ECOSYSTEM MANAGEMENT AND BIODIVERSITY CONSERVATION: APPLICATIONS TO INLAND PACIFIC NORTHWEST FORESTS

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ABSTRACT

We examined two alternatives for development of ecosystem management approaches on public lands in the Inland Pacific Northwest (i.e., east of the Cascade Mountains in Washington and Oregon to the western edge of the Rocky Mountains): intensive management and biodiversity conservation. Intensive management is based on the belief that because inland forests are inherently prone to disturbance (e.g., fire, insect and fungal pathogens), and because the likelihood of catastrophic (stand-replacement) disturbances has risen dramatically during the past century, such systems must be managed at landscape scales by commercial thinning and pruning, timber harvest, soil fertilization, and prescribed fire management to (1) reduce the spread of catastrophic fire and epizootics and/or mimic the role once played by natural disturbances (e.g., timber harvest mimics stand-replacement fires, livestock grazing mimics native herbivory); (2) increase efficiency levels of timber extraction while simultaneously maintaining biodiversity; and (3) provide a broader balance of seral stages than currently exists in watersheds made homogenous through custodial management (e.g., wilderness preservation strategies). Biodiversity conservation argues that ecosystem processes and biodiversity cannot be effectively maintained at regional scales absent a system of large reserves, riparian corridors, buffer zones, and matrix areas that are managed to maintain important and rare biodiversity components. We argue that ecosystem management approaches for inland forests must be solidly based on fundamental biodiversity conservation principles to maintain ecosystem integrity, provide adequate margins of safety for species vulnerable to intensive management, and conserve all components, processes, and resources of inland forests. Such processes cannot be effectively maintained or restored by managing commercial forests to attain structural features resembling native forest systems. A mixture of regulation, expansion of existing reserve networks, and targeted incentives that encourage cooperation from the private sector dependent on natural resource extraction on public lands should be a priority of land management practices throughout the region.

Keywords: biodiversity conservation, ecosystem management, disturbance, fire, Inland Pacific Northwest, intensive management, public lands, reserves

"If biodiversity protection is a principal goal, then we need to state it as an objective for management and not a constraint." (Forest Service Chief Jack Ward Thomas, Voices at the Summit, Ancient Forests in the Balance).

INTRODUCTION

The Columbia River Basin of the Inland and Pacific Northwest encompasses areas east of the Cascade Mountains in Washington and Oregon to the western edge of the Rocky Mountains in Idaho, Montana, and portions of northern Nevada (Figure 1). The forests of this vast region, often called inland forests of the Pacific Northwest, have been the subject of recent scientific assessments (Henjum et al. 1994), forest health assessments (Everett et al. 1993; O'Laughlin et al. 1993; Sampson and Adams 1993), and Environmental Impact Statements (EIS) currently being prepared by the USDA Forest Service (USFS) and USDI Bureau of Land Management (BLM) as part of ecosystem management projects in the region. Within the last century, inland forest ecosystems have been substantially altered by anthropogenic factors, including timber harvest (Everett et al. 1994; Robbins and Wolf 1994; Henjum et al. 1994), livestock grazing and concomitant spread of noxious weeds (Irwin et al. 1994; Wissmar et al. 1994), hydroelectric dams (Wissmar et al. 1994, McIntosh et al. 1994), fire suppression (Agee 1993, 1994), and mining and urbanization (Robbins and Wolf 1994). Such events have contributed to shifts in plant species composition (Agee 1994; Everett et al. 1993, 1994; Johnson et al. 1994), wide-spread population declines in native salmonids (*Oncorhynchus* spp.) and other aquatic species (McIntosh et al. 1994; Henjum et al. 1994), and substantial loss and severe fragmentation of old-growth forests (Henjum et al. 1994; Everett et al. 1994). Anthropogenic factors have also transformed regional landscapes to such an extent that instead of being effective at dampening the spread of disturbance, conditions now magnify disturbance events (Perry 1988, 1993; Franklin et al. 1989; Agee 1993, 1994).

Much of the controversy surrounding proposed ecosystem management strategies for the inland forests stems from different interpretations on how best to control current disturbance regimes and restore functions and processes within degraded ecosystems. We argue that established principles of conservation biology support the implementation of a system of strict protected areas, buffer zones, corridors, and matrix areas managed for biodiversity conservation as the best way to restore degraded ecosystems and to conserve all the components, processes, and resources of inland forests. Moreover, ecosystem management strategies that advocate intensive management implemented at

Published in proceedings of "Ecosystem Management in Western Interior Forests" held May 3-5, 1994, Spokane, WA, USA.
Compiled and edited by Richard L Everett and David M. Baumgartner, Washington State University Extension, Pullman, WA.
(Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912.) MISC0228. 245 pp.

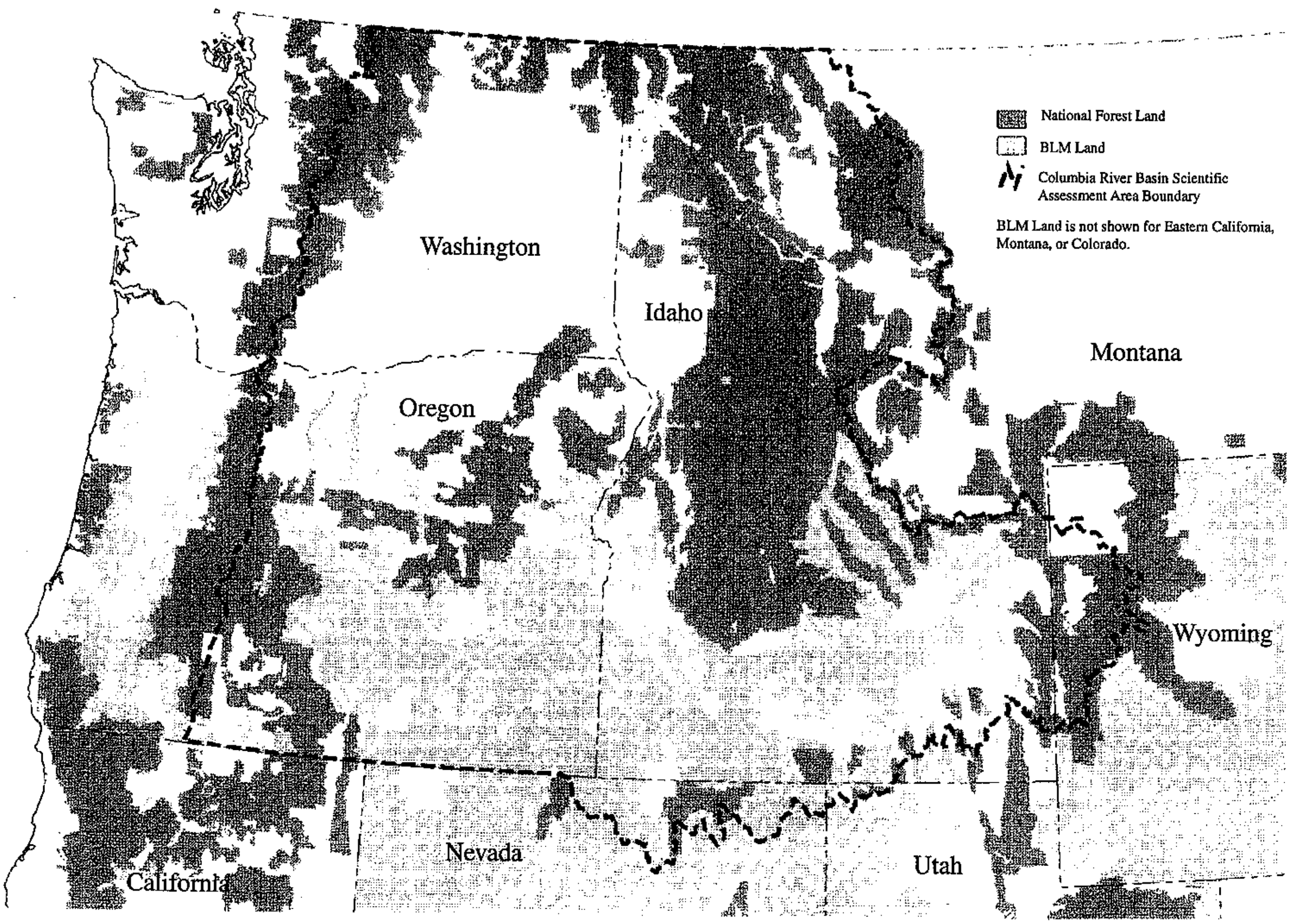

Figure 1.—Columbia River Basin Scientific Assessment boundary, which roughly parallels the boundary of the basin itself. Environmental Impact Statements are currently being prepared for basin lands east of the Cascade Mountains in Washington and Oregon to the continental divide in northwestern Montana.

landscape scales to control disturbances are likely to perpetuate conditions for catastrophic disturbances and the degradation and loss of inland forest communities, species, and other natural resources.

Pre-European Settlement Forest Ecosystems

Inland forests are characterized by five major forest series: (1) ponderosa pine (*Pinus ponderosa*) on dry sites widely distributed throughout the region; (2) Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and grand fir (*A. grandis*) ("mixed-conifer forests") in transitional zones between low elevation and high elevation subalpine forest; (3) lodgepole pine (*P. contorta*) on infertile, coarse material soils and in frost pockets; (4) western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) in maritime-influenced areas of the northern Rockies; and (5) subalpine fir (*A. lasiocarpa*) and mountain hemlock (*T. mertensiana*) just below tree line (Agee 1994). Throughout pre-European (herein referred to as pre-1850) settlement, wildfire and epizootics helped to shape regional landscapes by creating patches of various forest seral stages and shifting mosaics of different ecosystem types (Everett et al. 1993, 1994; Johnson et al. 1994). Moreover, the persistence of many native communities and species relied on periodic disturbances. For example, population dynamics in lodgepole pine forests were triggered by the complex interplay of wildfires and subsequent invasion by mountain pine beetle (*Dendroctonus ponderosae*) and fungal cohorts that returned biomass to soils and prepared forests for new growth and the next fire cycle (Geiszler et al. 1984; Gara 1988). Such species maintained multi-aged forest structures and gap-phase dynamics in lodgepole pine forests (Stuart et al. 1989).

Fueling the present controversy over disturbance processes is the scarcity of reliable data on disturbance regimes in pre-1850 forests. Both the magnitude and frequency of regional wildfires

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are thought to have varied considerably in these forests depending on vegetation types, climate regimes, and edaphic conditions (Agee 1993, 1994). Pre-1850 wildfires in this region are estimated to have ranged from periodic (5-15 years) surface fires in dry and warm ponderosa pine and Douglas-fir types to infrequent (>100 years) stand-replacement crown fires (>25,000 acres) in mesic and cool western redcedar and western hemlock forests (Agee 1993, 1994). Similarly, the extent, frequency, and intensity of forest alteration associated with epizootics likely varied widely depending on forest type, history, and physical factors.

At the heart of the inland forest debate is the concept of ecosystem integrity, or "the ability of an ecosystem to support a balanced, integrated, adaptive biological system having the full range of elements (genes, species, assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, metapopulation processes) expected in the natural habitat of a region" (Karr 1991, 1994). Ecosystem integrity also describes the capacity of an ecosystem to persist in association with natural disturbances, even if they are predictably frequent, intense, or widespread. In pre-1850 forests, fire and insect outbreaks periodically influenced large areas, yet inland forest communities persisted because the patchy nature of disturbance events and the presence of large tracts of contiguous forest allowed recolonization of disturbed areas. Together these processes maintained the dynamic mosaic of habitat types and seral stages at regional scales. In particular, pre-1850, old-growth forests occurred over a much greater percentage of the landscape than today due to continuous recruitment through forest succession. In addition, most stand-replacing fires, even those as large as the Yellowstone fires in 1988, were not monotonous scorches but a mosaic of many patches of varying fire intensity (Noss and Cooperrider 1994:187).

At local scales, pristine forests were characterized by numerous features that dampened the impact of disturbance events, including: (1) moisture gradients (e.g., bottomland and riparian forests) that acted as firebreaks within and among watersheds (Agee 1994); (2) older trees with insulated barks (e.g., Oregon white oak (*Quercus garryana*), Douglas-fir, ponderosa pine, and western larch (*Larix occidentalis*)) that enabled them to survive periodic fires (Agee 1994); (3) intact humus and duff layers that helped maintain high moisture content levels in forest understories; (4) diversity of tree species, genetic variability within tree populations, and complex age structures that provided forests with resiliency to insect and fungal outbreaks; and (5) diverse populations of natural insect enemies (e.g., insectivores, parasitoids) and fungivores that helped reduce the frequency and magnitude of epizootic events (Campbell et al. 1983; Torgersen in press).

Ecosystem Management Strategies for Inland Forests

Although many strategies exist, two approaches have been at the center of debate on ecosystem management in the inland forests: intensive management and biodiversity conservation (Table 1). The intensive management approach (Lippke and Oliver 1993 refer to this as landscape management; Everett et al. 1993 refer to this as ecosystem management) is based on the belief that because inland forests are inherently prone to disturbance (e.g., fire, insect and fungal pathogens) and because the likelihood of catastrophic (stand-replacement) disturbances has risen dramatically over the past century due to suppression of fire (Agee 1993, 1994) and epizootic events (Everett et al. 1993), such systems must be intensively managed at landscape scales to (1) reduce the spread of catastrophic fire and epizootics and/or mimic the role once played by natural disturbances (e.g., timber harvest mimics stand-replacement fires; Everett et al. 1993); (2) increase efficiency levels of timber extraction while simultaneously maintaining biodiversity (Lippke and Oliver 1993); and (3) provide a broader balance of seral stages than currently exists in landscapes made homogenous through fire suppression and wilderness designation (Lippke and Oliver 1993; Everett et al. 1993). Intensive management includes commercial thinning and pruning, timber harvest, prescribed fire, and soil fertilization that is broadly applied across forested landscapes (Lippke and Oliver 1993). Preservation of old growth or other rare biological communities is considered "custodial management," to be used on a limited basis and primarily as a short-term strategy for preserving unique species or habitats (Lippke and Oliver 1993; Everett et al. 1993; Johnson et al. 1994). The basic tenets of this approach have also been discussed at numerous workshops on ecosystem management and forest health within the region (e.g., Sampson and Adams 1993; O'Laughlin et al. 1993).

The biodiversity conservation approach (Table 1; Noss 1992; Rojas 1992; Franklin 1993; Grumbine 1990, 1994; Noss and Cooperrider 1994) argues that ecosystem processes and biodiversity cannot be effectively maintained at regional scales absent an adequate system of reserves. This strategy assumes that (1) large reserves well-distributed across biogeographical regions are necessary for maintaining biodiversity and ecosystem processes; (2) reserves should be, wherever possible, well-connected by corridors of sufficient size to allow species to persist within corridors and disperse across to adjacent reserves and matrix areas (i.e., those areas managed primarily for timber production; USFS and BLM 1994a); and (3) matrix areas must also maintain important and rare biodiversity components. In this paper, we argue that the biodiversity conservation approach is superior to intensive management for maintaining ecosystem processes and biodiversity in disturbance-prone systems such as the inland forests. Greater ecological integrity conferred by this approach also helps ensure the long-term persistence of forest resources.

The Focus on Public Lands

Because public lands in the Columbia River basin may be the last refuge for many declining species in the region, we primarily evaluated these two alternatives for application to lands managed by the USFS and BLM. Public lands within the basin support 191 federally-listed threatened and endangered plant and animal species, 1,100 candidate species (pers. comm., J. Blackwood, Eastside Ecosystem Management Team, 1994), 76 native salmon populations at high or moderate risk of extinction (Nehlsen et al.

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Table 1.—Contrasting intensive management and biodiversity conservation approaches for inland forests of the Pacific Northwest.

	Intensive Management	Biodiversity Conservation
Reserves	No additional reserves needed; preservation of limited areas of old growth or other rare structures.	Additional reserve network needed based on critical ecosystem size, spatial dynamics, and disturbance considerations. •core reserves •non-timber extraction reserves •restoration areas
Corridors	Existing stream buffers will suffice as corridors.	Additional corridors of sufficient width and habitat suitability are needed •inter-reserve corridors •inter-regional corridors •matrix corridors
Matrix	Managed primarily for timber extraction.	Managed first to maintain biodiversity and ecosystem processes while allowing for timber extraction as a secondary activity. •source pools •keystone resources
Management Objectives	Emphasize timber harvest, restoration of degraded systems, and biodiversity conservation. Dampen epizootics and catastrophic fire events.	Emphasize biodiversity conservation, restoration of degraded systems, and limited timber harvest Maintain epizootics and disturbance events in reserves, minimize spread of such processes in buffers and matrix areas.
Management Activities	Timber harvest and associated activities practiced at landscape scales. •Extensive clearcutting/selection cutting/salvage areas •Extensive thinning/pruning •Extensive prescribed fire management	Restoration/timber harvest. •Limited selection cutting/some salvage in matrix •Limited thinning/pruning in restoration areas •Extensive prescribed fire management

1991; Wissmar et al. 1994), and a federal candidate resident fish, the bull trout (*Salvelinus confluentus*) (McIntosh et al. 1994). In addition, public lands contain the best remaining blocks of habitat for numerous invertebrate species whose diversity we are just beginning to understand. Recent intensive surveys in northwestern Montana have found forest invertebrates to be much more diverse and habitat specific than was previously recognized (pers. comm., M. Ivie, Montana State Univ., 1994).

Escaping Ecological Misconceptions

Before land managers can effectively restore degraded ecosystems and conserve both biodiversity and natural resources in the region, five major misconceptions in forest management that permeate agency thinking and, in some cases, are used to support the intensive management approach must be dispelled: (1) clearcut and other logging activities are substitutes for natural disturbance; (2) epizootic species will quickly destroy forests if not intensively controlled (i.e., "cut the trees to save the forest"); (3) species diversity is maximized in modified landscapes; (4) native forests (i.e., forests containing populations of native species and natural processes within their natural range of variation) can be restored solely through management; and (5) the ecological effects of commercial cattle and sheep grazing, as these activities are currently practiced on public lands, mimic the effects of herbivory by native herbivores.

1. Clearcuts and Other Timber Harvest Practices Are Not Substitutes for Natural Disturbance

Wide-spread clearcut harvesting is not compensatory for the role once played by natural disturbances. Clearcut harvesting seldom leaves sufficient densities and size classes of standing dead trees (snags), live trees, and down woody materials to maintain species associated with old-growth conditions (see Thomas et al. 1993; Henjum et al. 1994 for species lists) at pre-disturbance population levels (McComb et al. 1993). Such forest attributes were part of pre-1850 landscapes and were present at

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sufficient levels even in fire-prone systems. Commercial harvesting also (1) disturbs soil horizons (Harvey et al. 1994) and associated microfauna and fungi that play vital roles in ecosystem processes such as nutrient uptake, disease resistance (e.g., mycorrhizae conferred resistance), mycorrhizae dispersal, and decomposition (Shaw et al. 1991; Niemela et al. 1993); (2) reduces habitat complexity, a critical factor in maintaining ecosystem integrity (Holling 1990); (3) removes from the system significant quantities of nutrients, minerals, and trace elements that have been sequestered over centuries and retained in the biomass through slow decomposition (Harvey et al. 1994); (4) reduces or removes bottomland habitats that are critical corridors and resource, fire, and weather refugia for wildlife, and are important source pools for recolonization of adjacent disturbed areas; and (5) damages aquatic habitats through siltation, reduction in stream complexity, and increased water temperatures (McIntosh et al. 1994). Moreover, extensive road building to access logging units does not mimic natural processes and has driven old-growth forests further below their natural range of variation in many heavily roaded watersheds (pers. comm., W. Romme, Ft. Lewis College, 1994).

Critics of the biodiversity conservation approach argue that forest management in the region is undergoing a paradigm shift away from the intensive forestry we describe to less intensive (e.g., selective logging, "New Perspectives Forestry"; Salwasser 1992) harvest methods. It is important to recognize that the effects of logging on ecological processes and species populations are scale dependent and that logging, whether based on traditional forestry or less intensive methods, applied extensively throughout the region will produce similar consequences to regional biodiversity if appropriate refugia are not part of an ecosystem management approach. For example, some forestry practices that produce small, infrequent, and widely-spaced disturbances with long rotations and that leave large overstory components (e.g., snags and residual old-growth components) may have little overall effect on native ecosystems and their biodiversity components. However, over the last century, the amount of inland forests altered by clearcuts and other types of logging practices dwarfs the area of forest that would have been disturbed by natural disturbances. The associated loss and fragmentation of original forest habitat has been so severe (see Henjum et al. 1994) that original ecological interactions and population dynamics of species associated with old-growth forests have certainly been significantly impacted. In addition, rotation ages in commercial forest landscapes seldom allow sufficient time for such ecosystem processes to recover from timber harvest and do not mimic historic intervals between fires that once maintained older forest types. Commercial forest rotation ages in this region range from 80 to 100 years on private lands (e.g., Boise Cascade Corporation and Potlatch Timber Company) and 80 to 140 years on public lands (e.g., Boise National Forest, Clearwater National Forest, Idaho Panhandle National Forest, ID; Colville National Forest, WA). Unless commercial forest rotation ages are extended (at least 200 years in some forest types; Noss and Cooperrider 1994:189; Henjum et al. 1994), some systems may never recover from logging or may require substantial investment in restoration where possible.

Selective logging and related types of harvest methods also (1) seldom leave sufficient densities of large trees and woody debris necessary to sustain viable populations of cavity-nesting and woody-debris dependent species; (2) remove large trees that are disease and fire resistant (e.g., salvage logging); (3) leave seed trees and "wildlife trees" that are prone to blowdown (e.g., partial cuts); and (4) may remove remaining overstory trees during subsequent entries (e.g., shelterwood with overstory removal). The cumulative impacts of multiple entries into watershed areas and soil compaction resulting from the use of heavy logging equipment, road building, and helicopter landing platforms to access logging units can be as severe as the more intensive forestry methods (Harvey et al. 1993; pers. comm. J. Belsky, Oregon Natural Resources Council, 1994). Moreover, thinning, pruning, and salvage operations if conducted at landscape scales to accomplish forest health objectives (see Lippke and Oliver 1993; O'Laughlin et al. 1993; Everett et al. 1993; Sampson and Adams 1993) will likely damage sensitive soils, remove coarse woody debris from the system, and present additional stresses to vulnerable species. *If ecosystem management is to be successful, we must recognize that commercial logging, at the scale it is currently practiced (whether intensive or extensive), represents a severe and persistent disturbance that occurs in addition to natural localized disturbance events and broader stresses from variation in rainfall and temperature.*

2. Epizootic Species Are Essential Components of Ecosystems

The life cycles of epizootic species such as mountain pine beetle, Douglas-fir Tussock moth (*Orygia pseudotsugata*), western spruce budworm (*Choristoneura occidentalis*), and root rots (e.g., laminated root rot, *Armillaria* root disease) are adapted to the dynamic disturbance regimes and heterogeneity of the region's original forests (Geiszler et al. 1984; Perry 1988; Gara 1988). Many species of plants, invertebrates, and vertebrates depend on or benefit from the patches of snags and modified wood associated with outbreaks of epizootic organisms. Small patches of trees affected by insects or fungi are common in native forests, often persisting for decades without increasing in area (Asquith 1990; van der Kamp 1991; pers. comm., A. Partridge, Univ. Idaho, 1994). Forest health assessments that are based on insect and disease hazard ratings (i.e., presence of susceptible host vegetation or "symptomatic" trees; Lehmkuhl et al. 1993; O'Laughlin et al. 1993) overlook the beneficial roles played by epizootics in maintaining ecosystem processes (van der Kamp 1991) and soil fertility (Schowalter and Sabin 1991), the population dynamics of these species (e.g., epizootics often experience "boom and bust" population cycles), chemical defense mechanisms of trees, and the variety of predators, insect parasitoids, and fungivores that suppress and delay population build-ups of epizootics and/or accelerate their decline (Otvos 1979; Schowalter et al. 1986; Torgersen in press). For instance, numerous bird, mammal, ant, fly, and parasitoid wasp and fly species prey on the Douglas-fir Tussock moth, western spruce budworm, and/or mountain pine beetle (Campbell et al. 1983; Torgersen et al. 1984; Torgersen and Mason 1987; Mason and Wickman 1991; Torgersen in press). Logging (Perry 1988) and intensive control

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measures (e.g., pesticide application; Richmond 1979) for epizootic species reduces or eliminates these natural checks and balances and produces conditions where large-scale outbreaks are more likely to occur (e.g., increased availability of stressed trees and higher densities of host species, Lehmkuhl et al. 1993; high mortality and extirpation of natural enemies of insects, Torgersen in press). A high diversity of insectivores, particularly of arthropod predators and parasitoids, appears to help pristine forests resist epizootic events (Perry 1988; Schowalter 1990). Furthermore, maintaining healthy populations of insectivores is a significantly more cost-effective method of managing epizootics than is aerial pesticide application to control outbreaks (see Takekawa and Garton 1984). Despite studies showing local effectiveness of control measures, it is unrealistic for proponents of the intensive management approach to expect similar success at the landscape level given the widespread degradation of native ecosystems at present and the inevitable occurrence of droughts and fires that act as catalysts for epizootic events. Restoring natural factors that dampen the frequency and magnitude of epizootics and managing forests to maintain diverse and abundant populations of natural enemies of insect pests and fungal pathogens (e.g., Langelier and Garton 1986) should be primary objectives of ecosystem management. *Managers should therefore concentrate less on pandemic levels of epizootics and more on the processes that keep such species at innocuous levels during non-outbreak periods* (Torgersen in press).

3. Species Diversity Is Highest In Old-Growth Forests

Sampling Error

Another commonly used, but inaccurate, argument is that the species diversity of a forest will be increased through habitat modifications associated with intensive logging. Clearly, a landscape that has a wide variety of habitat types will support more species, but pristine forests typically maintain a sufficient mosaic of habitat types to permit a broad assemblage of species to coexist over the landscape. This deceptive diversity argument reflects a problem of scale and technique in survey work. Much of the data used to justify this pattern has been derived from counts of larger vertebrates such as birds conducted in very local areas (e.g., Lay 1938; Johnston 1947). Forest-edge habitats created by logging are often highlighted because, at the level of a single locality and survey period, edges typically have high numbers of species due to an overlap of forest and open-area species and the ease of observation in these open habitats. If surveys are conducted at appropriate ecological scales, such as over entire watersheds and other landscape-scale features, and are carried out over several months or years, one would easily find that larger blocks of undisturbed forest (i.e., no disturbance from commercial logging or grazing) are significantly more diverse for the vast majority of taxa, particularly for plants and invertebrates, and are far more ecologically complex than managed forests or forest edges.

Quality vs. Quantity

Species diversity arguments based solely on species richness fail to account for the kinds of species that occupy edge habitat (e.g., weedy and common species along edges vs. rare or declining species in old-growth or interior forest habitats; Noss and Cooperrider 1994:196, 202). Ecosystem managers must concentrate their efforts on conserving species that are particularly vulnerable to human activities, including those that (1) cannot maintain viable populations in managed landscapes dominated by early-and mid-seral stages (e.g., northern spotted owl (*Strix occidentalis caurina)*, northern goshawk (*Accipter gentilis*); see Thomas et al. 1993; Henjum et al. 1994 for additional species); (2) have low reproductive capacity and/or naturally occur at low densities and are primary target species for hunters and poachers (e.g., grizzly bear (*Ursus arctos horribilis*), gray wolf (*Canis lupus*)); and (3) are distributed only within a limited geographic area (i.e., local endemics) or are associated with rare and/or patchily distributed habitat types. No ecosystem management plan can be considered adequate without a strong emphasis on the identification, location, and conservation of all sensitive native species, including rare plants, fungi, and invertebrates.

The Problem with Edges

The conspicuous activity of vertebrates and some invertebrates along forest edges can mask the negative impacts of edges on native forest biotas. Forest edges may function as "ecological traps," concentrating avian nests and thereby increasing density-dependent mortality associated with high predation rates along edges (Gates and Gysel 1978). Changes in microclimate conditions (e.g., increased temperature, desiccation, and wind velocities) associated with edges may extend hundreds of feet (up to 787 feet in one study Chen et al. 1990) into the forest interior. This depth-of-edge influence decreases with forest patch size (Chen et al. 1992). Moreover, highly fragmented forests may contain little core habitat (i.e., unaffected by edges) due to the prevalence of forest edges (Harris 1984; Groom and Shumaker 1993). Thus, large blocks of intact, old-growth forests are best capable of minimizing edge effects and provide important thermal and moisture refugia for interior-dwelling species (e.g., some neotropical migratory birds; Raphael et al. 1988; Finch 1991; carabid beetles; Niemela et al. 1993).

Homogenization of Landscapes

Critics of the biodiversity conservation approach contend that custodial management of wilderness areas and related reserves has contributed to the homogenization of forest landscapes and the loss of early- and mid-successional stages (Lippke and Oliver 1993; Everett et al. 1993; Johnson et al. 1994). Although this may be true for some watersheds in the region (Lehmkuhl et al. 1993), this argument reflects a profound misunderstanding of the distribution of seral stages (especially rare and declining ones) at landscape and regional scales. Clearly, the amount of old-growth forests has been substantially reduced and highly fragmented across the inland northwest, although some drainages still contain larger blocks (Lehmkuhl et al. 1993; Henjum et al. 1994). Thus, although individual watersheds may appear "homogeneous" due to an abundance of one seral stage, these watersheds may possess the last remaining blocks of contiguous old growth within the region. Moreover, within these larger forest blocks, natural disturbance processes will maintain an adequate propor-

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tion of early- and mid-seral stages to support the full suite of native species. We are unaware of any forest species that are declining due to homogenization of landscapes by the replacement of early- and mid-seral stages by late-seral stages. The available evidence indicates the opposite is trueædeclining/or vulnerable populations of species in the region are primarily associated with old growth and their components (e.g., northern spotted owl, northern goshawk, boreal owl (*Aegolius funereus*), flammulated owl (*Otus flammeoulus*), fisher (*Martes pennanti*), and several other species; see Thomas et al. 1993; Henjum et al. 1994). Although information is limited, this is likely to be the case for many plant and invertebrate species as well.

4. Not All Late-Successional Forests Are Old-Growth Forests and Old-Growth Forests Cannot Be Recreated Through Management

One of the most dangerous misconceptions for ecosystem management is the notion that all late-successional forests are biologically equivalent to old-growth forests (i.e., forests that are essentially undisturbed from pre-1850 times). This notion can lead to the myth that humans can restore old-growth ecosystems simply by letting clearcuts and planted monocultures grow back and by "managing" for old-growth structure (e.g., large trees and snags; Oliver 1992; Lippke and Oliver 1993). The species assemblages, structural complexity, and ecological interactions of old-growth forests have formed over millennia. Many of the characteristics of fully functional old-growth systems can only be re-established if there is (1) an adjacent block of undisturbed forest that can act as a source area for species and unaltered ecological interactions associated with old-growth ecosystems; and (2) if forests are allowed sufficient time to recover from disturbance events. Large blocks of original habitat will provide a richer source for diversity of old-growth species and intact ecological processes. Thus, remaining blocks of original forest should form the core of any viable ecosystem management strategy for inland forests.

5. Commercial Grazing Is Not Ecologically Equivalent To Herbivory By Native Vertebrates

Commercial grazing by sheep and cattle, at the scale it is currently practiced on public lands, significantly alters successional processes and degrades aquatic and understory communities, resulting in an overall reduction of ecosystem integrity (Orodho et al. 1990; Armour et al. 1991; Milchunas and Lauenroth 1993). Grazing by introduced herbivores is not functionally equivalent to herbivory by native species because: (1) cattle and sheep are typically stocked at much higher densities than natural abundances of native herbivores, often exceeding or altering ecosystem thresholds (e.g., reduction of native grasses can shift patterns of tree regeneration; see Gibson and Brown 1992; Orodho et al. 1990; heavy competition from livestock grazing reduces native herbivore populations, Irwin et al. 1994); (2) forage preferences and grazing behaviors of cattle and sheep (e.g., close cropping by sheep) differ markedly from those of native herbivores and many native plant species are not resilient to these new pressures (Rummell 1951; Madany and West 1983; Skovlin 1991; Wuerthner 1992); and (3) high stocking densities and the heavy weight of cattle commonly cause significant damage to aquatic habitats such as streams, seeps, bogs, and riparian communities (Armour et al. 1991; Irwin et al. 1994). In addition, livestock grazing has contributed to population declines of salmonids in the west (Wuerthner 1992; Irwin et al. 1994), as well as the decline of 5 federally threatened and 12 candidate bird species, and 10 endangered, 3 threatened, and 4 candidate mammal species in Arizona (Wuerthner 1992). Extensive grazing can also lead to accumulation of down woody fuels and associated increases in fire hazards (Zimmerman and Nuenschwander 1984). *Resource managers must therefore recognize commercial grazing, as it is currently practiced, is a widespread, pervasive, and significant factor lowering ecosystem integrity and adversely changing community composition.* Therefore, we recommend that commercial grazing be prohibited from all areas primarily designated for conserving native species and ecosystem processes.

Adequate Margins of Safety

The provision of an adequate margin of safety (i.e., large blocks of protected native forests) for species populations and ecological processes against extirpation from natural fluctuations in environmental conditions and resources and from anthropogenic disturbances represents a key difference between intensive management and biodiversity conservation. In addition to being important source pools, large blocks of native forests are critical for buffering species populations and ecological processes from fluctuations in environmental conditions that could drive species below extinction thresholds. Species populations periodically drop to low levels due to stochastic variation, mortality factors (e.g., predation and disease), natural disturbances, or changes in resource levels and climate over time. Intensive management over the entire inland forest landscape poses an additional stress on populations that could result in (1) greater and/or more frequent fluctuations in populations over time; (2) longer periods for populations to recover from disturbance; and (3) declines to extinction threshold (Holling 1973; Berger 1990; Wilcove 1993).

If ecosystem-management approaches for inland forests include development of models to assess species viability under different management scenarios, as was the case for westside forests (i.e., west of the Cascade Mountains, USFS and BLM 1994a), such models must include adequate margins of restored ecosystems. For instance, the strategy originally developed for the northern spotted owl by the Interagency Scientific Committee (Thomas et al. 1990) and later adapted for use in the westside Forest Plan (i.e., Option 9, USFS and BLM 1994a), allows for the near-term loss of up to 21% of approximately 4.5 million acres of remaining owl habitat (i.e., medium-large conifer, multi-story forest; FEMAT 1993, Table IV-10), assuming a net gain in habitat conditions over 50-100 years as commercial forests begin to mature. However, there is evidence that the rate of decline of owl populations is accelerating due to a decrease in the survival of adult females, low juvenile survival during dispersal, and other factors that could lead to owl extirpation within significant portions of their range in the near-term (Harrison et al. 1993).

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Ecosystem management approaches for inland forests should avoid this tendency to rely on restoration activities while permitting further degradation of old-growth forest during declining population phases.

Intensive management proponents have not addressed the critical fact that species require habitat refuges or demographic buffers during periods of stress and population declines. The intensive management approach provides only limited refugia and no adequate margin of safety for vulnerable species. As a consequence, ecosystem integrity will continue to be poor or deteriorate as many native species decline or are extirpated. A system of large, well-connected, protected areas must be established to provide adequate margins of safety from management uncertainties and natural environmental variation (Lande 1987; Grumbine 1990, 1994; Hobbs and Huenneke 1992; Noss 1992; Wilcove 1993; Schemske et al. 1994; Noss and Cooperrider 1994).

ELEMENTS OF THE BIODIVERSITY CONSERVATION APPROACH

In order to be consistent with biodiversity conservation goals, ecosystem management needs to be soundly based on four fundamental conservation principles: (1) representation of all native ecosystem types and seral stages across their natural range of variation in a system of protected areas (reserves); (2) maintenance of viable native populations in natural patterns of abundance and distribution; (3) maintenance of ecological and evolutionary processes; and (4) responsiveness to short- and long-term environmental change (Noss 1992; Grumbine 1994; Noss and Cooperrider 1994:129). Because the biodiversity conservation alternative emphasizes maintaining species populations and processes through a mixture of reserves, buffers, and matrix areas (Table 1), we argue that it is more consistent with these four fundamental conservation principles than the intensive management approach.

We recommend establishing a network of reserves with varying degrees of management, including (1) inviolate core reserves where natural disturbance events are allowed to run their course and human activities are restricted to low-impact recreation and research; (2) non-timber extraction reserves that function similar to core reserves but also permit extraction of "special" forest products (e.g., fungi, pine cones; USFS and BLM 1994a); and (3) restoration areas where silviculture is used to restore degraded systems and pre-1850 disturbance cycles (Figure 3). The major concepts of this approach have already gained wide acceptance as the model for biosphere reserves and, in general, effective conservation of biodiversity and natural resources in managed landscapes (e.g., see Noss and Cooperrider 1994).

Core Reserves

Proponents of intensive management argue that existing reserves (e.g., designated wilderness areas, national parks) are sufficient for maintaining regional biodiversity. Regional forest health assessments fail to address the importance of establishing a network of reserves to complement existing protected areas in order to maintain native biodiversity and species that are vulnerable to intensive management (e.g., Everett et al. 1993; Lippke and Oliver 1993; O'Laughlin et al. 1993). Although the establishment of additional core reserves amounts to custodial management (Everett et al. 1993), we feel that inland forest ecosystems cannot be effectively restored nor will regional biodiversity be maintained unless core reserves are designated as refugia for species vulnerable to intensive management. Designated wilderness areas and national parks cannot provide suitable protection for vulnerable species alone because (1) they have been typically chosen for their scenic rather than biological value (Noss 1991, 1992;Wright et al. 1994); (2) they tend to contain disproportionate amounts of high elevation and rocky terrains (Noss 1991); (3) lack sufficient representation of important ecosystem types (Noss 1991; Wright et al. 1994; Noss and Cooperrider 1994:172), particularly old-growth forests (pers. comm. J. Karr, Univ. Washington, 1994); and (4) are often of inadequate size or number to encompass landscape-level processes such as disturbance, patch dynamics, and between-community fluxes of organisms and materials (Noss 1991, Noss and Cooperrider 1994:172). Moreover, most national forest Research Natural Areas are too small (<2,500 acres) to effectively buffer edge effects and human-related poaching of wildlife (Noss 1991). Reserves must therefore be (1) large enough to reduce the probability of species extirpations resulting from low population levels, insufficient resources, or human predation; (2) as unfragmented as possible to reduce insularization and edge-related effects; (3) well-connected, wherever possible, to facilitate ecological interactions among patches in fragmented landscapes (Harris 1984; Burkey 1988; Noss 1992); and (4) representative of the full spectrum of ecosystem and demographic processes (e.g., genetic processes; mutualistic, predatory, and competitive interactions) and environmental variation at landscape scales (e.g., biological hot spots, endemism foci, rare and aquatic habitat types; Noss and Cooperrider 1994:99, pers. comm. J. Karr, Univ. Washington). At a minimum, even the large-scale manipulation of ecosystems proposed by intensive management proponents will require adequate "controls" in every habitat type to gauge the effectiveness of management efforts in achieving biodiversity conservation, ecosystem restoration, and commodity extraction goals, and to ensure scientific credibility of ecosystem management approaches. Meeting these requirements will involve supplementing existing reserves with the reserve network proposed under the biodiversity conservation approach.

Large blocks of original habitat must form the core of the protected area system because they offer the best chance to achieve the fundamental biodiversity conservation objectives of ecosystem management (Newmark 1985; Noss 1992; Franklin 1993; Grumbine 1990, 1994; Noss and Cooperrider 1994:138). However, we also recognize the value that small reserves provide in conserving representative communities and species, particularly in regions that are characterized by high levels of beta diversity (i.e., regional heterogeneity, or species turnover along environmental gradients or distance) (Quinn et al., in press). Many invertebrates and rare plants can be effectively conserved within small blocks of original habitat (Olson 1992; Schemske et al. 1994).

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Ecosystem-planning efforts for inland forests must provide a scientifically-based spatial analysis of reserves and harvest areas based on appropriate biological criteria to (1) protect remaining large blocks of old-growth forest (see Henjum et al. 1994 for similar recommendations); (2) minimize fragmentation of remaining low elevation, roadless areas, and contiguous late-successional forests; (3) maximize linkages between habitat blocks, wherever possible; and (4) represent all native habitats and species within a system of protected areas. This analysis should be set up using a tiered approach for prioritizing areas (Figure 2), focusing first on the persistence value of habitat blocks based on landscape parameters of habitat size, shape, location (e.g., intact watersheds), degree of fragmentation, redundancy, and linkages to other habitat blocks; and second, modifying priority habitats on the basis of important biodiversity features such as areas of high species endemism or richness, or rare habitat types such as low-elevation forests. Information on regional patterns of biodiversity for modifying reserve locations should be obtained from GAP analysis (Scott et al. 1993), state Natural Heritage databases, and related biological inventories of endemic, rare, and old-growth associated species. Where inventory data on species distributions are limited, reserves could be located on the basis of important predictors of beta diversity, species richness, and rare habitats, such as environmental gradients (e.g., elevation zones, moisture gradients, ecotonal zones) and unique soil types (e.g., serpentine soils).

The scarcity of large blocks of undisturbed native forests (see Henjum et al. 1994) means that core reserves initially need to encompass large areas containing a mixture of native and modified habitat types with the objective of eventual restoration to a fully functioning native ecosystem (see Figure 3 and discussion of Restoration Areas). Because of the potential abuses and unproven effectiveness of thinning, burning, and salvage operations in restoring native ecosystems, we advocate that management activities intended to facilitate restoration (with the exception of road removal, and thinning and controlled burns in exceptional cases) be excluded from core reserves. In addition, commercial grazing should be recognized as a major factor contributing to the degradation of native communities and the loss of ecosystem integrity, and must therefore be prohibited in core reserves and other conservation areas (e.g., wilderness areas, riparian corridors).

Non-timber Extraction Reserves

Non-timber extraction reserves have been promoted as a means for maintaining biodiversity while simultaneously providing a sustainable economic return to local people and governments (Salafsky et al. 1993). Although this concept has been largely developed in tropical forest systems with burgeoning human populations and associated economic pressures, it may provide economic and biodiversity benefits in inland forests as well. Non-timber extraction reserves would function like core reserves, except they would emphasize extraction of special forest products (e.g., floral greens, moss, pine cones, mushrooms), while maintaining overstory canopies and populations of commodity species at viable levels. In addition, if positioned adjacent to core reserves (Figure 3), non-timber extraction reserves could function to: (1) buffer core reserves from edge effects; (2) minimize frequency of poaching and mortality rates of vertebrates wandering out of protected areas; and (3) provide corridors for wildlife dispersal.

Because of the diffuse nature of trade in special forest products, it is difficult to assess their economic value. However, limited information suggests that the total dollar value of non-consumptive economic values of forests may dwarf those of timber values. For instance, the USFS and BLM (1994a) indicate that special forest products in westside forests were worth at least $70 million annually and provided multiple economic benefits to rural economies. Such reserves could also emphasize recreation as a special forest product, providing that recreational activities are consistent with biodiversity conservation. Guidelines for managing non-timber extractive reserves must be developed carefully, as there is evidence from westside forests that unregulated extraction (e.g., moss removal) can damage and alter ecosystems.

Restoration Areas

During the transition period from degraded forests to systems resembling native forests, restoration areas would be established in locations chosen to enhance landscape-scale ecosystem processes, such as in core reserves or buffer zones. The goal of ecological restoration in these areas should be to produce self-sustaining systems as similar as possible to native biological communities (Angermeier and Karr, in press). To accomplish this, restoration activities will need to be conducted at appropriate spatio-temporal scales that are large enough to incorporate the full range of habitats that would occur under expected disturbance regimes (Angermeier and Karr, in press). Thus, we recommend that small pockets of native habitat and surrounding degraded areas be managed so that the restored habitat eventually acquires functions and biotic components of the smaller original habitats and supplements it through increased size over time (Figure 3). Even small patches of original habitat can contribute as source pools for the restoration of native communities. Degraded watersheds represent the scale at which restoration areas would be minimally effective.

Restoration areas also provide opportunities to reverse the landscape changes associated with loss of biodiversity through the use of restoration forestry approaches (see Noss and Cooperrider 1994:217). As such, we recognize that some elements of the intensive management approach, if conducted at appropriate spatio-temporal scales and designed with the restoration of native forests as primary objectives, can in fact be compatible with biodiversity conservation. An example might include restoring species composition and pre-1850 fire cycles in fire-climax ponderosa pine communities that have experienced shifts in plant species composition due to fire suppression, and other forest types where high stocking densities have contributed to excessive fuel build up and fuel ladders (Agee 1994). Combining light thinning (i.e., thinning from below-the-tree canopy) of shade-tolerant trees (e.g., true firs *Abies* spp.) that have encroached since fire suppression with prescribed fire management could be used in these areas to return fire cycles and fire-tolerant

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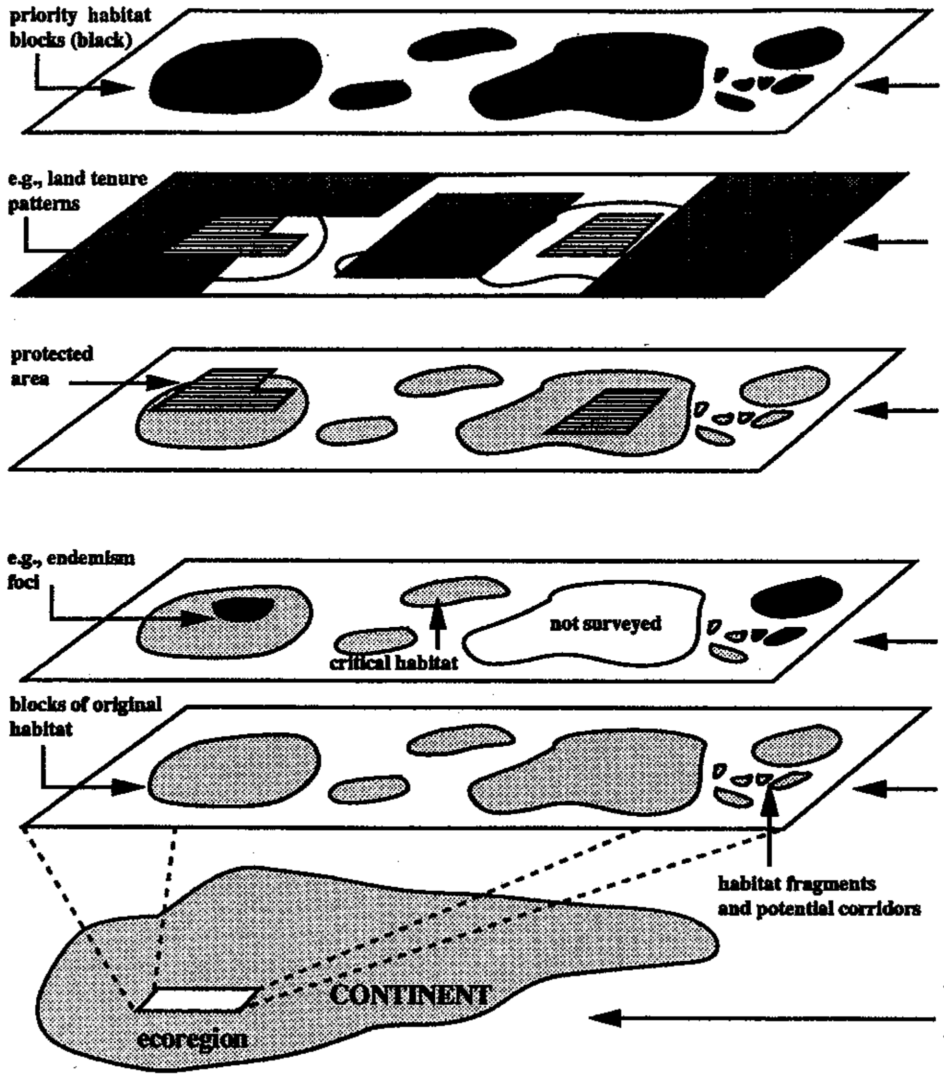

f. Combining all of the layers of data (or coverages) in a GIS-analysis helps to identify **conservation priorities** for the ecoregion. The severity of habitat loss and fragmentation of native forests in the Inland region of the Pacific Northwest necessitate the conservation of all remaining patches of old-growth forests.

e. The fourth tier considers land-use, land tenure, economic activities, and other **social, economic, and political variables** that potentially influence biodiversity conservation. Unlike landscape features and patterns of biodiversity (layers a and b), negative trends in this tier are potentially reversible or can be mitigated by changes in legislation and economic restructuring.

d. The third tier of the analysis examines the size, number, and configuration of **protected areas** within the ecoregion and the effectiveness of **management** within and around conservation units. Most studies begin setting priorities at this level even though most protected area systems have major gaps and some ecoregions lack protected areas. In some cases, the existing network may correspond little with conservable areas from a landscape perpective or they neglect areas of high biological value. Many existing conservation areas fall into these categories.

c. The second tier of the analysis overlays **geographic patterns of biodiversity**, such as zones of varying species richness and endemism, beta-diversity gradients (i.e., the change in species composition with distance or elevation), unique biotic assemblages, critical habitats for migratory species, or refugia from periodic disturbance. Remaining patches of original habitat with low persistence values based on landscape features may need to be assessed as highly valuable due to their biological uniqueness.

b. Important **landscape features** are analyzed for each ecoregion. One would record the number, size, and configuration of remaining blocks of original habitat, their isolation and connectivity, and the presence of intact watersheds. These features are the building blocks for conservation potential and ultimately, the long-term persistence of biodiversity and ecological processes within an ecoregion. *Their loss is essentially irreversible.* We also examine other landscape parameters that undermine conservation of biodiversity, such as the level of fragmentation and the extent of habitat loss. *This essential analysis has largely been ignored in recent attempts to set conservation priorities for ecosystem management in the Pacific Northwest region.*

a. The first step is to classify a biogeographic region into **distinct ecoregions** through consultation with experts and a review of the literature. This achieves the goal of representation - - that all ecoregions are considered in a regional analysis.

Box 1. Analyzing several layers of information is essential for developing effective ecosystem management strategies. Integration of the variables in this figure provide the basis for setting priorities within and among ecoregions. By using a GIS-based approach, the most revealing variables can be isolated and overlaid to yield a better view of conservation potential and threat. Currently, adequate analyses of landscape features and patterns of biodiversity have not been conducted for the Inland forest region.

Figure 2.—Analyzing several layers of information is essential for developing effective ecosystem management strategies. Integration of the variables in this figure provide the basis for setting priorities within and among ecoregions. By using a GIS-based approach, the most revealing variables can be isolated and overlaid to yield a better view of conservation potential and threat. Currently, adequate analyses of landscape features and patterns of biodiversity have not been conducted for the Inland forest region.

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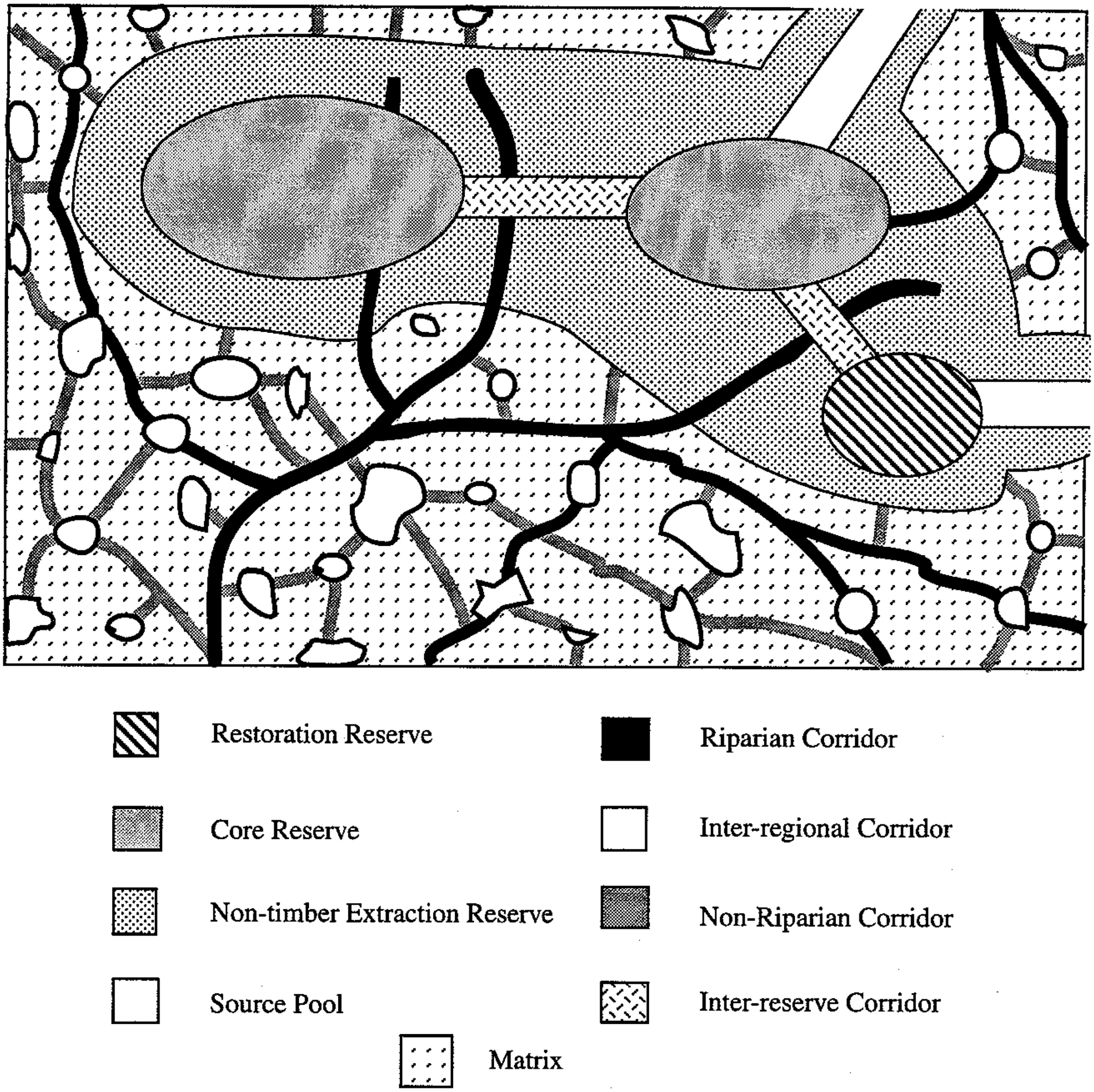

Figure 3.—A conceptual model for reserves, corridors, and matrix areas in inland forests of the Pacific Northwest. Adapted in part from Noss (1992).

ponderosa pine communities to pre-suppression levels. The Forest Service has already begun pilot projects (e.g., San Juan National Forest in southwest Colorado) that combine removal of small trees from heavily stocked second-growth ponderosa pine forests with prescribed fire management and road closures that are designed to eventually return forests to pre-1850 conditions (pers. comm., W. Romme, Ft. Lewis College, 1994). In addition, road obliteration should be a major part of region-wide salmon and bull trout recovery efforts to be performed in restoration areas and associated key watersheds. Everett et al. (1993) estimate that up to 19,000 miles of roads may no longer be needed in eastside forests. Such large-scale restoration activities provide opportunities to implement federal restoration and reforestation programs that employ displaced loggers to rehabilitate degraded watersheds (see discussion of Education and Technical Assistance).

Corridors

Habitat corridors maintain critical large-scale ecosystem processes such as natal wildlife dispersal, seasonal (e.g., altitudinal) or disturbance-induced migration (e.g., migration due to displacement by fire or resource fluctuation), metapopulation dynamics, and gene flow (Noss 1992; Harrison 1992; Lindenmayer and Nix 1993). Although there is little empirical evidence for the use of corridors by wildlife in the inland northwest region, the high level of fragmentation of forest landscapes has disrupted

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natural pathways for species dispersal and contributed to population declines due to insularization effects (see Harris 1984; Noss and Cooperrider 1994:50 for reviews). Therefore, wherever possible, corridors should be maintained to provide conditions adequate for effective dispersal, provide linkages between reserves within (i.e., inter-reserve) and among biogeographical regions (i.e., inter-regional), provide intact altitudinal zones, and help maintain metapopulation dynamics and other large-scale ecosystem processes at local and regional scales (Figure 3). Although we consider corridors an important component of ecosystem management, we feel it is important to recognize that many components of biodiversity can persist in large blocks of unconnected habitat and that unique isolated areas have significant conservation value as well. Indeed, some isolated areas may be critical for representation of unique communities in a protected area system, particularly in areas of high beta diversity (pers. comm., J. Quinn, Univ. California, Davis). Such areas should be as located as close as possible to similar habitat types in order to permit species to disperse among the reserve network (Noss and Cooperrider 1994:155).

The value of riparian areas as wildlife corridors in drier regions such as the inland northwest may be particularly important in facilitating dispersal, since over 90% of terrestrial vertebrate species rely on riparian zones for some part of their life cycle (Thomas 1979). Therefore, we recommend that, at a minimum, sufficiently wide riparian corridors be established to protect aquatic ecosystems and to provide connectivity among reserves. The preservation of riparian corridors is further justified by their benefits to water quality, habitat for riparian obligate species, critical resource and refuge habitats for wildlife, and aesthetic and recreational values (Naiman et al. 1993). However, in matrix areas the complex nature of some landscapes may require the establishment of non-riparian corridors to link blocks of habitat not easily joined through stream or river networks (Figure 3). Such corridors may represent the only means of linking remaining blocks of original habitat in highly fragmented landscapes.

The effectiveness of corridors in facilitating wildlife dispersal will depend on conditions within (e.g., corridor width, habitat suitability) and outside (e.g., landscape context) corridors. In some cases, 300-foot streamside buffers proposed as aquatic habitat and riparian-area management strategies for fish bearing streams in the inland forests (commonly referred to as PACFISH; USFS and BLM 1994b) may also provide corridors for species with small home ranges (e.g., neotropical migrants, small mammals) and those associated with riparian and aquatic areas (e.g., terrestrial molluscs, salamanders; see Thomas 1979; Thomas et al. 1993; Henjum et al. 1994 for species lists). However, such corridors must also be wide enough to minimize edge effects originating from activities in surrounding upland areas and to provide interior habitat conditions for species associated with forest microclimates. For instance, many salamander species are associated with microhabitat conditions found primarily in mature riparian forests (Bury 1983; Welsh 1990); thus, corridors for these species may need to be at least as wide as the depth-of-edge influence (e.g., 787 feet; Chen et al. 1990). Therefore, we recommend that the USFS and BLM begin monitoring corridors of varying widths to determine their effectiveness in facilitating dispersal and persistence of species within reserves and corridors.

In addition, we recommend that matrix areas contain adequate provisions to facilitate the movement of large-predatory mammals such as gray wolf, grizzly bear, and mountain lion (*Felis concolor*) by meeting prey (e.g., ungulates) and security habitat requirements of these species. This can be accomplished by minimizing road densities, prohibiting timber harvesting in remaining roadless areas (see Henjum et al. 1994 for similar recommendations), and including inter-reserve, inter-regional, riparian, and non-riparian corridors wherever possible (Figure 3). A series of small "stepping stone" reserves spaced close to each other and to large core reserves may also contribute to movements of large-predatory mammals (pers. comm., W. Romme, Ft. Lewis College, 1994).

Concerns have been expressed regarding the likelihood of corridors funneling disturbances among reserves and matrix areas, and spreading the transmission of infectious diseases among populations of highly vagile species (e.g., see Hess 1994). However, the benefits provided by corridors in facilitating gene flow, maintaining metapopulation dynamics through recolonization events, providing routes for seasonal and disturbance-induced migration, and enhancing habitat continuity for other large-scale ecosystem processes must be weighed against these potential problems. If populations are managed at viable levels and are well-distributed across regional landscapes, they should be capable of rebounding from or avoiding disease epidemics or other mortality events. Moreover, buffer zones, restoration areas, and the matrix provide opportunities for controlling disturbances outside of the reserve system (see discussions of Restoration Areas and Transition). In contrast, the potential cost, lack of scientific evidence for the efficacy of intensive management in preventing catastrophic disturbances, and historical precedents from other exploited ecosystems warn against implementing intensive management.

Matrix Areas

Proper matrix design and management can enhance the compatibility of timber extraction with biodiversity conservation objectives. Matrix areas would support some forms of timber extraction that are compatible with biodiversity conservation, including elements of the intensive management approach (e.g., limited thinning and salvage, partial cuts), providing they are managed to minimize edge effects, reduce contrast with adjacent reserves (Franklin 1993), and are conducted at appropriate spatio-temporal scales that minimize impacts. Matrix areas also provide opportunities for implementing new forestry (Swanson and Franklin 1992; Salwasser 1992; Noss and Cooperrider 1994:210) and ecoforestry (Hammond 1992; Nixon 1994) approaches.

Within matrix areas, all remaining fragments of old-growth forests should be retained to act as wildlife refugia and source pools for species and ecological processes for the regenerating matrix (see Henjum et al. 1994 for similar recommendations). We recommend that the USFS and BLM monitor recovery with

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different configurations of source pools to develop appropriate guidelines for protection of these "pocket" forests (e.g., LS/OG3 forests, see FEMAT 1993). Additional blocks of maturing forest should be designated for future old-growth nodes where appropriate. Adequate buffer zones on streams that permeate matrix areas regardless of whether streams are fish bearing (Henjum et al. 1994) are necessary to effectively protect all aquatic habitats and biota, maintain critical riparian habitats for wildlife, and provide connectivity among habitat blocks. In addition, non-riparian habitat corridors (Figure 3) would link habitat blocks not easily joined through riparian networks. Timber extraction practices should minimize road building and disturbance of soil horizons with heavy equipment and be limited to small-scale logging operations (e.g., selection and partial cuts, limited salvage and thinning; Noss and Cooperrider 1994:178), providing that such activities do not attempt to compensate for associated reductions in total board feet harvested nor contribute to additional fragmentation of relatively contiguous old growth and roadless areas. Commercial forest rotation ages should be extended in matrix areas to allow sufficient recovery of logged forests and development of old-growth characteristics. Keystone resources such as large trees, snags, woody debris, and complex understories should be retained within the matrix to meet habitat requirements of insectivorous species. For instance, snag and large tree densities within the matrix should be maintained at levels consistent with 100% of the maximum potential population densities of cavity-nesting birds (see Thomas et al. 1979: 69, 74) or should be based on current snag density models available for some species (e.g., 3-4 snags/ac >15 in dbh for pileated woodpeckers (*Dryocopus pileatus*); Bull and Holthausen 1993). In addition, woody debris should be retained at appropriate size and decomposition classes for insectivorous small mammals and herpetofauna (see Maser et al. 1979), and regenerating forests should be managed to enhance vertical and horizontal structure for insectivorous forest birds (see Langelier and Garton 1986; McComb et al. 1993). Large trees and snags should be positioned along edges to help "feather" boundaries between matrix areas and reserves (Perry 1988; Franklin 1993). Maintaining such heterogeneity within the matrix will strengthen natural mechanisms for moderating both fire and epizootic events, minimize contrast between the matrix and adjacent reserves, and provide habitat for dispersal of species across reserves.

THE TRANSITION

Opponents of an expanded reserve system argue that current conditions in inland forests will promote catastrophic disturbances that will destroy whole forests before a reserve system of native forests can fully regenerate. Clearly, for reasons discussed above, restoration of native forest conditions and retention of remaining native habitats are the best ways to enhance or maintain overall ecosystem integrity. Continuous intensive and extensive management of inland forests will only contribute to the potential for catastrophic fires on a regional basis. To avoid catastrophic losses and still achieve a functioning reserve system, managers should implement 5, 10, 20, and 50 year objectives (or some other set of year intervals appropriate for different habitat types) with adaptive management options to achieve ecosystem restoration targets. The adaptive management process should be used to fine-tune regional forest plans should the results of monitoring reveal poor ecosystem integrity and/or continued population declines of vulnerable species. In addition, management activities should not eliminate source pools, reduce population viability of vulnerable species, or compromise ecosystem integrity. In areas where adequate patches of undisturbed forests exist to act as source pools, natural regeneration and succession will effectively recreate native forest conditions over time. Intervention in the form of thinning or control burning may be necessary in cases where there are no other options for reducing the risk of catastrophic fires or promoting the regeneration of pre-1850 forest communities, but these activities must be curtailed and access roads obliterated when monitoring suggests that natural processes will be sufficient for meeting the long-term habitat objectives for an area.

The rash of fire that has plagued the inland northwest during the current drought cycle has prompted some opponents of the biodiversity conservation approach to step-up timber harvest in order to "fire-proof" forests (e.g., Congressional Record - House testimony of Idaho Congressman Larry LaRocco, July 14, 1994). We recognize that at local scales some forms of intensive management may temporarily reduce the spread and frequency of fires (e.g., thinning of stands with high stocking densities). However, at landscape scales the increased homogenization of forests combined with management prescriptions that reduce fire frequencies may contribute to long-term increases in fire severity and spread of fires across homogenous landscapes, particularly through the loss of bottomland, moist forest pockets and large fire resistant trees. Moreover, intensive timber management contributes to additional fire hazards due to greater road access and associated increases in human-caused fires, operation of logging equipment, slash build-up following logging, and the associated decrease in moisture content of forest understories. *In addition, managing to fire-proof forests will contribute little to the maintenance of population viability of species vulnerable to forest management practices and is inconsistent with the intent of Congress to manage the national forests to maintain viable populations (e.g., National Forest Management Act 1976).* The biodiversity conservation approach provides the best alternative for meeting population viability requirements on public lands while allowing fire cycles to gradually return to pre-suppression levels during transitional periods.

Because prescribed burning programs on public lands have historically been out-of-step with the build up of fuels in the region, the role of prescribed fire in ecosystem management will need to be increased substantially in order to achieve process-oriented ecosystem management goals. For instance, Mutch et al. (1993) recommend a 10-fold increase in the number of acres presently burned each year to reduce fuel loads within fire hazardous landscapes and Agee (1994) indicates that about 830,000 acres per year would need to be burned to reintroduce fire on a 15-year rotation in ponderosa pine ecosystems and on a 30-year cycle in mixed-conifer ecosystems. Such large increases in prescribed fire management will need to be accomplished using less-severe burn prescriptions to minimize smoke emis-

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sions and build public support (Little 1990; Agee 1993:181). For instance, Agee (1993:402) recommends that to accomplish fuel reductions in fire hazardous landscapes and to minimize smoke emissions, fuel loads will need to be gradually and incrementally reduced in one or two low-intensity burns followed by periodic fire management until fire cycles are restored. In addition, because of the extensive area requiring prescribed fire management and air quality concerns, fire management sites will need to be prioritized for fuel reduction with high priority sites (e.g., near towns) receiving treatment first and secondary sites receiving treatment if public acceptance improves (Agee 1993:402).

Large blocks of public land provide the best opportunities to restore fire cycles through a combination of prescribed fire management and natural (i.e., lightning induced) fires that are allowed to burn without human intervention. For instance, natural fires in large, core reserves located in remote areas should be allowed to burn in order to maintain ecosystem processes and natural fuel levels. Forests that have not experienced human-induced fire suppression and associated fuel build-ups provide an example of areas that should be allowed to burn. However, some intervention will still be required to prevent the spread of fire from core reserves located near towns and rural areas. Providing fuel-limited zones (e.g., limited thinning and/or prescribe fire management) around core reserves will help to minimize the risk of fire escaping from core reserves and begin the slow process of returning fire cycles to historic levels (Agee 1993:393). Restoration areas and matrix areas provide opportunities for positioning fuel-limited zones around core reserves.

Reserves in fire-prone regions of the inland northwest will need special measures to ensure that rare and degraded ecosystems and old-growth forests are well represented in the event of fire loss. Because the biodiversity conservation approach emphasizes representation of native habitat types in redundant patterns at regional and landscape scales (Noss 1992; Noss and Cooperrider 1994:140), rare communities are more likely to persist during the transition to restored ecosystems and fire cycles. In addition, selecting reserves to be as large as possible and increasing the size of reserves through restoration activities should reduce the likelihood of dramatic shifts in landscape dynamics due to disturbance events (Turner et al. 1994).

Restoring fire cycles in areas designated for recovery of endangered or threatened species will also require special measures to ensure persistence of critical habitat areas during transitional periods. Fire cycles should be experimentally reintroduced in small fire-management cells to minimize the risk of crown fires in critical habitat and to determine appropriate fire treatments through the adaptive management process (DellaSala et al. 1987; Agee 1993:397). In addition, underburning in these areas may reduce horizontal complexity that could contribute to diminished habitat suitability for prey species of spotted owls (Agee 1993:400).

INTEGRATING SOCIETAL VALUES WITH ECOSYSTEM MANAGEMENT

The consensus in conservation science is that ecosystem integrity must take precedence over all other management goals to adequately ensure long-term viability of natural resources, the species they support, and the survival of local economies dependent on natural resource extraction (e.g., Grumbine 1994; Noss and Cooperrider 1994:210). For this to occur, society must recognize that ecosystems have limits and operating within these limits must become a political and economic reality (Karr 1993). Ecosystem management policies currently being developed by the USFS and BLM in the region stress societal values (e.g., Everett et al. 1993) and consensus building within rural communities to help guide resource utilization through an adaptive management process (i.e., to blend ecosystem sustainability with human desires, Salwasser 1992). However, conflicts between proponents of biodiversity conservation and intensive management will likely intensify as demands for natural resources compete with ecosystem integrity goals, especially given the dire economic status of many rural communities in the region. Conflicts over proposed solutions to declining anadromous fisheries and severe fires in the inland Northwest continue to generate significant controversy. In utilizing consensus building and socio-economic factors, federal agencies must establish ecosystem integrity as the cornerstone of their ecosystem management policies. Attempts to placate all stakeholders without first maintaining ecosystem integrity will result in (1) fragmentation of remaining native habitat areas needed to maintain vulnerable species at viable levels; (2) fewer management options for future generations; and (3) uncertainty for public and private natural resource management plans (e.g., future endangered species listings).

We recognize that to implement a biodiversity conservation approach that accomplishes the above stated goals, participation by rural communities and landowners must be made a critical element of the process. However, to effectively participate in ecosystem management planning communities will require significant federal assistance and technology transfer to develop sustainable and diversified economic infrastructures. The President's Forest Plan for the westside forests sparked debate over the need and methods for achieving economic diversification in timber dependent communities. While the vast resources contained within public lands have significance to all citizens of the United States, policies and programs that target natural resource dependent communities in proximity to national forests are a cost-effective way to create greater public awareness for biodiversity conservation. Developing support for a biodiversity conservation approach that recognizes the need for community stability translates into political will to address the conservation and economic challenges facing the inland Northwest. The inland forest region is held in mixed ownership with an intermingling of federal, state, tribal, and private industrial and small land holdings. The following discussion enumerates mechanisms for rural communities to reduce their reliance on national forest timber harvests, encourage biodiversity conservation on private lands, and enable communities to make informed economic

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development decisions. It is in no way comprehensive and makes two basic assumptions: (1) maintaining biodiversity and ecosystem integrity is critical for sustaining local economic development; and (2) providing technical and financial information and assistance will help create an environment in which stewardship of natural resources becomes a long-term and implementable goal for communities in the region.

Four key areas of the status quo must change for ecosystem management to be compatible with environmentally sound economic development: (1) removal of "perverse incentives"; (2) increased availability of financial incentives to landowners and communities that engage in biodiversity conservation activities; (3) improvement of community and regional level educational and technical assistance opportunities for both private land stewardship and economic diversification; and (4) reorientation of federal agencies away from commodity extraction to policies focused on restoring degraded ecosystems.

Removal of Perverse Incentives

Among the public subsidies that encourage short-term and destructive land management practices are below-cost timber sales and grazing fees, loopholes in the federal log export ban, and the private sectors's lack of responsibility for environmental costs associated with extractive activities (Glick 1994, pers. comm., T. Power, Univ. Montana, 1994). Many federal timber sales lose money and cause unnecessary environmental degradation because the USFS accounting methods inappropriately factor the cost of road construction and timber sale preparation (O'Toole 1988:26). Eliminating these perverse incentives would free up funds to restore degraded forests and watersheds and help the USFS develop economic diversification programs for timber dependent communities.

Legislation restricting log exports from federal lands (16 U.S.C. Section 620(a)-(j) 1993) contains loopholes that enable timber to still be shipped abroad by allowing minimum processing prior to export. Closing these loopholes and taxing exports from private lands can deter industry and private forest landowners from seeking short-term economic gains at the expense of regional and national timber markets. Mixing tax penalties with tax incentives and subsidies that support sawmill modernization (Osborn 1992) and secondary manufacturing for wood products (i.e., treated lumber, furniture components, decorative moldings; Mater 1992) can create a positive environment for communities to diversify their wood products industries.

Indirect Perverse Incentives

An obstacle to sound economic development facing many rural Northwest communities is their reliance on federal timber harvests for jobs and tax revenues. Federal law allocates 25% of the gross receipts from national forests within county boundaries in lieu of the government paying property taxes (O'Toole 1988:4). This relationship between timber harvests and county income makes communities resistant to reduced timber sales. Where national forest lands comprise a significant portion of the land base, the government should provide appropriate compensation to counties by using revenues generated from a variety of federal programs. This can be accomplished in part through the federal payments in lieu of taxes program that authorizes payments to communities according to a standardized formula if the payments exceed timber receipts. Replacing timber receipts, which vary annually, with a system of "fair and consistent compensation" for tax-exempt public lands (Barber et al. 1994:95) would provide counties with a more stable source of revenue from which to build up their infrastructure and to secure a stronger position for expanding their economic activities. The role of non-timber commodity production (i.e., recreation, fisheries, non-timber forest products) needs to be expanded to help maintain county revenues while simultaneously reducing the disproportionate amount of proceeds generated from timber harvests (pers. comm., R. O'Toole, Cascade Holistic Economic Consultants, 1994). Raising user fees for non-timber activities according to market demand would also provide funds for restoration projects on public lands.

Incentives

Incentives for economic diversification offer communities opportunities to smooth the transition to more sustainable economies and to help ease some of the conflicts facing the region. Although traditionally described in monetary terms, incentives encompass a wide range of options designed to encourage and facilitate desired types of behavior. Some tools available to foster active participation in ecosystem management by communities include fiscal and tax incentives, private sector partnerships, federal and state educational and technical assistance programs for non-industrial forest landowners, retraining and education programs for unemployed workers, and legislative initiatives designed to encourage local and regional economic activity. These types of incentives can serve several goals related to biodiversity conservation: (1) provide benefits to participating landowners through voluntary compliance rather than penalties for noncompliance; (2) assist timber-dependent communities and other single source economies with economic diversification (Barber et al. 1994:103); (3) promote sustainable land-use management practices (Brown et al. 1993); and (4) ensure ecological and economic benefits are available to subsequent generations (Hutter 1992).

Fiscal and tax incentives can be used to restore forest productivity on private lands and encourage long-term capital investments for reforestation and refitting of locally owned sawmills to process smaller logs obtained from second-growth forests and restoration areas. In addition, tax credits for biodiversity conservation on private lands can offset expenses incurred in ecosystem protection. Linking implementation of state or federal approved management plans for restoration or protection activities with other technical assistance and cost-sharing programs would simplify the process for landowners and provide a series of financial incentives spread out over time.

Incentives can also be used to encourage community logging operations on public and private lands. Small-scale harvests (e.g., limited salvage and selection cuts accessed by existing roads) can be less damaging to the surrounding area than clearcuts if they are properly spaced across the landscape and utilize

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human labor and low-impact harvest methods. Selling timber through community sales and processing logs locally would also generate revenue streams that flow directly into local communities (pers. comm., L. Lombardi, Clearwater Forest Watch Coalition, 1994).

Private Sector Partnerships

Innovative financing programs and technical assistance from the private and non-profit sectors to aid development of non-timber product markets (Johnson 1993) should be supported by low-interest loans and investment tax credits that encourage sustainable environmental businesses (Barber et al. 1994). Examples of such enterprises include timber certification programs. In Oregon, the Rogue Institute for Ecology and Economy has a community forestry program that certifies timber managed for long-term sustainability. WalMart, Inc. purchased 200,000 board feet of wood certified by the Rogue Institute for use in its Kansas "Eco-Mart" store (Johnson 1993). This example suggests the potential for "green" products to move beyond "specialty markets" (e.g., custom furniture, woodworking), and enter mainstream markets where goods are less costly and more widely available.

The increasing interest in environmentally sustainable businesses is creating investment opportunities for the private sector as well. Partnerships that bring together communities, non-private, and private organizations to develop these business enterprises can encourage biodiversity conservation by tapping into societal and economic needs at the local and national level. EcoTrust, a Portland-based non-profit environmental organization, and the Shorebank Corporation recently joined together to provide financing, market development, and technical assistance to businesses and development that encourage community based conservation in the Pacific Northwest and southeast Alaska (Johnson 1993; pers. comm., E. Kellogg, EcoTrust, 1994). Partnerships between the private and non-profit sectors targeting rural communities can offer start-up and long-term assistance for local communities interested in making the transition to sustainable economies.

Comprehensive Planning

The quality of life in communities of the Pacific Northwest is attracting an increasing number of people and businesses. This relocation surge can provide an economic boost for timber-dependent towns. However, projected region-wide increases in population will place additional pressure on an already stressed system. As part of an integrated ecosystem approach, long-range planning at the community level is essential to ensure that uncontrolled growth does not threaten natural resources, ecological integrity, and the culture of the region. The problems facing property owners during the 1994 fire season epitomize the need for a biodiversity conservation approach that incorporates the natural disturbance cycles of the region. Economic enterprise zones that concentrate development away from fire-prone areas together with no-build fire zones and appropriate fire building codes need to be incorporated into regional and county development plans to help minimize property losses due to fire.

Inadequacies in the Free-Market Approach to Incentives

The intensive management approach (Lippke and Oliver 1993) assumes biodiversity protection and timber production are compatible. A corollary to this premise is that incentives make co-managing for both activities cost-effective resulting in greater biodiversity conservation than provided by the existing regulatory framework. It is assumed that land managers will voluntarily manage lands on a sustainable basis as long as they receive adequate compensation for (1) investments that do not generate income from timber production; and (2) financial risks associated with biodiversity protection (e.g., Endangered Species Act compliance; Lippke and Oliver 1993). This approach to incentives continues to emphasize timber values while discounting other forest-associated values. In retaining timber production as the linchpin of an incentives program, the environmental costs of timber production are set at zero (Lippke and Oliver 1993).

Two results follow from this approach: (1) incentives for biodiversity conservation will be ineffectual since timber companies are not held responsible for the true environmental costs associated with logging (The Wilderness Society (TWS) and Environmental Defense Fund (EDF) 1993); and (2) landowners are overcompensated while net societal benefits are reduced because the free-market approach emphasizes using incentives that are based on direct-use values (Lippke and Oliver 1993) while failing to account for non-market conservation benefits (de Groot 1992:133; Brown et al. 1993; Barber et al. 1994:55). One option for countering these results is the imposition of tax penalties for degradation of environmental values due to unsustainable forest practices. Penalties can be used to discourage activities which contradict ecosystem management goals by requiring landowners and industry to internalize a portion of the cost to the public coupled with a concomitant reduction in their monetary gain (Forest Policy Center 1993).

The traditional supply and demand theory, which underlies the approach advocated by Lippke and Oliver (1993), assesses costs and benefits of an activity. Forest products have assignable dollar values, but indirect values (e.g., watershed protection, carbon storage, genetic diversity) are not easily measured. Other components of the total economic value of biological diversity that are grossly undervalued include option values (i.e., the value of having a known or potential resource available for future generations; de Groot 1992:135), and intrinsic values (i.e., simply knowing a species exists; Brown 1993). Since these values lack organized markets to measure them against, market-based incentives favor commodity production at the expense of biodiversity conservation.

Using the Market to Advance Biodiversity Conservation

Market-driven incentives that equalize multiple use objectives on public lands can have a beneficial effect on ecosystem management. All users of public lands should share responsibility for their ecologically sound maintenance. Recreation activities, ranging from large numbers of hikers to mountain biking and

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ATVs, involve environmental costs that should be mitigated, at least partially, by the user group to meet restoration objectives and encourage careful use of the resources. Setting recreational, grazing, mining, and other impact fees at fair-market value would also alleviate some of the institutional burden on forest managers to maximize timber receipts (O'Toole 1988:196, TWS and EDF 1993), create pressure to engage in more efficient and environmentally-sound resource extraction activities (TWS and EDF 1993), and provide additional funds for restoration projects. Replacing funds channelled to counties from timber harvests with funds derived from market-level user fees has the potential to be a more sustainable revenue source given current declines in timber harvests.

Education and Technical Assistance

Educating local and regional stakeholders on the connections between biodiversity conservation, economic development, and unsustainable timber management is also critical to integrating human needs with effective ecosystem management. This includes acknowledging that the timber industry itself contributes to the destabilization of local economies through automation, sending logs out of the community for processing, selling harvested lands for residential development, and failing to supply unemployment insurance for laid off workers (Whitelaw and Niemi 1994).

There is a wide array of federal programs designed to assist local economic development and promulgate natural resources stewardship. A basic element of these program must be the dissemination of information to target communities in a format they can utilize and implement. The USFS stresses, as part of its overall mission, the need to help communities become sustainable. To help accomplish this, we recommend that the USFS integrate conservation and socio-economic mandates by supporting technical assistance offices within national forest districts. Such offices should function to help disseminate information on applicable programs and community development models and act as liaisons between non-profit and private organizations interested in linking biodiversity conservation with economic diversification. As part of the administration's movement towards ecosystem management, both the USFS and U.S. Fish & Wildlife Service have created job programs for dislocated timber workers that involve restoration of damaged resources through riparian and streamside enhancement efforts and road obliteration. This type of employment can help offset negative effects associated with reduced timber harvests on public lands. However, congressional appropriations often fall short of federal job and rural assistance program needs and require continued public and agency support for adequate funding levels. Federal programs such as the Forest Stewardship Program (16 U.S.C. §2103) are intended to encourage sustainable multiple-use objectives on nonindustrial private forests by providing funds and technical assistance for reforestation, restoration, and enhancement of small woodlots. The USDA Cooperative Extension Service offers a series of natural resources, forestry training, and environmental education programs targeting landowners, loggers, and other user groups. Such programs should be an integral part of the federal agencies' shift away from commodity extraction to a greater reliance on ecosystem integrity to meet long-term environmental, social, and economic goals.

Providing grants and low-interest loans, instead of outright payments to displaced workers for education, is another avenue that requires refining the federal government's commitment to diversifying rural economies (General Accounting Office 1986). Retraining and education programs can provide long-term employment opportunities, particularly in the Northwest which is experiencing increasing relocation of businesses from other parts of the country.

SUMMARY

The intensive management approach to inland forests is inconsistent with fundamental conservation biology principles and is at odds with similar management strategies developed for the westside forests. Westside ecosystem management strategies have embraced many fundamental components of the biodiversity conservation approach (USFS and BLM 1994a), yet, based on our experience at various ecosystem management workshops and meetings of the Interagency Eastside Ecosystem Management Team (Walla Walla, WA), these approaches are not receiving adequate consideration in the planning process for inland forests (also see Everett et al. 1993 discussion of custodial management). Ecosystems do not operate in "black boxes," nor do they follow political or jurisdictional boundaries. Biodiversity principles need to be applied on both sides of the Cascades in order to sustain ecosystem processes, the species they support, and rural economies dependent on natural resources.

The inland forests provide multiple benefits through biological diversity, timber, recreation and tourism, commercial fisheries, non-timber products, and regional quality of life. Ecological functions of these forests are the underpinnings of a sustainable economic resource base — protecting them through a mix of regulation, natural reserves, targeted incentives, and the removal of perverse incentives should be a priority of land management practices. Finding the right mix will entail participation from local communities, small businesses and industry, federal and state agencies, and the non-profit sector. Incentives alone are not a panacea for the complex ecosystem management issues encountered in the region. It is clear, however, that ecosystem management must address both the present and long-term social and economic needs of humans in order to achieve effective biodiversity conservation.

ACKNOWLEDGMENTS

We are grateful to the following individuals for discussions leading to development of this paper: K. Engel; S. Folger; E. Frost; L. Lombardi; R. O'Toole; A. Partridge; and T. Torgersen. Special thanks to: J. Adams; J. Belsky; C. Hutter; J. Karr; M. O'Brien; D. Perry; T. Powers; J. Quinn; W. Romme; and A. Stahl for manuscript reviews.

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Published in proceedings of "Ecosystem Management in Western Interior Forests" held May 3-5, 1994, Spokane, WA, USA.
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