy 1982; Noss 1987) assumes that conserving land areas and representative habitats, such as old forests or streamside zones, will provide for the needs of all associated species, communities, environments, and ecological processes. In contrast, a fine-filtered approach specifically provides for only the habitats, substrates, and conditions for a single or few species. An example is the Forest Service’s management requirements for pileated woodpecker (*Dryocopus pileatus*).

The efficacy of a coarse-filter approach has seldom been tested. An example is the coarse-filter management program proposed by The Nature Conservancy (1982), which has estimated that 85 to 90 percent of target species would occur within their representative ecosystems. Another example of testing a coarse-filter approach is the viability assessment of plant and animal species associated with old-growth forests of Washington and Oregon in the range of the northern spotted owl (*Strix occidentalis caurina*), as conducted by Thomas and others (1993). They demonstrated that, to ensure protection of the complete old-growth forest community, a coarse-filter approach to conserving old growth would still have to consider a wide variety of rare and locally endemic species and other species of the upland forests at a species-specific scale. Their evaluation demonstrated that the fine-filter approach to managing habitat for the northern spotted owl would provide for only about a third of all plants and animals closely associated with old-growth forests within the owl's range in National Forests. Hence, the conclusion is that, to ensure conservation of the entire old-growth community, a combination of both coarse-filter management for single species and fine-filter management for multiple species would be needed. Additional details of this case are discussed below.

The coarse-filter approach is appealing in its cost savings. However, assumptions that a complete community or assemblage of plants or animals would be provided needs to be evaluated on a case-specific basis.

Related to the coarse-filter approach is the use of umbrella or flagship species, which are usually large, charismatic birds or mammals with broad distributions or area needs. The working assumption—seldom tested, and likely not often valid—is that managing habitats for umbrella or flagship species adequately provides for the host of all other species found in those habitats. One example of the flagship-species approach is management of forest reserves for tigers (*Panthera tigris*) in India.

Managing With Ecological Indicator Species

Another approach to multiple-species management is through the use of ecological indicator species. An ecological indicator species is one whose presence, distribution, and population trend is assumed to index those of other species associated with a common geographic area or habitat. The more effective indicator species chosen for management have narrow tolerances to environmental conditions; such species readily respond to changes in those conditions.

The USDA Forest Service uses ecological indicator species to simplify developing and implementing management guidelines (Sidle and Suring 1986). The indicator species concept was originally developed to evaluate how the vitality of a particular species—commonly, but not always, a plant—reflects the overall trophic health of its environment. Examples of using indicator species for management include: assessing richness of algae species as an index to the degree of aquatic eutrophication (Nygaard 1949); lichen species indicating continuity and overall health of conifer forests (Tibell 1992); vascular plants correlating with condition of pastureland in Great Britain (Helliwell 1978); presence and abundance of litter spiders indexing forest recovery after clearcutting (McIver and others 1990); and tiger beetles indexing overall biological diversity (Pearson and Cassola 1992). Other examples are found in the literature.

In recent years, however, much doubt has been cast on the assumption that any forest vertebrate species can adequately indicate the specific population size and trend of other vertebrate species (Landres and others 1988, Morrison and others 1992, Patton 1987). This use of ecological indicator species typically fails because each species has its own unique niche and distinctive response to environmental conditions, and differs from other species in morphology, behavior, resources used, competitive interactions, and other biological and ecological characteristics (Morrison and others 1992). Moreover, coincidence in population size or trend between two or more species does not necessarily lead to an understanding of the cause. This is problematic if the indicators are used to test management standards. Discerning whether species are responding to the same conditions as the indicator species is impossible.

Ecological indicator species are but one type of "management indicator," that is, a quantifiable property of an environment that correlates with desirable conditions (for example, Hunsaker and others 1990). Management indicators other than ecological indicator species are legitimate and useful tools for tracking and predicting environmental conditions and trends, such as for ecosystem recovery (Kelly and Harwell 1990) or for management of biodiversity (Noss 1990, Williams and Marcot 1991). Some of these tools are described below.

Managing With Indicator Guilds

An approach related to that of ecological indicator species is that of using species guilds to simplify assessing effects or devising management standards (Hunter 1990). In this approach, a guild of species having similar ecological characteristics is treated as a group. Guilds may be composed of ecologically similar species from very diverse taxa. For example, some rodents, birds, and ants may be within one guild of seed-eating species. The assumption—seldom tested and likely not often valid—is that all species of the guild will respond similarly to changes in environmental conditions.

Morrison and others (1992) evaluated such a "guild indicator" approach to species management of forest birds. They concluded that fundamental ecological differences between species of a guild typically resulted in individual species responding differently—sometimes with opposite numerical responses—to environmental conditions. Thus, to be reliable, a guild indicator approach to multiple-species management requires case-specific empirical testing.

Managing With Species-Habitat Matrices

Another approach to multiple-species management is the use of species-habitat matrices. Species-habitat matrices depict the relative quality of vegetation associations and seral stages for various life needs, typically for reproduction, feeding, and resting or cover. Also depicted is information on use of sundry vegetation substrates and components, such as snags and down wood and logs. One of the original species-habitat matrices was developed for eastern Washington and Oregon (Thomas 1979). This early work led to the formation of the Wildlife-Habitat Relationships Program within the USDA Forest Service, including creation of species-habitat matrices among other regions and ecological provinces (Salwasser and others 1980).

Species-habitat matrices have been used in forest planning to help identify forest types, conditions, and seral stages, and special habitats—such as cliffs, caves, lakes and ponds, riparian vegetation, snags and wildlife trees, and down logs—for managing multiple species of wildlife (Patton 1992, Toth and others 1986). Validation studies of these matrix models (Dedon and others 1986, Laymon 1990, Raphael and Marcot 1986), however, have demonstrated that their most effective use is for forest planning over the scale of watersheds and landscapes, rather than for predicting individual population responses to stand-scale conditions and changes.

Managing With Other Modeling Approaches

Other approaches to assessment and management of multiple species include models of habitat and population response. For example, Hansen and others (1990) modeled responses of wildlife habitats to management and to change in climate. This habitat response model could then be used in conjunction with information on species-habitat relationships to predict trends in vertebrate community composition over broad areas, such as was predicted from empirical studies of terrestrial vertebrates in northwestern California (Raphael and others 1988, Raphael and Marcot 1989).

In a mathematical approach, Hof and Raphael (in press) developed an optimization model for predicting the most equitable combination of habitats (forest types and their seral stages) that would meet management objectives for multiple species simultaneously. In a similar but qualitative approach, Toth and others (1986) used species-habitat matrices to develop schematics of forest habitat patch layout patterns that would meet

the needs of multiple species requiring two or more kinds of habitats.
Still other population and habitat modeling approaches include: habitat capability and suitability index models; habitat evaluation procedures; Bayesian and pattern recognition models; models of optimal foraging; population viability models; wildlife community structure models; and models of vegetation structure, stand growth, and forest succession. Attributes and examples of these models were reviewed by Morrison and others (1992).

This brief summary of a few of the more popular approaches to multiple-species assessment and management underscores our conclusion that no short cut to evaluating species' responses and requirements exists. Instead, the traditional species focus needs to be continued but must be integrated into an ecosystem context as our knowledge and tools for analysis become more sophisticated.

Further Considerations for Managing Species and Unique Habitats

Several National Forests have integrated management for multiple species combining the most stringent requirements among a set of species. For example, the Tahoe National Forest in California (Chapel and others 1992) and Tongass National Forest in Alaska (Samson and others 1989) developed management recommendations for conserving old-growth forests for wildlife. In the Pacific Northwest, similar old growth management recommendations were developed for threatened species, species deemed to be at risk of extirpation, and groups of species sharing similar ecologies. This last example, which identified management needs incrementally, is discussed below.

Management of unique habitats can entail a different approach that includes mapping the location and extent of the habitat and superimposing proposed management activities to identify areas of potential conflict. Also, by use of area analysis or cumulative effects analysis, the effects of off-site and previous management activities can be identified, mapped, and evaluated to help determine how they influence conservation of desired habitat conditions on site. This entails the use of area analysis or cumulative effects analysis.

Another consideration in management for species and unique habitats is the effect of such management on the sustainability and productivity of the land for other organisms and objectives. For example, protection of large forest stands from timber harvest, silvicultural manipulation, and fire control might induce higher risks of insect outbreaks and stand-replacing fires. This is especially true if such stands had previously been protected from natural fires and, as a result, changed in composition or accumulated a high fuel volume. Emphasis on management for single objectives that ignores either fire hazards or the need for a natural fire regime might adversely influence future ecological conditions. A good knowledge of disturbance dynamics of each ecosystem is needed. Such knowledge can be gained from reconstructing historical locations, frequencies, and intensities of disturbances such as fires and outbreaks of forest insects. Historical fire atlases, and retrospective studies on past vegetation conditions and disturbance dynamics, are two tools that will be in greater demand under a broader ecosystem management approach.

Management alternatives that affect plant and animal species have been traditionally considered in local contexts only. Management practices commonly have been implemented at stand and subdrainage scales without explicit consideration of broader areas. Recently, however, the Forest Service has begun to conduct hierarchical analyses in space and time to assess the collective needs of plant, fish, and terrestrial wildlife populations and species. They are now bringing together, over large spatial scales and long time frames, each of the essential components of landscapes, watersheds, basins, and regions that collectively meet the long-term habitat requirements of featured, threatened, and other species. They have only begun to evaluate ecosystem diversity, productivity, and sustainability.

In this spirit, nested scales of space and time should be considered when assessing effects, when defining management objectives and desired future conditions, and when developing mitigations and management standards and guidelines. In a dynamic forest ecosystem and landscape, desired future conditions are not necessarily a single, static state; rather, they can be expressed as a span of conditions. For example, Caraher and others (1992) described a range of natural conditions of various attributes of the Blue Mountains in northeastern Oregon.

In this type of analysis, a major factor is the potential for conflicts among simultaneous management objectives. For example, consider an approach to optimize and balance the needs of multiple objectives, such as for featured, game, rare, sensitive, threatened, or endangered species. Some game species require early successional vegetation. For example, black-tailed deer (*Odocoileus hemionus*) require shrub openings close to hiding cover. And hunters require road and trail access to the deer. In the same general landscape, another species might require a very different condition. As examples, Brotherella roelhi, a rare species of moss, is closely associated with old-growth and closed canopy conditions in the Pacific Northwest. Although not an old-growth obligate, wolverines (*Gulo gulo*) and grizzly bears (*Ursus horribilis*) require large roadless tracts. Thus, landscape and vegetation conditions that would maximize one species might be antithetical for conservation of another. Only by considering all needs and objectives at the onset can habitat requirements of multiple species be optimized. Examples of conflicting objectives and a resolution method are discussed below.

More often than not, when managing for multiple species and ecosystems, we are faced with a dearth of information on environmental conditions and species' life histories, ecologies, and population status. Although developing management guidelines under such conditions is possible, we emphasize the need for basic information, particularly value- and resource-free inventories and classifications of ecological conditions. In the Pacific Northwest, much information is needed on status, trends, and habitat relationships of many plant and animal species. Such information can be gathered through basic research, inventory, and monitoring programs, and evaluated for use in an adaptive management framework.

Additional management considerations are outside the scope of this paper and include social, political, and economic effects, as well as effects on abiotic resources, such as water quality, visual resources, air quality, and roads.

INTEGRATING SPECIES AND ECOSYSTEM MANAGEMENT: THREE CASE STUDIES

We offer three examples of integrating management for species with management for ecosystems: managing elk (*Cervus elaphus*) in the Blue Mountains of eastern Washington and Oregon, managing fish species and stocks in eastern Washington and Oregon, and managing plant and animal species closely associated with old-growth forests in western Washington, Oregon, and California. The purpose of presenting these examples is to show that solutions to ecosystem and multiple-species management are typically case-specific and no one approach applies to all. Despite differences in methods, the objectives among these examples are similar and attempt to maintain species viability and ecosystem health, productivity, diversity, and sustainability.

Example 1: Managing for Elk in the Blue Mountains of Eastern Oregon

In this example, we apply principles of landscape ecology to managing diverse wildlife guilds. The setting for this example is the Blue Mountains Province of northeastern Oregon and southeastern Washington. Our intent is to stimulate new paradigms for wildlife and ecosystem management. To this end, we demonstrate a hypothetical method to evaluate landscapes in a holistic manner, for a featured species and some dissimilar wildlife guilds. We also discuss landscape designs to accommodate these divergent needs. Our example uses species and guilds composed of large mammals and birds because their life requisites are better known than those of most amphibians, reptiles, and small mammals. Consequently, our discussion and example apply to the spatial scales commensurate with the home ranges and dispersal distances of large vertebrates, typically areas of subwatershed and watershed scales. Subwatersheds in the Blue Mountains generally range from 1000 to 10,000 acres. Watersheds, as aggregates of subwatersheds, generally range from 10,000 to 50,000 acres.

However, for a complete analysis of wildlife use of landscapes, smaller spatial scale evaluations, such as of an individual tree, snag, log, or vegetation stand, also are required. These scales are especially important when considering the needs of small mammals, amphibians, reptiles, and some resident birds, which often have substantially smaller home ranges than do large mammals and other birds. In our example, however, we do not discuss the effects of individual sites and stand structures per se. Rather, we focus on the effects of vegetation patch sizes and arrangements at scales of the subwatershed and watershed. Such an analysis should be considered a complement to stand-scale management.

Historical elk management: emphasis on game species—Wildlife managers have traditionally emphasized the production of game species for consumption. Management usually focused on producing a single species for a single user group. Nongame species, without benefit of a strong constituency, often were given little attention. Moreover, the ecological role and effect of game management rarely was addressed in the context of a functioning ecosystem.

In North America, many game species use two or more distinct types of habitat to meet life requisites. These "multitype" species benefit from close proximity of different seral stages (Thomas and others 1979). Hence, wildlife managers often have advocated fragmenting habitat patches of different seral stages to maintain a high edge effect. Their intent was to maintain two or more desired habitats, each representing a distinct seral or structural stage, close to one another to meet multiple-habitat requisites within the species' home range (Thomas and others 1979).

Leopold's Game Management (1933) reflected this approach. Leopold developed his law of interspersion (1933:129-132) at a time when wildlife management was just emerging as a science in North America. He was the first scientist to use edge effect as a popular concept (also see Lay 1938). Although it has been recently challenged (Harris 1988, Reese and Ratti 1988), this paradigm remains a popular and ecologically sound approach for managing multitype or edge-associated species (Guthery and Bingham 1992).

Examples of multitype species in the Blue Mountains include elk, wild turkey (*Meleagris gallapavo*), blue grouse (*Dendragapus obscurus*), mountain bluebird (*Sailia currucoides*), northern flicker (*Colaptes auratus*), great horned owl (*Bubo virginianus*), and great gray owl (*Strix nebulosa*). Such species benefit from interspersion of habitat patches, along with a useful ecotone between the patches (Guthery and Bingham 1992). In general, the useful ecotone is the edge that occurs between young and old forest seral stages or between grassland and forest, referred to as "high contrast edge" by Thomas and others (1979). Edges between mid-seral and old forests, for example, likely are not used by these multitype species as frequently as are edges between young and old forests (Thomas and others 1979).

A myriad of other wildlife species do not benefit from, and often are adversely affected by, high interspersion or fragmentation of habitat patches (Harris and Silva-Lopez 1992, Morrison and others 1992). These "unitype" or habitat-interior species are associated primarily with one seral or structural stage. (The categories of unitype and multitype species are a simplification for management purposes; it is difficult to categorize some species as either type.) Examples of habitat-interior species in the Pacific Northwest have been identified in field research studies by Hansen and others (1990), Lehmkuhl (1990), Lehmkuhl and others (1991), Lehmkuhl and Ruggiero (1991), Marcot (1985), and Rosenburg and Raphael (1986). These studies identified various species associated with large or interior conditions of forest stands (such as varied thrush (*Ixoreus naevius*), Hansen and others 1990) or clearcuts (such as western wood peewee (*Contopus sordidu-*

lus), Marcot 1985). Such species generally respond negatively to a high contrast edge between young and old seral stages; they persist optimally in large habitat patches that contain minimal edge and maximal interior. In general, as the area of interior habitat increases, so does the likelihood of occurrence and persistence of unitype species associated with the patch (Morrison and others 1992).

Persistence of unitype species also depends on the connectivity of like habitat patches across the landscape. In general, the shorter the distance between and among like patches, the higher the probability of sufficient connectivity to maintain adequate population size. Adequate population size is defined as that needed to withstand stochastic declines in breeding, dispersal, and survival that threaten a species' persistence at defined spatial and temporal scales.

Much attention has been given to landscape designs that minimize fragmentation and enhance connectivity of old forest patches (Franklin and Forman 1987, Lamberson and others 1992). Examples of species likely to benefit from such designs in the Blue Mountains include northern goshawk (*Accipiter gentilis*), Townsend's warbler (*Dendroica coronata*), pileated woodpecker (*Dryocopus pileatus*), black-backed woodpecker (*Picoides articus*), Vaux's swift (*Chaetura vauxi*), northern flying squirrel (*Glaucomys sabrinus*), and Townsend's big-eared bat (*Plecotus townsendii*).

Other unitype species may persist in large habitat patches of early seral stages (Hansen and others 1990, Marcot 1985). Examples in the Blue Mountains include mourning dove (*Zenaida macroura*), chipping sparrow (*Spizella passerina*), American goldfinch (*Carduelis tristis*), Brewer's blackbird (*Euphagus cyanocephalus*), Columbian ground squirrel (*Spermophilus columbianus*), and northern pocket gopher (*Thomomys talpoides*).

Few if any unitype species in the Blue Mountains seem to be closely associated with mid-seral forest stages. The sharp-shinned hawk (*Accipiter striatus*) appears to come closest; it makes extensive use of mid-seral forests but also forages in both young and old forests. Thus, it is more a multitype species than a unitype species.

Landscape relationships of elk and unitype species—How are landscapes used by dissimilar guilds, especially when one species is "featured," perhaps to the detriment of others? If we knew the answer, we might understand a bit more about ecosystem management for wildlife. We attempt here to describe how landscapes of the Blue Mountains are used by a featured species in relation to wildlife guilds that have highly dissimilar needs.

We chose elk as the featured species because it is designated as "featured" by nearly every National Forest in which it occurs, including those of the Blue Mountains. We contrast this species' predicted patterns of use with those of unitype or habitat-interior species for three distinct landscapes. Ecological relationships that form the basis for this evaluation are described as follows (also see table 1).

Elk: a multitype species—Elk is an edge-associated species that responds positively to increasing fragmentation of seral stages (Thomas and others 1988, Wisdom and others 1986). Landscape management of elk involves two complementary strategies: manipulating their spatial and temporal distribution through effective land treatments; and controlling their population size and manipulating their sex and age composition (population structure) through effective harvest regimes.

The first strategy, commonly referred to as "elk habitat effectiveness," is defined by Lyon and Christensen (1992:4) as the "percentage of available habitat that is usable by elk outside the hunting season." This percentage is a gross index of the ability of land managers to "grow elk" and influence their distribution.

The second strategy, coined as "elk vulnerability," is defined as "the susceptibility of elk to being killed during the hunting season" (Lyon and Christensen 1992:3). Elk vulnerability pertains to the ability of population managers to manipulate the number and population structure of elk through hunting (Thomas 1991).

Models of habitat effectiveness predict the relative distribution of elk within and among habitat patches by subwatershed. Predictions are based on elk response to the interspersion and quality of habitat patches and to the density of roads. Thomas and others (1988) developed a habitat effectiveness model for elk winter ranges in the Blue Mountains that predicts elk distribution based on four variables: size and spacing of forage and cover patches; density of roads open to motorized traffic; quality of cover patches; and quantity and quality of forage (table 1).

Models of elk vulnerability are under development. The variables thought to significantly increase elk vulnerability to harvest include: high density of hunters, high density of roads, loss or absence of large cover patches, and gentle terrain (Thomas 1991). Effects of these and other variables on elk harvest are shown in tables 1 and 2.

Unitype species associated with old forests—Many species in the Blue Mountains are associated with old (late-successional, including mature and old-growth) forests. Few data exist, however, about specific responses of these species to changes in patch size, amount, and arrangement. We therefore borrow principles of landscape ecology derived from other provinces and regions for our discussion here.

In general, the occurrence and persistence of species associated with old forest patches increases with increasing patch size and connectivity of such patches, as described earlier and as summarized by Morrison and others (1992). Moreover, microclimate inside old forest patches is modified with increasing distance from openings. For example, Chen and others (1992), working in southern Washington and central Oregon, found evidence that extremes in microclimate were partially or fully modified within interior portions of forest patches of old-growth Douglas-fir (*Pseudotsuga menziesia*) that exceeded 150 yards from openings (young forests). Also, susceptibility to windthrow likely decreases with increasing size and interior portions of old forest patches.

Moderation of thermal environment and reduction in windthrow along edges are confounded by physiography (Chen and others 1992). For example, an old forest patch exposed on a ridgetop and surrounded by young forests likely is more susceptible to windthrow and is subject to greater extremes in weather than a similar patch downslope. The relations described above are generally predictable (table 1) but require local adjustment to account for effects of physiography.

Table 1—Descriptive effects of landscape changes on elk and unitype species within subwatersheds of the Blue Mountains

	Elk		Unitype Species	
Landscape Changes	**HE[1]**	**ES[2]**	**Young Forest**	**Old Forest**
Increasing fragmentation or edge effect	Positive[3]	Negative	Negative	Negative
Increasing road density and human uses	Negative[4]	Negative	Negative	Negative
Increasing size and connectivity of old forest patches	Variable[5]	Positive	Negative	Positive
Increasing size and connectivity of young forest patches	Variable[6]	Negative	Positive	Negative

[1] Habitat Effectiveness

[2] Elk survival during hunting season; Negative = low survival or high vulnerability to harvest; Positive = high survival or low vulnerability to harvest

[3] Increases HE related to size and spacing of habitats (HEs)

[4] Decreases HE related to density of open roads (HEr)

[5] Increases HE related to covefquality (HEc); decreases HE related to size and spacing (HEs)

[6] May increase HE related to forage quantity and quality (HEf); decreases HE related to size and spacing (HEs)

Table 2—Landscape problems that increase elk vulnerability to harvest and the corresponding landscape remedies (from Thomas 1991:319)

Landscape Problems	Landscape Remedies
1. Increasing density of roads	1. Design roads to minimize effects. Close roads permanently or temporarily. Enforce road closures
2. Increasing density of hunters	2. Restrict hunter numbers
3. Decreasing amounts of cover	3. Control stand configuration, juxtaposition, and size through modifications in timber management program
4. Fragmenting of cover into smaller patches	4. Retain adequate escape cover in the form of stands of several hundred or more acres
5. No restriction on antler class in bull harvest	5. Impose regulations on what can be taken — such as allowing the kill of spike antlered bulls only
6. Setting of open seasons that include the rutting period	6. Ensure that open seasons do not include the rutting period.
7. Improving technology	7. Preclude “modern” weapons
8. Long open seasons	8. Shorten the open season
9. Relatively gentle terrain	9. Decrease road density, maintain more cover, increase size of cover patches, decrease hunter numbers
10. Increasing number of hunter days	10. Related to both items 2 and 8 above. Reduce hunter numbers or reduce length of hunting season, or both

Unitype species associated with young forests—In contrast to species associated with old forests, even fewer data are available about the response of young forest-associated species to landscape change. This subject has been largely ignored by researchers of landscape ecology. Working in young-growth Douglas-fir in northwestern California, Marcot (1985) found that, on average, 25 percent of the variance in bird abundance that was not explained by site conditions was explained by landscape attributes. Such attributes included slope angle, slope position, distance to nearest permanent water, distance to next nearest similar habitat, habitat patch size, and number of different edges (adjacent stands). For example, during the breeding season, variation in abundance of western wood pewees, warbling vireos (*Vireo gilvus*), and western tanagers (*Piranga ludoviciana*) was accounted for by proximity to the next nearest shrub patch. During the winter season, chestnut-backed chickadees (*Parus rufescens*), cedar waxwings (*Bombycilla cedrorum*), and evening grosbeaks (*Coccothraustes vespertinus*) exhibited this pattern. However, the majority (71 percent) of the 91 bird species observed showed no correlations with landscape attributes. Autecological studies are needed to better determine landscape relationships of species associated closely with young seral stages.

Although data are scant, it is logical to assume that unitype species associated with young forests respond similarly to patch size and arrangement of their selected habitats, as do unitypes that use old forests. That is, species occurrence and persistence can be expected to increase with increasing size and connectivity of desired patches (table 1).

Landscape distribution of elk and unitype species—Both multitype and unitype species appear to respond to a common attribute: distance from edge between young and old forests. Hence, this attribute can be used to evaluate the probability of species or guild use of habitat patches within a subwatershed. (Other attributes could be similarly evaluated.) Predicted use can be described in terms of a relative probability distribution, which is defined as the relative proportion of time or area that a habitat patch is used by a species or guild. Probability distributions of use of distance bands from edges can be scaled from 0.0 to 1.0, where 1.0 represents 100 percent probability of use by a species or guild relative to other areas having probabilities less than 100 percent. Similarly, 0.0 is equal to 0 percent probability that a particular area is used. The sum of all probabilities within a subwatershed, weighted by area, equals the composite, relative probability of species or guild use for the subwatershed as a whole.

Thomas and others (1988) defined elk use of habitat patches in this manner. Their size and spacing variable described a probability distribution for elk by 100-yard distance bands from edges, into both forage and cover areas in a given subwatershed (table 3). Thomas and others (1988) defined forage areas as patches with an overhead canopy closure of 40 percent or less. They defined cover areas as patches with an overhead canopy closure exceeding 40 percent. They further classified cover into two types: marginal cover, which are patches with overstory canopy closure of 41 to 69 percent having overstory trees 10 to 39 feet tall; and satisfactory cover, which are patches with 70 percent overhead canopy closure and overstory trees 40 feet tall or taller.

We used these definitions to determine that forage areas are analogous to young forests, marginal cover is analogous to mid-seral forests, and satisfactory cover is analogous to old forests. Meaningful edge is the ecotone between forage areas and marginal or satisfactory cover, but not between marginal and satisfactory cover (Thomas and others 1988).

These concepts can also be applied to unitype species. What follows must be considered a working management hypothesis that requires rigorous testing and validation. We present this hypothesis as a first attempt to implement landscape evaluation and management of unitype wildlife guilds. It is not a tool to predict absolute probabilities of species occurrence or persistence. It may be useful, however, in estimating the relative "fitness" of subwatersheds for these guilds, and in demonstrating the relative likelihood of guild use within and among habitat patches. (Also, the caveats given above—that species within indicator guilds often display disparate numerical responses to environmental conditions—also should be tested for this example.) The following five assumptions form the basis of our working management hypothesis:

- Assumption 1: Unitype species distribute themselves positively and incrementally away from meaningful edge. Meaningful edge in the Blue Mountains is between young and old forests, or between young and mid-seral forests. Definitions of forage and cover areas for elk (Thomas and others 1988) can serve as interim descriptors of young versus mid-seral or old forest patches, respectively, until new research provides more specific definitions.

Table 3--Hypothetical probability distributions of elk and unitype species in relation to distance from edge between young, mid-seral and old forest patches

	-------- Relative probability distribution --------		
Distance from edge [1] (yards) Into young forest (elk forage areas)	**Elk**	**Young forest species**	**Old forest species**
0 -100	1.00	0.25	0.00
100 - 200	0.54	0.50	0.00
201 - 300	0.54	1.00	0.00
301 - 500	0.14	1.00	0.00
> 500	0.04	1.00	0.00
Into mid-seral forest (elk marginal cover)			
0 -100	1.00	0.00	0.125
101 - 200	0.14	0.00	0.25
201 - 300	0.14	0.00	0.50
> 300	0.005	0.00	0.50
Into old forest (elk satisfactory cover)			
0 -100	1.00	0.00	0.25
101 - 200	0.14	0.00	0.50
201 - 300	0.14	0.00	1.00
300	0.005	0.00	1.00

[1] Edges are defined as the ecotone between young and mid-seral forests, and the ecotone between young and old forests.

- Assumption 2: Unitype species that use old forests are distributed most positively (with a use index value of 1.0) in portions of old forest (elk satisfactory cover) that exceed 200 yards from an edge with young forest (elk forage areas). Mid-seral forest (elk marginal cover) is used by unitypes as well, but highest use is suboptimal (use index value of 0.5) to that of old forest. Areas of mid-seral or old forest over 200 yards from edges of young forests represent the interior portions of habitat that experience the least variation in microclimate and least susceptibility to windthrow. Also, habitat-interior species are more vulnerable to predation by edge-associated species with increasing proximity to edge (Harris and Silva-Gomez 1992). We assume that the distribution of old forest species thus declines linearly with increasing proximity to edge with young forest, with none of the young forest edge itself used (use index value of 0.0). Table 3 summarized these hypothesized probability distributions of use by 100-yard distance bands from meaningful edge into early-, mid-, and late-seral stages.
- Assumption 3: Unitype species closely associated with young forests are distributed most positively (use index value of 1.0) in portions of young forests greater than 200 yards from an edge with mid-seral or old forest. We hypothesize that the distribution of young forest species declines linearly with increasing proximity to edge with mid-seral or old forest, with none of the mid- and late-seral forest edge itself used (use index value of 0.0) (table 3).
- Assumption 4: Effect of variations in vegetative structure and composition on abundance of unitype species within and among habitat patches is not specifically addressed in this example and is assumed to not influence species distribution and abundance. These variations include individual structures such as snags, logs, and trees, as well as composition of overstory and understory woody and herbaceous vegetation. Response of Blue Mountains fauna to management of these stand-scale attributes has been addressed previously (Thomas 1979). Our hypothesis is designed as a complement to stand-scale management, not as a substitute. That is, we assume that stand-scale management of vegetation structure and composition for wildlife is already underway in the Blue Mountains. We further assume that unitype species respond to patch size and arrangement described here only if forest structures desired by such wildlife are well distributed across the associated patches and seral stages. If these stand-scale needs are not actively managed, our hypothesis is invalid.
- Assumption 5: We assume that our hypothesis is more applicable to subwatersheds under even-aged silvicultural forest management than to more complex stand structures resulting from uneven- or all-aged management. Even-aged silviculture typically results in seral stages that can be delineated and identified as distinct patches. By contrast, uneven-aged treatments often result in patches that contain elements of multiple seral stages; distinct patches (and edges) may not be evident. Effects of uneven-aged management on unitype guilds require more intensive evaluation at the stand scale, and responses of wildlife may be independent of patch size or arrangement.

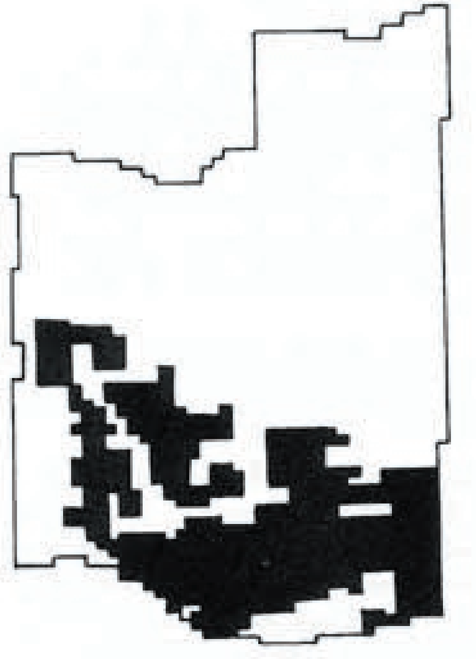
Also, a comprehensive list of unitype species for ecosystems of the Blue Mountains is not available. Such a list should be developed as part of the research required to test this hypothesis.

Evaluating subwatersheds—Our hypothesis can be applied to ecosystems of the Blue Mountains to demonstrate the theoretical effects of subwatershed management on disparate wildlife guilds. We did so by applying the probability distributions in table 3 to three subwatersheds of the Umatilla National Forest. Subwatersheds were selected to reflect three distinct landscapes: subwatershed 1 is dominated by patches of large, relatively unfragmented young forests (fig. 1); subwatershed 2 contains patches of large, relatively unfragmented mid-seral and old forests (fig. 2); and subwatershed 3 is composed of highly fragmented patches of all seral stages (fig. 3).

Acreages of all seral stages within each 100-yard distance band away from edge in each of these three test subwatersheds were estimated by using a geographic information system and software developed by Hitchcock and Ager (1992). Summaries of the distance band analyses are shown in figures 1, 2, and 3. The results (table 4) show dramatic differences in probability distributions of potential use by elk and unitype guilds among the three subwatersheds. As expected, subwatershed 1 provides the greatest probabilities of use by unitype species associated with young forests, and the lowest probabilities of use by old-forest species and elk. Subwatershed 2 provides a higher probability of potential use by old-forest species, yet a low probability of use by elk and by young-forest species. Subwatershed 3 provides the greatest probability of use by elk, but a low probability of use by both young- and old-forest species.

Application of this method shows its potential utility in ranking the relative condition of subwatersheds for dissimilar wildlife guilds. Such a tool, if validated by research, could provide managers with a new approach for managing for multiple species of wildlife. Specifically, it could be used to design patch size, amount, and arrangement to accommodate the needs of various wildlife guilds at the subwatershed scale. This method also could be useful for analyzing cumulative effects of timber sales and other silvicultural treatments within and among subwatersheds.

At the subwatershed scale, this method accounts for the effects of amount, arrangement, size, and, to a limited degree, connectivity of patches. It does so by estimating the area within various distance bands away from meaningful edge, by seral stage, for the entire subwatershed. This method is in contrast to other indices of habitat fragmentation that typically rely on estimating perimeter length in relation to interior area for specific patches (Harris and Silva-Lopez 1992), or on more abstruse indices of fractal dimensions or distributions of patch size (O'Neill and others 1988) that can be hard to relate to actual species' responses. Using more complex indices of habitat patch patterns may be difficult in evaluating fragmentation effects for a variety of wildlife guilds across a myriad of patches that make up a subwatershed. Also, defining a habitat patch (from which perimeter and area measurements are obtained) is a tricky judgment. Finally, the distance-band tool has already been incorporated into software commonly used in National Forests of the Blue Mountains (Hitchcock and Ager 1992), although it remains to be empirically validated for species other than elk.



Legend 1

Band	Young	Mid	Old
1-100	189.6	100.9	100.0
101-200	77.5	84.7	0.0
201-300	66.1	21.2	0.0
301-400	56.8	0.0	0.0
401-500	62.5	0.0	0.0
> 500	599.2	0.0	0.0
Total Acres 1358.5	**1051.7**	**206.8**	**100.0**

Figure 1. Subwatershed 1: 1358 acres, of which 1052 acres are young forest, 206 mid-seral, and 100 old forest. Young is light shading. Mid-seral and old are dark shading. Acreage within distance bands away from edges is shown in Legend 1 above.

Legend 2

Band	Young	Mid	Old
1-100	178.2	92.5	171.5
101-200	23.2	72.3	148.2
201-300	1.0	28.9	125.5
301-400	0.0	11.4	97.1
401-500	0.0	7.7	92.5
> 500	0.0	11.9	238.1
Total Acres **1300.1**	**202.5** **15.6%**	**224.7** **17.3%**	**872.9** **67.1 %**

Figure 2. Subwatershed 2: 1300 acres, of which 202 acres are young forest, 225 mid-seral, and 873 old forest. Young is light shading. Mid-seral and old are dark shading. Acreage within distance bands away from edges is shown in Legend 2 above.

Legend 3

Band	Young	Mid	Old
1-100	614.2	242.3	344.5
101-200	233.5	100.2	152.9
201-300	65.6	28.4	62.0
301-400	24.3	6.7	6.7
401-500	5.7	0.0	0.0
> 500	0.0	0.5	38.2
Total Acres **1925.6**	**943.2** **49.0%**	**378.1** **19.6%**	**604.3** **31.4%**

Figure 3. Subwatershed 3: 1926 acres, of which 943 acres are young forest, 378 mid-seral, and 604 old forest. Young is light shading. Mid-seral and old are dark shading. Acreage within distance bands away from edges is shown in Legend 3 above.

Evaluating watersheds—Once probability distributions of potential use are estimated for a cluster of subwatersheds, trends may become evident for the watershed as a whole. One might detect such trends by assessing the number or percentage of subwatersheds that favor elk, young forest, or old forest species within a watershed. Connectivity of habitat for unitype guilds might also be assessed by identifying subwatersheds that appear to be “weak links” (low use probabilities) relative to surrounding subwatersheds.

Table 4—Relative probability distributions of elk and unitype species for the 3 subwatersheds shown in figures 1, 2 and 3

	- - - - - - - - - - Relative probability distribution [1] - - - - - - - - - -		
Site	**Elk**	**Young forest**	**Old forest**
Subwatershed 1 (fig. 1)	0.39	0.64	0.05
Subwatershed 2 (fig. 2)	0.40	0.05	0.52
Subwatershed 3 (fig. 3)	0.74	0.19	0.18

[1] Calculations: Relative probability = [(area in distance band) x (probability distribution in distance band)] summed for all distance bands in all patches of a subwatershed.

To illustrate, consider a hypothetical watershed comprised of 10 subwatersheds (fig. 4); 5 favor elk or multitype guilds, 3 favor unitypes associated with young forest, and 2 favor unitypes that use old forests. Assessment of these spatial conditions might provide insight as to deficiencies and needs of particular guilds within a watershed. Such assessments would help managers identify opportunities for designing management goals to balance the needs for managing dissimilar species and guilds. This balancing could be done within and among subwatersheds and watersheds across an entire National Forest.

Habitat allocation for elk and unitype species—Which of the three landscapes in figures 1, 2, and 3 is best for wildlife? The answer depends on one's objectives. Management that favors edge-associated species (fig. 3) does not provide optimal conditions for habitat-interior species that use large, unfragmented landscapes. Likewise, management solely aimed at minimizing fragmentation of old forests (fig. 2) does not provide optimal conditions for multitype species that use several vegetation seral stages and edges, or for unitypes that occur in unfragmented, young forests.

How should dissimilar needs be accommodated within a single landscape? What specifically should be the desired future conditions in such landscapes? The short answer is that a balance must be struck among competing interests. Balance can be achieved at the subwatershed and watershed scales through manipulating patch sizes and arrangements. At different times, too, a given area can serve to provide unfragmented and fragmented conditions.

Conceptually, such manipulation requires the following steps:

- providing large, well-connected patches of old forests (fig 2);
- providing large, well-connected patches of young forests (fig. 1);

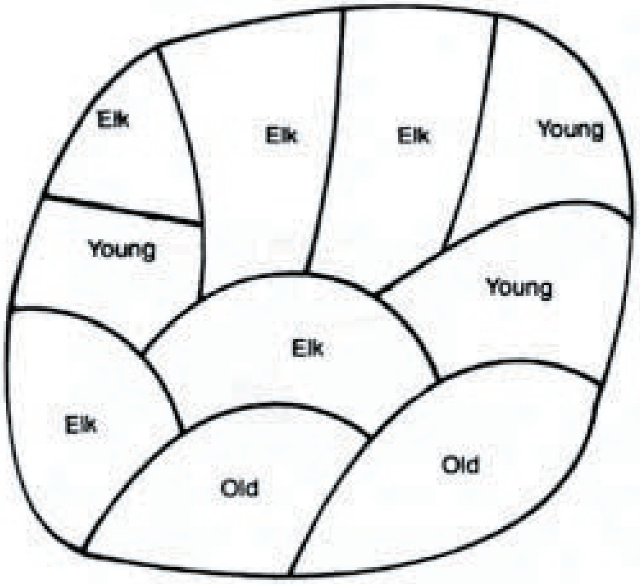


Figure 4. Hypothetical watershed composed of 10 subwatersheds: 5 favor elk or multitype species, three favor young forest species, and 2 favor oldforests species.

- compromising the size and connectivity of both old and young forests as a trade-off to sustain each over time (fig. 5); and
- providing some habitat interspersion among old and young forests as an outcome of the compromise (fig. 5).

This same process can then be repeated at the scale of the watershed, and again at the scale of a District or Forest. Of course, the practicality of any such optimal pattern must be fitted to the ground with consideration for roads, geologic hazards, other existing land allocations, and other factors.

Also, there are other management considerations for a featured species like elk that might be compatible with the requirements of unitype species. For example, management to reduce elk vulnerability to harvest requires large, well-connected patches of mid-seral or old forests and low densities of roads (tables 1 and 2). Such a management strategy would favor old-forest species as well (table 2).

The outcome of a compromise strategy (fig. 5) meets less than the maximum possible habitat requisites of both multitype and unitype guilds. Moreover, such a strategy may not meet the individual needs of sensitive, threatened, or endangered species. This possibility points to the obvious: explicit goals must be set at subwatershed and watershed scales, for both single species and dissimilar wildlife guilds, for trade-offs evaluated among each, and for designs implemented that likely favor one or more species or guilds over others. Only then can current conditions and effects of proposed actions be judged against desired objectives.

Objectives do not have to specify the layout design of habitats within a landscape; instead, they could describe a range of probabilities of potential use of the landscape. In this way, descriptions of desired future conditions would be flexible enough to allow for various on-the-ground solutions, with a variety of specific schedules of activities in space and time to meet the stated objectives.

Although such an approach might account for management needs of multiple species and guilds, the needs of sensitive, threatened, and endangered species must be addressed first. Single-species management cannot be abandoned for the sake of guild or multispecies management when the goal is to achieve a more holistic, ecosystem approach of landscape designs for wildlife. Ecosystem management is thus not a substitute for species management. Rather, it is additive and complementary.

Recommendations—Like most forest ecosystems of North America, past management in the Blue Mountains appears to have favored elk and other multitype species through increasing fragmentation of disjunct seral stages. Current National Forest Land and Resource Management Plans ("Forest Plans") could stand to address the needs of unitype species in a holistic manner, especially those associated with old forests. The amount of undisturbed old forest remaining in the Blue Mountains is scant and fragmented, as is true with late-successional and old-growth forests in western Oregon and Washington (Johnson and others 1991).

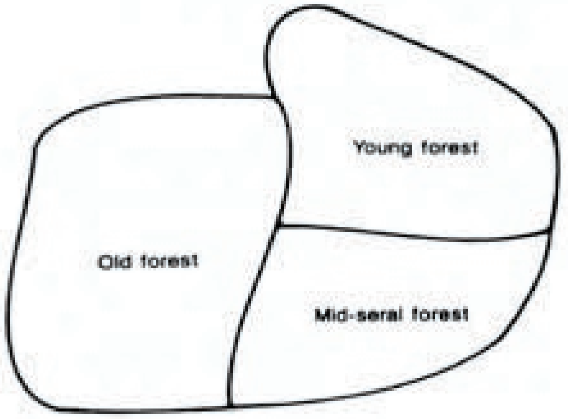


Figure 5. Hypothetical subwatershed of 1800 acres that would yield a probability distribution above 0.5 for old-forest species, and above 0.3 for both young-forest species and elk.

This situation is exacerbated by the fact that landscapes of the Blue Mountains are naturally fragmented. Applying our method across multiple subwatersheds and watersheds of the Province would likely help identify conditions that favor multitype guilds over unitypes. We recommend that such an assessment be done to validate this premise. We also recommend that the validity of this method be tested through research. Both of these efforts in tandem would help provide new insights for managing wildlife from an ecosystem perspective.

Example 2: Managing for Sustainable Native Fish Faunas in Eastern Oregon and Washington

In this example, we explore conditions and methods for managing multiple species of native fish in eastern Oregon and Washington. The premise is that managers of eastside forests should manage for native coldwater stenotherms, that is, fishes with very narrow physiological tolerances and that require the highest quality water.

Coldwater stenotherms are declining on the eastside because of landscape problems resulting from abusive land-use practices. These species include the most prized sport fishes of North America and are of great commercial and cultural value. We argue that management for these featured, threatened, endangered, and sensitive species, and other species having moderate to high risk of extirpation, will lead to maximum species diversity of all fishes within the catchment basin. This approach is consistent with the principles of sustained-ecosystem management and a coarse-filtered approach. To understand why this is true, a brief synopsis of the ecology of fishes in streams is needed. The following section summarizes information on stream ecology as it applies to riverine fishes (Bayley and Li 1992).

Stream reaches and fish distributions: theory—In general, streams can be subdivided into two major subsystems connected by a transition zone, which can be either abrupt or gradual. The upper zone is shaded, small, steep, swift, rocky, highly oxygenated, and cold. The fishes that live in this zone, the rhithron, are coldwater stenotherms with high metabolic rates. They feed on aquatic insect drift and benthic invertebrates. Terrestrial drift is especially important because the riparian canopy reduces primary productivity and herbivorous insects are few. The lower zone, the potamon, is large, exposed to sunlight, of low gradient, sluggish, composed of smaller substrates, lower in dissolved oxygen, and warm. Fishes inhabiting this zone are warmwater fishes with low metabolic rates, tolerant of anoxic conditions, and ones that feed on a wider array of food. Piscivory, herbivory, and detritus feeding are more prominent trophic modes in the potamon community. The transition zone between the rhithron and potamon is composed of a mixture of these types of fish assemblages as well as coolwater, transitional forms.

The number of fish species is greater downstream than upstream. Different assemblage patterns (species combinations) occur depending on the degree to which shifts in physical gradients are abrupt (Rahel and Hubert 1991). If change is gradual, the number of species increases downstream in an additive manner because the transition zone is wide and the coldwater and warmwater faunas tend to overlap. If change is abrupt, patterns of zonation occur because the transition zone is narrow and the two types of faunas are more segregated. Patterns of distribution can shift up or downstream depending on the quality and quantity of water.

Stream reaches and fish distributions: management implications—Warmwater species are more abundant than coldwater species and the extent of warmwater reaches far exceeds those that are cold. Therefore, extending the coldwater zone further downstream increases species diversity of the catchment basin as a whole, as well as promoting the numbers of sensitive (coldwater) species. Species diversity is often indexed by combining species richness and equitability (relative abundance) of individuals among species. Ironically, managing for species diversity alone can reduce species richness in reaches of the upper basin because the more diverse species, the warmwater fishes, are pushed further downstream. The catchment basin is the most appropriate scale to conduct management; however, because it can include the entire fish fauna, it is an ecosystem on which boundaries can be placed for management and evaluation purposes (Frissell and others 1986).

Adaptation of stream fishes to disturbance—Evidence suggests that stream fishes have adapted to recurring patterns of disturbance over evolutionary time (Bayley and Li 1992, Meffe 1984, Resh and others 1988). The fish fauna of the Pacific Northwest has not adapted well to the radical modifications to the ecosystem caused by human activity (Li and others 1987, Reeves and Sedell 1992, Wissmar and others 1993).

Among the more serious threats are introductions of alien species. Alien species change the rules governing species assemblage structure and impose new rules on land managers. Native species that compete with or are preyed upon by alien species may become more sensitive to activities such as logging, which increases sedimentation and temperatures and results in the loss of coarse woody debris that creates and maintains pools and riffles. However, most of the documentation that alien species outcompete or directly exclude native fish species is correlative. Further direct synecological, experimental studies are needed to better determine the extent to which native species may have declined because of introduced species.

Alien species often predominate in systems that are badly disturbed by humans. Such effects described by Elton (1958) hold true for aquatic systems (Li and Moyle, in press; Moyle 1976). For instance, introduced smallmouth bass (*Micropterus dolomieui*) are now recognized to be major predators of native chinook salmon (*Oncorhynchus tshawytscha*) (T. Poe, pers. comm.; Tabor and others, in press). Once, smallmouth bass might have been excluded from chinook rearing areas by cold water, but elevated water temperatures caused by human activity now permit smallmouth bass to reside in chinook salmon rearing habitat in the John Day Basin where in 20 years they have expanded their range 640 miles upstream.

Types of disturbances—When large woody debris falls into streams, the riparian forest provides raw materials for habitat creation and habitat structure for fishes (Gregory and others 1991). This structure buffers large floods by providing refuges for fishes. When riparian vegetation and the flood plain remain intact, floods create new habitats and redistribute structural and organic materials within the aquatic ecosystem. Otherwise, floods are destructive (Junk and others 1989, Gregory and others 1991). For example, clearcut logging can cause catastrophic landslides (Lamberti and others 1991), decreased nutrient retention of the stream (Lamberti and others 1989), and resistance of the fish fauna to catastrophic floods (Fausch and Bramblett 1991, Pearsons and others 1992). Reduction of the flood plain and riparian forests alters the hydrograph, elevates stream temperatures, increases the silt burden, reduces habitat complexity and availability, and increases frequencies of flash flooding on eastside landscapes. Summer low flow conditions for coldwater fishes are more harsh because of water diversions and changes in runoff patterns. Silt from logging operations reduces spawning grounds (Platts and others 1989) by suffocating fish eggs (Reiser and White 1988). Elevated water temperature from logging can increase summer temperatures, adversely change the forage base of fishes, and cause a decline of fish standing crops (Graynoth 1979). Reduction of the riparian canopy on eastside streams caused by livestock grazing causes similar problems. Elevated stream temperatures stress coldwater fishes while diminishing their prey base (Li and others, in press; Tait and others, in press). Destruction of riparian vegetation has reduced the capacity of eastside basins to buffer the fish fauna from flash floods (Pearsons and others 1992).

Theory of resilience of stream fishes to disturbances—Successional patterns of fish assemblages in streams are different from those of terrestrial organisms (Vannote and others 1980). Successional patterns in streams are spatial rather than temporal (Fisher 1983). Stream fishes, especially in the Pacific Northwest, are specialized inhabitants of specific environments: coldwater specialists, warmwater specialists, small stream forms, and big river forms (Bayley and Li 1992). Specialization for temporal stages of ecological succession are not observed (for example, pioneering species); instead, with changes in environmental conditions, the affected fauna relocates during recolonization and in response to periodic disturbances such as floods and droughts (Matthews 1986, Matthews and others 1988).

Fishes are exposed to profound changes in water quality and quantity over an annual cycle and exhibit strong patterns of seasonal movement (Junk and others 1989). Recurring disturbances act like a reset button on a computer. In streams providing refuges, habitats can be quickly recolonized and faunal elements restored in a matter of months (Freeman and others 1988, Matthews 1986, Matthews and others 1988). But flood plains and riparian forests must remain intact; otherwise, recolonization will take decades.

Management implications of disturbances— Because one does not have to manage for different successional stages, managing for biodiversity in lotic ecosystems is different than in terrestrial ecosystems. To maintain biodiversity, all faunal elements should be present within the basin. For this example, managing for the most sensitive species—the cold-water fishes—should benefit the fauna as a whole.

To transplant or introduce alien species to lotic ecosystems is undesirable because, once established, they are extremely difficult to remove. Problems they create will further constrain human activities because the native fauna is often more sensitive to human-caused or natural changes in the physical environment than is an established alien fauna. For example, the range of habitats occupied by the eastern brook trout is increasingly limited in its native waters because of displacement by introduced salmonids (Fausch and White 1981, 1986; Larson and Moore 1985). Alien salmonids dominate in areas where the habitat has been altered. To avoid this scenario in eastern Washington and Oregon, the most important factor is to preserve the functions of the riparian forests and the floodplain. Unnatural landscape disturbances must be minimized and human patterns of land use should mimic natural patterns of environmental variation whenever possible (Poff and Ward 1989, Resh and others 1988).

Sensitive fauna as indicators of forest health: background on river fishes of eastside forests—The species richness of fishes in a catchment basin reflects its zoogeographical history and the condition of its watershed (Bayley and Li 1992, Hocutt and Wiley 1986, Hynes 1975). Management can affect both factors. We can affect zoogeography by creating or eliminating barriers to dispersal and by introducing species. Watershed condition affects the composition of fishes from the available species pool because water flows downhill. Therefore, disturbances at the top of the watershed can affect the water quality and habitat availability in the catchment downstream.

Zoogeographical history reveals that fish taxa of the Pacific Northwest have been subjected to periodic, immense geological and climatic changes (McPhail and Lindsey 1986, Minkley and others 1986). These changes include the massive and periodic Bretz floods in the Columbia Basin, tectonic uplift, glaciation, and volcanism. The fauna of the lower Columbia Basin reflects these major geologic upheavals, in that the fauna are extremely well suited for dispersal and colonization over long distances (Li and others 1987). More than 50 percent of the fishes can disperse through the sea (McPhail and Lindsey 1986). This capacity has been compromised now because few areas are sufficiently intact to generate needed dispersants to disturbed areas. The tributaries of the mid-Columbia are much harsher environments for salmonids than the lower basins (McPhail and Lindsey 1986, Mullen and others 1992); they are more subject to drought and high temperatures. The mean standing crops (2-3 g/m^2) of the Methow, Entiat, and Wenatchee rivers are among the lowest recorded for the western United States. River-wide means have not been determined for the John Day River, but standing crops in selected sites range from 0 to 15 g/m^2 (Li and others, in press), and we suspect that most reaches are at the low end of the range. The margined sculpin (*Cottus marginatus*) may be endemic and restricted to the cooler streams in the Blue Mountains of southeastern Washington and northeastern Oregon (McPhail and Lindsey 1986).

The northern third of the Columbia Basin was affected by glaciation, is mountainous, and is comprised of cold, high-gradient streams. The following fishes appear to be remnants of a preglacial, western, coldwater fauna: pygmy whitefish (*Prosopium coulteri*), lake chub (*Couesius plumbeus*), burbot (*Lota lota*), slimy sculpin (*Cottus cognatus*), and the bull trout (*Salvelinus confluentus*) (McPhail and Lindsey 1986). These fishes are scattered throughout the West in mountainous areas of relatively pristine conditions and appear to be confined to coldwater habitats.

Drainages of southeastern Oregon were subject to at least three major oscillating periods of desiccation and inundation during the late Miocene to the Pleistocene. The oscillations resulted in massive extinctions of lake-adapted forms and the relict distribution patterns of today. The surviving fauna of each dry period found refugia and "were poised to expand and recolonize areas during the next wet phase" (Minkley and others 1986). The problem is that the western fish fauna is on the verge of disappearing completely because of human activity (Mickley and others 1986, Minckley and Douglas 1991). Although small relict populations might be going extinct, the paleontological record certainly suggests that conservation meet biodiversity objectives.

Sensitive fauna as indicators of forest health: management implications—Eastside management should focus on the habitat requirements of coldwater native fishes, which will also benefit native warmwater fishes because water quality for the basin will improve. We hypothesize that the resiliency of a fish fauna to human disturbance of a catchment basin (for example, salvage logging, fire suppression, creation of logging roads and water diversions, grazing, and application of pesticides) is related inversely to the number of species:

- of threatened, endangered, and sensitive status;
- of special concern;
- with high or moderate risk of extirpation; and
- with localized distributions, represented in its fish communities.

This hypothesis is an extension of the Index of Biological Integrity proposed by Karr and others (1986). The distribution and abundance of coldwater fishes should be used as indicators of biological integrity for the drainage.

To assess the resiliency of fish faunas in catchment basins and the health of watersheds on various National Forests, we mapped the reported distributions of species found: east of the Pacific Crest Scenic Trail in National Forests in Oregon, Washington, or both states; and inside National Forests or up to 25 miles outside of National Forests (hereafter referred to as species associated with National Forests) (figs. 6 and 7, table 5). Species included in the maps belong to at least one of the following categories:

- threatened, endangered, or special concern species (Williams and others 1989);
- sensitive species of Oregon (threatened or endangered species, or species which might quality for threatened or endangered status in the future; Marshall and others 1992);
- salmonids of high or moderate risk of extinction (Nehlsen and others 1991);
- fish of limited distribution (found within less than 8400 kml in a state) and associated with National Forests; and
- other fish associated with National Forests.

Some of the fishes in these designations are unique populations at the level of subspecies, races, or stocks. The data were obtained from faunal guides, publications, and lists of the status of native fishes (Behnke 1992, Currens and others 1990; Haas and McPhail 1991; Howell and Buchanan 1992; Knutson and others 1992; Lee and others 1980; Marshall and others 1992; McPhail and Lindsey 1986; Minckley and others 1986; Mullen and others 1986,1992; Nelson 1968; Nehlsen and others 1991; Williams and others 1989; Wydowski and Whitney 1979).

Results show that threatened, endangered, or sensitive fish species occur on every National Forest in eastern Washington and Oregon. The total number of fish taxa that are threatened, endangered, species of special concern, species with localized distribution, or species with high or moderate risk of extirpation, is inversely proportional to the resilience of catchment basins in National Forests. The decreasing order in this resilience index of National Forests in eastern Oregon was: Malheur (3 fish taxa), Ochoco (3), Deschutes (4), Mount Hood (4), Umatilla (4), Wallowa-Whitman (5), Winema (10), and Fremont (11). Hence, natural or human disturbances to fish communities seem to have been most adverse in Fremont and Winema National Forests. The decreasing order in the resilience index of National Forests in eastern Washington was: Mount Baker-Snoqualmie (2), Gifford Pinchot (3), Colville (4), Okanogan (4), Wenatchee (5), and Umatilla (6). These indices suggest an overall lower resilience for catchment basins in National Forests in Oregon than in Washington. When sensitive species listed by the State of Oregon were added to the resilience index, differences in relative order of resilience among catchment basins associated with National Forests in Oregon became more evident: Ochoco (4), Deschutes (5), Malheur (5), Mount Hood (6), Umatilla (7), Wallowa-Whitman (7), Winema (10), and Fremont (14). The State of Washington has not issued a list of sensitive species of fish.

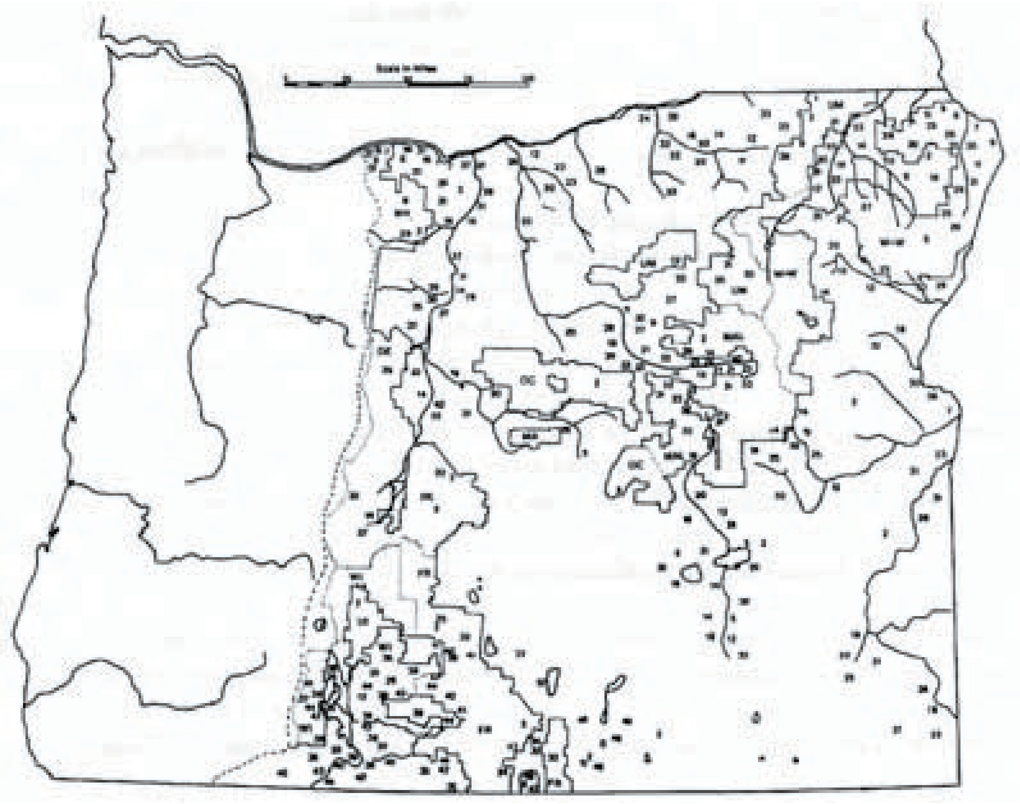


Figure 6. Distribution of fish associated with National Forests east of the Cascade Range in Oregon. (See table 5 for key to species names.) Codes for National Forests are: DE = Deschutes, FRE = Fremont, MAL = Malheur, MH = Mount Hood, OC = Ochoco (MA = Maury Ranger District), UM = Umatilla, WI = Winema, and WW = Wallowa-Whitman.

Many species with localized distributions were exclusively associated with the Winema and Fremont National Forests. Some of these species were also classified as sensitive (figs. 6 and 7, table 5). The total number of species of fish, for all categories combined, associated with National Forests in eastern Oregon were: Wallowa-Whitman (23), Umatilla (20), Malheur (19), Fremont (18), Mount Hood (15), Winema (15), Ochoco (13), and Deschutes (11). In eastern Washington, these totals were: Wenatchee (21), Okanogan (18), Umatilla (16), Colville (12), Mount Baker-Snoqualmie (12), and Gifford Pinchot (11) (table 1).

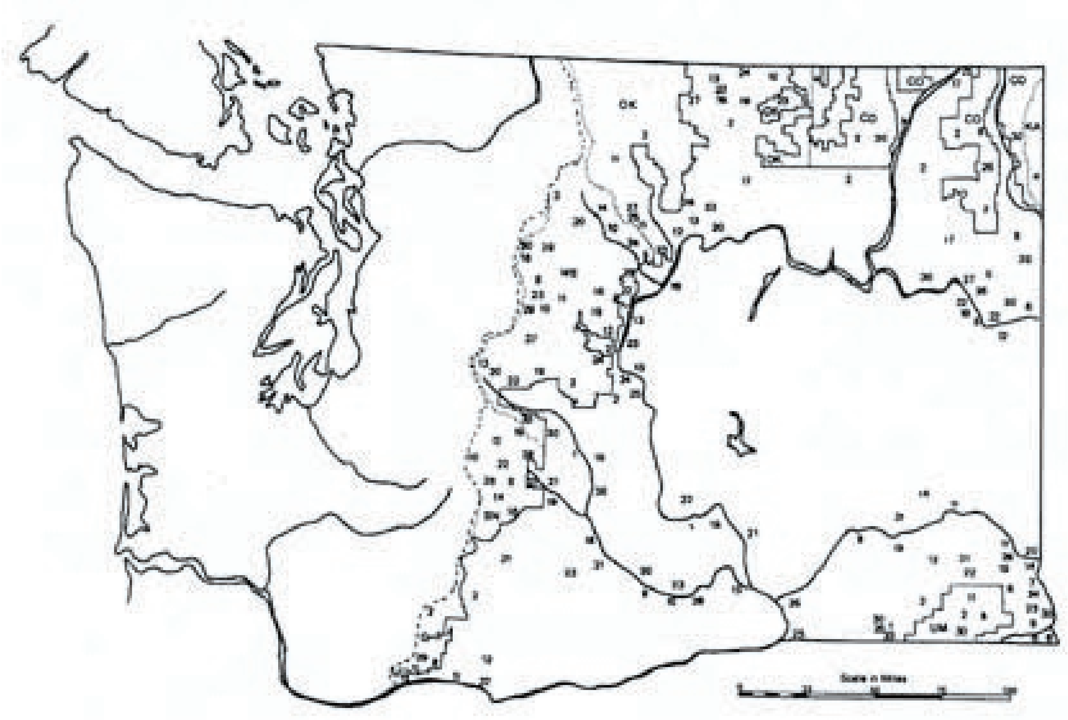


Figure 7. Distribution of fish associated with National Forests east of the Cascade Range in Washington. (See table 5 for key to species names.) Codes for National Forests are: CO = Colville (KA = Kaniksu Ranger District), GP = Gifford Pinchot, OK = Okanaogan, SN = Mount Baker-Snoqualimie, UM = Umatilla, and WE = Wenatchee.

Example 3: Management for Species Closely Associated with Old-Growth Forests of the Pacific Northwest

In this example, we summarize a recent evaluation of species viability conducted in the Pacific Northwest (Thomas and others 1993). Here, we discuss the methods used to conduct a viability risk analysis of species closely associated with late-successional and old-growth forests. This project was completed in response to a court order to evaluate potential effects on old-growth species of implementing a conservation strategy for the northern spotted owl on National Forests.

The evaluation had three phases: identifying plant and animal species closely associated with old-growth forests and components of old-growth forests; evaluating potential effects on long-term viability of each species, under planning alternatives presented in a previous environmental impact statement; and identifying mitigations for habitat management to help ensure a high likelihood that all affected species would not be extirpated from the National Forests as a result of management actions. The process also addressed scientific uncertainty and lack of information that could influence the outcome of the evaluations of species viability. As per the court order, the evaluations were qualitative, based on the best available scientific information and professional judgment, but were not quantitative analyses of population and habitat dynamics.

This evaluation extended far beyond previous assessments of old-growth species (Johnson and others 1991, Lehmkuhl and others 1991, Ruggiero and others 1991) by including consideration for plant and animal taxa. This approach was inspired by the evaluations of how spotted owl planning will also provide for other species as conducted by Anthony and others (1992) for the Draft Spotted Owl Recovery Plan.

Identifying old-growth species—The following process was used to identify species associated with old-growth forests of the Pacific Northwest. First, a long list was constructed of species that find optimal habitat conditions in mature or old-growth forests for one or more life needs. The long list drew from existing literature and included more than 1200 species.

Table 5—Native species of fish living in National Forests east of the Cascade Mountains in Oregon (OR), Washington (WA) or both. National Forests cited parenthetically have fish up to 25 miles outside forest limits. Status of fishes: E = endangered. T = threatened. SE = sensitive. SC = special concern. A = high risk of extinction. B = moderate risk of extinction. LD = limited distribution. Dashed line = not reported. (Species codes indicates the distribution of fish in figures 6 and 7.

Species code	Scientific name and status	National Forests Oregon	 Washington
1	*Percopsis transmontana*	Umatilla (Mt. Hood)	— (Gifford Pinchot, Umatilla, Wenatchee)
2	*Oncorhynchus mykiss* ssp. OR: SC, SE, A B. WA: A, B	All National Forests east of the Cascade Mountains	All National Forests east of the Cascade Mountains
3	*Cottus cognatus* WA: LD	— —	Wenatchee —
4	*Catostomus catastomus*	—	Kaniksu
5	*Cottus bairdi* ssp. OR: SE, SC	Ochoco (Malheur, Maury, Umatilla)	Snoqualmie, Wenatchee (Colville, Okanogan)
6	*Oncorhynchus clarki* ssp. OR: SC	Wallowa-Whitman (Mt. Hood)	Colville, Umatilla —
7	*Acipenser transmontanus* WA: LO	Wallowa-Whitman, Mt. Hood —	— (Umatilla)
8	*Oncorhynchus kisutch* OR: SE, LD. WA: LD	Mt. Hood —	Gifford Pinchot —
9	*Lampertra tridentata* OR: SE, SC.	Wallowa-Whitman, Umatilla (Deschutes, Malheur, Fremont)	Wenatchee (Umatilla)
10	*Oncorhynchus nerka* OR: A, SC	Deschutes, Mt. Hood, Wallowa-Whitman —	Gifford Pinchot, Wenatchee (Colville, Okanogan)
11	*Oncorhynchus tshawytscha* OR: SE, A, B. WA: A, B	Wallowa-Whitman (Malheur, Mt. Hood, Ochoco, Umatilla)	Gifford Pinchot, Okanogan, Umatilla Wenatchee
12	*Richardsonius balteatus*	Umatilla, Winema (Malheur, Wallowa-Whitman)	Snoqualmie, Wenatchee (Gifford Pinchot, Okanogan)
13	*Rhinichthys falcatus*	— (Wallowa-Whitman)	Wenatchee (Okanogan, Snoqualmie)
14	*Prosopium williamsoni*	Malheur, Deschutes (Mt. Hood, Umatilla, Wallowa-Whitman)	Snoqualmie, Wenatchee (Gifford Pinchot, Okanogan)
15	*Lampetra ayresi* WA: LD	Mt. Hood —	— (Gifford Pinchot)
16	*Cottus asper* —	— (Okanogan)	Snoqualmie, Wenatchee
17	*Prosopium coulteri* WA: LD	— —	— (Colville, Okanogan)
18	*Gasterosteus aculeatus*	— —	— (Okanogan, Wenatchee, Snoqualmie)
19	*Catostomus colombianus*	Malheur (Ochoco, Umatilla, Wallowa-Whitman)	Snoqualmie, Wenatchee (Colville, Okanogan, Umatilla)
20	*Catostomus macrocheilus*	Wallowa-Whitman, Malheur (Maury, Ochoco, Umatilla)	Wenatchee (Okanogan, Umatilla)
21	*Catostomus platyrhynchus*	Malheur (Ochoco, Wallowa-Whitman, Umatilla)	— (Gifford Pinchot, Snoqualmie, Umatilla)
22	*Rhinichthys osculus*	Malheur, Wallowa-Whitman, Umatilla (Ochoco)	Snoqualmie, Wenatchee (Colville, Okanogan)
23	*Ptychocheilus oregonensis*	Malheur, Wallowa-Whitman (Ochoco, Umatilla)	Okanogan, Wenatchee (Colville, Snoqualmie, Umatilla)
24	*Mylocheilus caurinus*	— —	Wenatchee (Okanogan, Umatilla)
25	*Salvelinus confluentus* OR: SE, SC. WA: SC	Fremont, Umatilla, Wallowa-Whitman Winema (Deschutes, Mt. Hood, Malheur)	Wenatchee, Okanogan Colville, Umatilla
26	*Acrocheilus alutaceus*	Malheur, Umatilla, Wallowa-Whitman (Ochoco, Maury)	Snoqualmie (Colville, Okanogan, Umatilla)

Table 5—Native species of fish living in National Forests east of Cascade Mountains in Oregon (OR), Washington (WA) or both. National Forests cited parenthetically have fish up to 25 miles outside forest limits. Status of fishes: E = endangered. T = threatened. SE = sensitive. SC = special concern. A = high risk of extinction. B = moderate risk of extinction. LD = limited distribution. Dashed line = not reported. (Species codes indicates the distribution of fish in figures 6 and 7.

Species code	Scientific name and status	National Forests Oregon	 Washington
27	*Cottus rhotheus*	Wallowa-Whitman (Deschutes, Mt. Hood, Malheur, Ochoco, Umatilla)	Okanogan, Wenatchee (Colville)
28	*Lampetra richardsoni*	Malheur (Ochoco)	Snoqualmie —
29	*Cottus confusus*	Deschutes, Wallowa-Whitman (Malheur, Umatilla)	Gifford Pinchot, Wenatchee —
30	*Rhinichthys cataractae* OR: SE. WA: T	Malheur, Wallowa-Whitman (Deschutes, Mt. Hood, Ochoco, Umatilla)	Colville, Umatilla, Wenatchee (Kaniksu, Snoqualmie)
31	*Cottus beldingi*	Malheur, Umatilla, (Maury, Mt. Hood, Ochoco, Wallowa-Whitman)	— (Umatilla)
32	*Gila bicolor* ssp. OR: T, SC, SE. WA: LD	Deschutes, Winema, Fremont (Malheur, Wallowa-Whitman)	— —
33	*Cottus marginatus* OR: SE, LD. WA: LD	— (Umatilla)	— (Umatilla)
34	*Catostomus occidentalis* OR: SE, SC, LD	Fremont —	— —
35	*Catostomus luxatus* OR: LD	Winema (Fremont)	— —
36	*Lampetra similis* OR: LD	Winema —	— —
37	*Cottus perplexus*	Deschutes, Mt. Hood, Winema	Gifford Pinchot
38	*Cottus tenuis* OR: SC, LD	Fremont, Winema —	— —
39	*Cottus princeps* OR: LD	Winema (Fremont)	— —
40	*Gila coerulea*	Fremont, Winema (Deschutes)	— —
41	*Lampetra lethophaga* OR: LO	Fremont, Winema —	—
42	*Cottus klamathensis* OR: LD	Fremont, Winema —	— —
43	*Catostomus rimiculus* OR: SC	— (Winema)	— —
44	*Catostomus snyderi* OR: LD	Fremont, Winema —	— —
45	*Chasmistes brevirostris* OR: LD	Winema (Fremont)	—
46	*Catostomus warnerensis* OR: E, LO	— (Fremont)	— —
47	*Hesperoleucus symmetricus mitrulus* OR: SE, LD	Fremont —	—
48	*Cottus pitensis* OR: LD, SE	— (Fremont)	— —
49	*Gila bicolor eurysoma* OR; SC, LD, SE	— (Fremont)	— —
50	*Oncorhynchus clarki lewisi* Or: SE, LO	Malheur, Umatilla (Wallowa-Whitman)	— —
51	*Oncorhynchus clarki clarki* OR: SE, SC	Mt. Hood —	— —
52	*Gila bicolor oregonensis* OR: SE, LD	— (Fremont)	— —

From this long list, a short list of species closely associated with old-growth forests or components (large snags, live trees, and down wood) was constructed based on a compilation of data on distribution, ecological attributes, and habitat studies of each species. A set of repeatable rules were developed by which each species was assessed for membership on the short list (Thomas and others 1993). Next, all species on the short list were evaluated for effects on viability resulting from each of the spotted owl planning alternatives, and mitigation options were identified for those species that ranked less than medium high in viability under the selected alternative. Five panels of species experts were convened to refine the short list and to assess viability and mitigations for plants and terrestrial vertebrates. Invertebrates were assessed through contracts with regional experts, and fish were evaluated with aid from a concurrent panel's (PacFish) analysis of anadromous salmonids (USDA 1992). The short list eventually included 667 species evaluated in all or in portions of their range, or fish stocks (hereafter, "species or ranges"): 190 fungi, lichen, and nonvascular plants; 122 vascular plants; 149 invertebrates associated with old-growth and riparian habitats; 112 anadromous salmonid fish stocks; 21 amphibians (no species of reptiles was identified as closely associated with old-growth forests); 38 birds; and 35 mammals.

Evaluation of potential viability effects—The expert panels evaluated the potential effects on 50-year viability of each species. They did so by ranking each combination of species and planning alternatives according to a five-class rank order scale depicting degree of protection (table 6). The 50-year time frame chosen for the evaluation models a harvest period for most old-growth forest on lands suitable for timber production in National Forests. From the viability rankings, each species was assigned to one of four categories of extirpation risk: high (viability rankings of medium low or low), medium (viability rankings of medium), low (viability rankings of high or medium high), and unknown (not enough scientific information available by which to judge potential effects on viability).

In combination with existing Forest Plan standards and guidelines, each species was rated for potential effects on viability under each spotted owl planning alternative. Results indicated that existing Forest Plans, in combination with the strategy selected in the previous environmental impact statement for conservation of spotted owl habitat, would protect some 280 species or ranges, or about one third of all species closely associated with old-growth forests. This strategy still leaves some 387 species or ranges at risk of extirpation on one or more National Forests.

Identification of mitigations—For these 387 species or ranges, additional mitigations for habitat management were developed to help ensure they would not become extirpated over a 50-year period. Cumulatively, these mitigations included recommended standards and guidelines, developed first for those species or species groups with the broadest distributions—in this case, for species of riparian habitats (with a focus on the 112 stocks of at-risk anadromous salmonid fish) and for marbled murrelet (*Brachyramphus marmoratus*), a Federally listed threatened species. Mitigations for riparian habitat and for marbled murrelet habitat would also provide for an additional 42 species or ranges. Then, other mitigations were developed and added for the remaining species still at risk: rare and locally endemic species (17 species or ranges) and other upland forest matrix species (7 species or ranges). With the accumulation of all mitigation steps, habitat for some 459 species or ranges would be provided so as to avoid extirpation.

Species with no information—Scant or no scientific information is available for judging the viability effects on the residual 208 species. Of this total, 23 species would likely be afforded some (unknown) degree of protection based on their ecological similarity to other species that occupy habitats and ranges already provided in the mitigation steps above. The remaining 185 species were truly unknown, and protection for them could not be judged. They included 19 fungi (mushrooms), lichens, and nonvascular plants; 8 vascular plants; all 149 invertebrate species, which as a group are poorly known; and 9 mammals, all of which were species of bats. For these unknown species, and for some others only potentially protected, further inventories and scientific studies were strongly recommended.

Table 6—Five-class ranking scale used to assess viability of populations of species closely associated with old-growth forests in the Pacific Northwest under various planning alternatives (Source: Thomas and others 1993:264)

HIGH - There is a high likelihood that the population(s) of the species would stabilize in National Forests within the range of the northern spotted owl. This provides broad latitude for natural catastrophes and uncertainties in knowledge. The likelihood of widespread or complete extirpation is low.

MEDIUM. HIGH - There is a moderately high likelihood, somewhat better than 50/50, that the population(s) of the species would stabilize in National Forests within the range of the northern spotted owl. This provides limited latitude for natural catastrophes and uncertainties in knowledge. There is less than a 50/50 likelihood of widespread or complete extirpation.

MEDIUM - There is roughly a 50/50 likelihood that the population would stabilize, and a similar likelihood of widespread or complete extirpation in National Forests within the range of the northern spotted owl. This provides extremely limited latitude for natural catastrophes and uncertainties in knowledge.

MEDIUM LOW - There is less than a 50/50 likelihood that the population would stabilize, and greater than 50/50 likelihood of widespread or complete extirpation in National Forests within the range of the northern spotted owl. This provides no latitude for natural catastrophes and uncertainties in knowledge.

LOW - It is highly unlikely that the species' population would stabilize, and there is high likelihood of widespread or complete extirpation in National Forests within the range of the northern spotted owl. There is no latitude for natural catastrophes and uncertainties in knowledge.

Conclusions—This example demonstrates the feasibility of evaluating vast numbers of plant and animal species, and the need to consider the full array of species in a habitat planning program. Assessing all species avoids the problems related to using ecological indicator species, indicator guilds, or featured species in management planning. The investment in time, money, and personnel for this scale of venture, however, precludes its use in everyday management. Thus, information and databases, developed for this project, on ecological requirements of each species are being prepared for publication and general use (Thomas and others 1993), to avoid "set-up" costs associated with gathering such basic data for future assessments.

This example demonstrates the potential of multiple-species evaluations and planning. However, Thomas and others (1993) emphasized the need to treat these viability evaluations and proposed mitigations as preliminary management hypotheses needing further quantification, refinement, and testing. Still, this multiple species approach, even within these limits, is a big step toward ecosystem management.

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Continued total reliance on a species-by-species approach to preserve biodiversity likely will fail because of inefficiency and economics, and the associated direct and opportunity costs (Thomas and others 1993:8).

The three examples chosen for this chapter highlight the vast differences in approaches possible for multiple-species and ecosystem management. Each case presents unique solutions to different management needs. For species groups requiring conflicting habitat and landscape attributes—interior environments of habitat patches and species edges or several types of habitat patches—the elk habitat management example illustrated one approach to combining management direction. The fish habitat management example emphasized how to consider zoogeography, site history, geology, and habitat ecology of aquatic systems in developing optimal management regimes for cold-water fishes. Consideration of ecosystem processes will become a greater focus in species management over time. The old-growth species management example demonstrated that requirements of all species of a biotic community can indeed be considered; that effects on potential viability can be qualitatively judged to help identify species requiring additional management consideration;

that new standards and guidelines for helping ensure long-term viability can be crafted to meet the needs of an entire biotic community; and that scientific uncertainty and unknowns can be directly factored into viability evaluations and management recommendations.

What is the need to evaluate species and habitats in such detail? If species extinctions and speciations (evolution of new species) occur naturally, do we need to concern ourselves with such in-depth analyses? Records indicate that natural extinctions occur typically over a much longer time (2 to 4 orders of magnitude longer) than the life of National Forest management plans. Local extinctions have occurred not at constant rates over recent geologic history, but rather in sporadic episodes, such as the local extinctions of many forest dwelling plant and animal species from the Mount St. Helens 1980 eruption and from the prehistoric floods of the Columbia River (McPhail and Lindsey 1986). Speciation occurs over even longer periods than the recent human induced global "extinction spasm," about 3 to 5 orders of magnitude longer than the life of management plans.

Historical local and global extinctions of species are not a reasonable justification for accepting local extirpation of species resulting from management activities as natural events. Lynch (1989) investigated several modes of speciation. His results suggest that 71 percent of species extinctions through geologic time were due to one species evolving into several new forms and not due to irreparable loss to the lineage. Therefore, extinction is also the result of creative, generative processes in addition to degenerative, destructive ones. Extinction as an evolutionary process is often misperceived by laypersons as the end of a lineage. The accelerated loss of species resulting from recent human activities is clearly a separate and distinct phenomenon in geologic history.

The regulations implementing NFMA call for insuring viability of all native and desired nonnative species within each planning area (National Forest, 36 CFR 219.19). Given the present state-of-the-art, even predictions of effects, during 100 years—that result from implementing a relatively short-term, 10-year forest management plan-cannot begin to balance long-term speciation with short-term extirpation and local extinctions. But to rationalize local, management—caused extirpations by citing natural speciation is to submit to the tyranny of short-term decisions and to ignore the creative aspects of long-term evolution of new life forms. One of the three tenets of ecosystem management—conserving or restoring natural biodiversity—would be violated.

For many species, the question becomes: At what finest scales of space and time is it acceptable to allow local extirpations yet still maintain the population and species throughout the planning area, physiographic province, and region? The answer must vary according to several factors: degree of rarity of the species and its selected habitat(s), or of a unique habitat; mandates of policy and dint of an accepted recovery plan for threatened or endangered species; and ecological attributes of the species, such as its metapopulation dynamics, degree of vagility, dynamics of immigration and emigration, and degree of habitat and resource specificity. For example, clearcutting an old-growth stand eliminates habitat for brown creepers (*Certhia americana*) on that site, yet the local population may continue to survive throughout the subwatershed if other old-growth forest stands persist. On the other hand, the same clearcut stand might have been the only location of colonies of red tree voles (*Arborimus longicaudus*) in the subwatershed. We must also consider that, for featured species such as ungulate game species, disturbance is necessary for producing substrates, cover, or resources for some life needs, such as forage.

Another example is instructive for threatened species management: the recent controversy over protection of a small bird—the California gnatcatcher (*Polioptila californica californica*)—and protection of the highly fragmented coastal sage scrub of southern California. In this case, developers, conservationists, and government agencies are seeking a common solution to conserve the bird's remaining ecosystem, only 10 percent of which remains, rather than seek litigation focused on protecting the species per se under the Endangered Species Act. One proposal has as its compromise the destruction of parts of the bird's habitat under agreement by developers if adequate amounts of critical habitat are set aside elsewhere to sustain the bird and its ecosystem. In a coarse-filter approach, this plan would also provide for at least some of the habitat's other associated species, avoiding future legal battles over other threatened or endangered species associated with the coastal sage scrub habitat. The concept of protecting habitat of multiple species is fast becoming the favored approach to avoid conflicts over single-species management (Reinhold 1993).

This approach fits well with one of the primary stated purposes of the Endangered Species Act: "...to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved..." (Endangered Species Act, Sec. 2(b)). The outcome of the case with the California gnatcatcher might determine how future maintenance and recovery planning for threatened and endangered species are handled on both private and public lands. Likewise, the Forest Service must decide how to interpret its legal mandates, such as the Endangered Species Act and the National Forest Management Act.

Another consideration in managing for featured species in an ecosystem context is meeting the needs of Native Americans. Management programs are culturally biased for species of high commodity and social value to Euro-Americans to the exclusion of those favored by Native Americans (Hunn 1990). For instance, suckers, mountain whitefish, lamprey, and redside shiners are commonly considered "trash" fish by Euro-American sportsfishers. These same species are considered food fishes by the Sahaptin peoples (Native Americans of the mid-Columbia Plateau) and are held in high regard. Sculpins and crayfish are considered sacred icons and are not to be harmed. Black tree lichen (*Bryoria fremonti*), pine nuts, acorns, huckleberry, camas roots, and other plants are prized food items. Historically, many armed conflicts arose because of the insensitivity of Euro-Americans to adverse land use impacts on camas. This can cause conflicts in management policy because Native Americans retain rights to resources on lands ceded to the Federal Government. These rights have the same legal standing as treaties between sovereign nations. In keeping with Forest Service policy, it is incumbent to manage Forest Service lands to ensure substantial and sustainable yields of resources deemed important to native peoples.

In the end, successful integration of species and ecosystem management lies in clearly defining specific objectives at several scales of time and space and in proactively integrating all objectives. Successful integration of objectives can only be achieved by following the three basic principles of ecosystem management: to maintain or restore biodiversity, to maintain long-term site productivity, and to maintain sustainability of natural resource production. All activities, plans, and projects should be weighed at local, provincial, and regional scales against these three principles.

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GLOSSARY

Alien (or exotic) species—Species of fish or wildlife, deliberately or accidentally introduced in an ecosystem, which have become permanently established; alien species often, but not always, have undesirable effects on native species; called "non-native species" in National Forest Management Act regulations (36 CFS 219).

Anoxic—Devoid of oxygen.

Bretz floods—A series of catastrophic floods caused by the rupture of glacial dams approximately 19,000 to 12,000 years ago; the energy released by these floods (about 380 cubic miles of water dropping 3700 feet in elevation) has been likened to the explosion of a hydrogen bomb every 36 minutes over a 10-day period.

Coarse-filter management—Conservation of land areas and representative habitats with the assumption that the needs of all associated species, communities, environments, and ecological processes will be met; compare with fine-filter management.

Connectivity (of habitats)—The linkage of similar but spatially separated vegetation stands (such as mature forests) by patches, corridors, or "stepping stones" of like vegetation across the landscape; also, the degree to which similar habitats are so linked.

Cumulative effects—The addition of effects (positive or negative) on achieving a forest management objective, such as maintaining the viability of a wildlife species, from forest management activities conducted outside the immediate project area or before the current project.

Cumulative effects analysis—The prediction of cumulative effects through modeling and analysis (see cumulative effects).

Detritus—Decaying organic matter.

Ecological indicator species—A species whose population size and trend is assumed to reflect population size and trend of other species associated with the same geographic area and habitats; one type of management indicator species (see management indicator species).

Ecosystem management—Conservation and use of natural resources that serves to maintain biological diversity, long-term site productivity, and sustainability of resource production and use; the new management paradigm on National Forests.

Ecotone—See habitat edge.

Exotic species—See alien species.

Edge—See habitat edge.

Featured species—A species of fish or wildlife for which specific management guidelines have been written.

Fine-filter management—Specific management for a single or a few species rather than broad management for a habitat or ecosystem (see coarse-filter management).

Flagship species—A highly charismatic species, typically a large-bodied mammal or bird, that is in some peril of extirpation and that can be managed so as to also provide habitats and resources for other species; compare with umbrella species.

Floodplain—The terrestrial environment subject to periodic flooding.

Forest health—As a specific condition, refers to a growing forest having many or all of its native species of plants and animals; as a management objective, refers to maintaining or restoring the capacity of a forest to achieve health.

Fragmentation—See habitat fragmentation.

Guild—A set of species that share a common habitat (such as old-growth forests), that use the same resources (such as foods), or that use resources in the same manner (such as mode of foraging).

Guild indicator—Alternate name for indicator guild (see indicator guild).

Habitat edge—The margin where two or more vegetation patches meet, such as the boundary of a clearcut next to a mature forest stand; also see habitat fragmentation.

Habitat fragmentation—The splitting and isolating of patches of habitat, typically forest cover (but could also apply to grass fields, shrub patches, and other habitats); habitat can be fragmented from natural conditions, such as thin or variable soils, or from forest management activities, such as clearcut logging.

Habitat interior species—See unitype species.

Harvestable surplus—The number of game animals or fish that can be removed from a population, typically for hunting or fishing, that will not cause the population to unduly decline; sustainable harvestable surplus is the number that can be removed every year or harvest season for an indefinite period of time.

Herbivory—Eating vegetation.

Hydrograph—A graph of water discharge versus time.

Indicator guild—A set of species sharing a common habitat or resource use characteristic, for which management guidelines can be directed; all species of an indicator guild are sometimes assumed—erroneously—to respond identically to management activities and environmental conditions.

Indicator species—See management indicator species and ecological indicator species.

Lotic (ecosystem or environment)—Moving water environments such as streams and rivers.

Management indicator—An index or attribute of the landscape that can be quantified to simplify land management planning to determine the success of implementation of planning guidelines; one type of management indicator is the management indicator species.

Management indicator species—A species of fish or wildlife for which a set of management guidelines have been written, chosen for simplifying land management planning; one type of management indicator species is the ecological indicator species.

Mid-seral forest—See seral stage.

Multitype species—A wildlife species that uses and requires two or more kinds of habitats or successional stages.

Piscivory—Eating fish.

Population viability—The likelihood of continued existence of well-distributed populations of a species throughout National Forests for a specified period of time; for example, high population viability connotes a high likelihood of continued existence of well-distributed populations throughout at least their current range on National Forests for a century or longer.

Potamon—Fishes that live in the lower, warm water, sluggish zone of stream systems; compare with rhithron.

Relict populations—Organisms once distributed broadly but now confined to remnant habitats over the landscape.

Rhithron—Fishes that live in the upper, cold water, swift zone of stream systems; rhithron are cold-water stenotherms (see stenotherm); compare with potamon.

Riparian habitat (or vegetation)—Vegetation associated with edges of, and directly influenced by, streams, rivers, ponds, lakes, and other water bodies.

Seral stage—The developmental or growth phase of a forest stand with characteristic structure and plant species composition; typically, young-seral forest refers to seedling or sapling growth stages; midseral forest refers to pole or medium sawtimber growth stages; and old or old-seral forests refers to mature and old-growth stages.

Sere—The entire set of all developmental or growth phases of a forest stand; each developmental phase is a seral stage (see seral stage).

Species-habitat matrix (or matrices)—A table, book, or data base depicting the relative quality of vegetation associations and seral stages for meeting various life needs of wildlife species, typically for reproduction, feeding, and resting or cover.

Stenotherm—Fishes with very narrow physiological tolerances to temperature.

Subwatershed—Portions of watersheds (see watershed) defined for management purposes; in the Blue Mountains of eastern Washington and Oregon, subwatersheds typically range from 1,000 to 10,000 acres.

Succession—The orderly and predictable development of vegetation on a site dominated first by grasses and forbs, then by shrubs, then by trees; typically follows stand-replacing disturbances such as clearcut logging or other regeneration timber harvests, or crown fires; see sere and seral stage.

Successional stage—See seral stage.

Sustainable harvestable surplus—See harvestable surplus.

Umbrella species—A large-bodied, popular species having a large home range and broad requirements for habitats and resources, that can be managed to also provide habitats and resources for other species; similar to flagship species.

Unitype species—A wildlife species that uses and requires only one kind of habitat or successional stage, typically their interiors.

Viability—See population viability.

Watershed—The entire drainage area of a river and its tributaries; in the Blue Mountains of eastern Washington and Oregon, watersheds typically range from 10,000 to 50,000 acres or larger.

Wildlife-habitat relationships program—A management program under the Fish, Wildlife, and Botany Units of USDA Forest Service that develops and applies scientific information on species-habitat relationships for managing habitats; an analogous program deals with fish-habitat relationships.

Windthrow—Trees blown over by the wind.

Young-seral forest—See seral stage.

Zoogeography—The study of the evolutionary history and prehistoric and current distributions of animals.

Marcot, Bruce G.; Wisdom, Michael J.; LI, Hiram W.; Castillo, Gonzalo C. 1994. Managing for featured, threatened, endangered, and sensitive species and unique habitats for ecosystem sustainability. Gen. Tech. Rep. PNW-GTR-329. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 39 p. (Everett, Richard L., assessment team leader; Eastside forest ecosystem health assessment; Hessburg, Paul F., science team leader and tech. ed., Volume III: assessment).

The traditional approach to wildlife management has focused on single specieshistorically game species and more recently threatened and endangered species. Newer approaches to managing for multiple species and biological diversity include managing coarse filters, ecological indicator species, indicator guilds, and use of species-habitat matrices. Such modeling approaches each have strong as well as weak points, including conflicts among objectives for species with disparate needs. We present three case examples of integrating management for single species with management for multiple species and ecosystems: managing elk habitat in the Blue Mountains of eastern Oregon; managing for sustainable native fish faunas in eastern Oregon and Washington; and managing plant and animal species closely associated with old-growth forests in the Pacific Northwest.

Keywords: Wildlife habitat, fish habitat, biodiversity, eastside, threatened species, endangered species, sensitive species, management indicator species, species planning.

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