LANDSCAPES, HUMANS AND OTHER SYSTEM-LEVEL CONSIDERATIONS: A DISCOURSE ON ECSTASY AND LAUNDRY

David A. Perry

"Nature to be commanded must be obeyed."
Sir Francis Bacon

ABSTRACT

Ecosystem management is distinguished by two general features: recognition of how different management approaches influence interconnections and interrelationships (which are the primary definers of ecosystems), and accounting for processes that extend across space and time. Landscape patterns determine the variety, integrity, and interconnectedness of habitats within a region. Landscape patterns also govern flows of energy and matter, hence determine hydrology, microclimate, migration, dispersal (gene flow and the integrity of populations), and the behavior (e.g., rate of spread, intensity) of all types of disturbances. The primary objectives of landscape management (where management includes the option of doing nothing) correspond to the functional roles of pattern in the natural landscape. This paper discusses three objectives in particular: creating and maintaining a proper mix of habitats, creating and maintaining suitable migration and movement corridors, and buffering the energy of natural forces that have the potential to become overly destructive (especially fire, herbivorous insects, and pathogens). Deciding what landscape patterns are most likely to achieve goals requires knowledge of relationships among landscape patterns, habitats, and ecological processes within a given area. It also requires some understanding of the basic principles of two relatively new disciplines, landscape ecology and conservation biology. Restoring historic patterns of disturbance will require restoring dry forest types to a higher proportion relatively open forests dominated by large, fire resistant early successional trees. The major challenge in restoring regional forest health is to heal one set of problems without exacerbating others or creating new ones. This will require careful planning at both the stand and landscape scale, paying particular attention not only to improving tree health, but also to protecting critical habitats, soils, and residual trees.

INTRODUCTION

Before getting into the main topic of this paper, I want to step back and pose the question of why we are all here. For me, and I think for most of us, the issue centers around sustainability. There are a number of things on the table to be sustained: the viability and health of our life support systems, numerous species that keep our life support system running and bring us companionship and beauty, and decent jobs at fair wages. Some of these are automatically compatible with one another, and others are compatible only if we use knowledge, ingenuity, and our will. This initiates the latter process by asking where the tradeoffs are and how we achieve balance among competing values and needs.

The mandate for this task is clear. While it is a basic ecological fact that humans must live from the products of the earth, there is also strong sentiment for protecting resources. Polls clearly show that, by far, the majority of Americans consider themselves environmentalists (in one, conducted by Brent Steele and Peter List of Oregon State University, 90% of respondents nationwide expressed an ethical obligation to protect other species). The popularity of "ecologically-certified" wood products has grown both here and abroad. There is nothing new in the conflicts engendered by the competing goals of utilization and protection. Three strong currents have shaped human societies throughout history—the economic, the ecological, and the ethical (or spiritual)—and every society has either implicitly or explicitly faced the challenge of reconciling them. Whether we like it or not, our region has assumed center stage in this ancient struggle. From my experience in talking with people around the nation and the world, many share Worldwatch President Lester Brown's view that "The Pacific Northwest is the proving ground for sustainability—human progress that does not harm the earth".

Balance is achieved in a democratic society through politics and ethics, not science and technology. But to produce a sustainable society, political and ethical choices must be informed by possibilities and limitations. This is where the scientists and managers come in. Understanding the possibilities and limitations inherent in any ecological/economic system requires, in turn, at least two things: knowledge about how our life support systems work, and creativity in developing technologies that blend with and complement natural rhythms. Put another way, if we wish to sustain the healthy patterns and processes of nature, we must first ask how these patterns and processes sustain themselves, and then use our ingenuity to participate in that sustaining flow. In doing so, we become ecological, as well as economic animals.

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There is an old saying: "after ecstasy, the laundry". Phrases like "ecosystem management" and "humans are part of ecosystems" are what I call statements of ecstasy; philosophical positions that provide important context for societal direction, but yield little or no guidance about what to do on the ground. The balance of this paper deals with issues of laundry, the frequently messy and thankless job of translating philosophy into meaningful action.

The paper proceeds as follows. I begin with the logical starting point for a discussion of ecosystem management—the definition of ecosystem. Having done that, I move to a discussion of basic principles of landscape ecology, conservation biology, and the implications of these principles for management. That is followed by a more detailed look at the issue of forest health and, finally, by a closing section on achieving balance among potentially competing values.

WHAT IS AN ECOSYSTEM?

Ecosystems have the following distinguishing characteristics (Perry 1994).

1. A web of interactions and interdependencies among the parts. Animals and microbes require the energy supplied by plants, and plants cannot persist without animals and microbes to cycle nutrients and regulate ecosystem processes. Note that the interdependencies within ecosystems relate to function, i.e., there must be species that photosynthesize, species whose feeding results in nutrients being cycled, predators that keep populations of plant-eaters from growing too large, and so on. Some system functions may be performed by more than one species, while in other cases a single species plays a unique functional role (such species are called keystones).

2. Synergy, which is the "...behavior of whole systems unpredicted by the behavior or integral characteristics of any of the parts of the system when the parts are considered only separately" (Fuller 1981). Synergy characterizes any system whose components are tied together through interaction and interdependence.

3. Stability, a simple yet complicated concept that does not mean "no change", but rather is analogous to the balanced movement of a dancer or a bicycle rider (Mollison 1990). The processes of disturbance, growth, and decay produce continual change in nature. Stability means: a) changes in ecosystem structure and function are maintained within certain bounds; b) species persist; and c) key processes (such as energy capture) and potentials (such as the productive potential of soil) are protected and maintained.

4. Diffuse Boundaries. Unlike an organism, an ecosystem does not have a skin that clearly separates it from the external world. Ecosystems are defined by connections extended through space and time, integrating every local ecosystem within a network of larger and larger ecosystems that comprise landscapes, regions, and eventually the entire Earth. Any given forest influences, and is influenced by, cities, oceans, deserts, the atmosphere, and forests elsewhere on the globe. Moreover, every local ecosystem produces patterns that propagate through time, communicating with and shaping the nature of future ecosystems. The interconnections among ecosystems that exist at many different spatial and temporal scales result in what is termed hierarchical structure. This simply means that each ecosystem we can define in space comprises numerous smaller ecosystems, and at the same time is part of, and in interaction with, a hierarchy of larger systems.

It follows that ecosystem management is distinguished by two general features: recognition of how different management approaches influence interconnections and interrelationships, and accounting for processes that extend across space and time. Ecosystem managers must understand the historic forces that have shaped ecosystems, and how current management influences future system trajectories. Ecosystem managers must also account for processes occurring across scales from microscopic (e.g., the organisms that cycle nutrients), to landscapes, regions, and ultimately the globe. From the ecological (as opposed to social) standpoint, one of the more striking departures of "new" from "old" forestry is the recognition that (to paraphrase John Dunne) no stand is an island, rather every stand is a part of, and is influenced by, a larger whole. The sum of ecological communities and biomes shape large scale processes such as climate, migration, and the spread of disturbances, and these large scale processes shape the structure of local ecosystems and the smaller scale processes that go on within them. Finally, ecosystem management requires explicit recognition of humans as legitimate components of ecosystems (Bormann et al. 1993), as well as recognition of the unique power of humankind and the responsibilities inherent in that power.

SPATIAL SCALE AND CONTEXT: LANDSCAPES AND REGIONS

Landscape patterns determine the variety, integrity and interconnectedness of habitats within a region. Landscapes are also the medium through which everything moves. By governing flows of energy and matter, patterns of community types and age classes across landscapes determine hydrology, microclimate, migration, and the behavior of all types of disturbances (Turner 1987; Perry 1988; Turner et al. 1993). Insects, pathogens, fire, wind—forces that are relatively innocuous, even beneficial, at certain levels—can become highly destructive in a landscape that magnifies, rather than buffers and absorbs, their destructive energy. Change in landscape pattern during the 20th century is at the root of current forest health problems in the Inland West. My understanding of the ecology of the region leads me to conclude that restoring historic landscape patterns is likely the only solution.

The primary objectives of landscape management correspond to the functional roles of pattern in the natural landscape. I will discuss three objectives in particular: creating and maintaining a proper mix of habitats, creating and maintaining suitable migration and movement corridors, and buffering the energy of natural

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forces that have the potential to become overly destructive (especially fire, herbivorous insects, and pathogens). These objectives are not necessarily compatible with one another, hence, attaining a proper balance requires careful planning, especially at the landscape scale.

At any large scale the forested landscape will comprise a mosaic of different vegetation types, successional stages within a given type, and ownerships. The central questions facing landscape management are what should the mosaic look like and why? This leads in turn to questions about how different mosaics influence the ability to achieve societal goals, and how different ownerships can contribute to these goals. Landscapes are variable in space and dynamic in time, which means that all landscape "pieces" do not function in the same way at all times. One of the many advantages of landscape and regional analysis is that questions concerning differential function can be explicitly addressed (e.g., Can different ownerships play different roles without sacrificing regional goals?)

Figure 1.—Schematic maps of three possible landscape patterns, representing (a to c) increasing levels of conservation. (From Perry 1994, with permission of Johns Hopkins University Press).

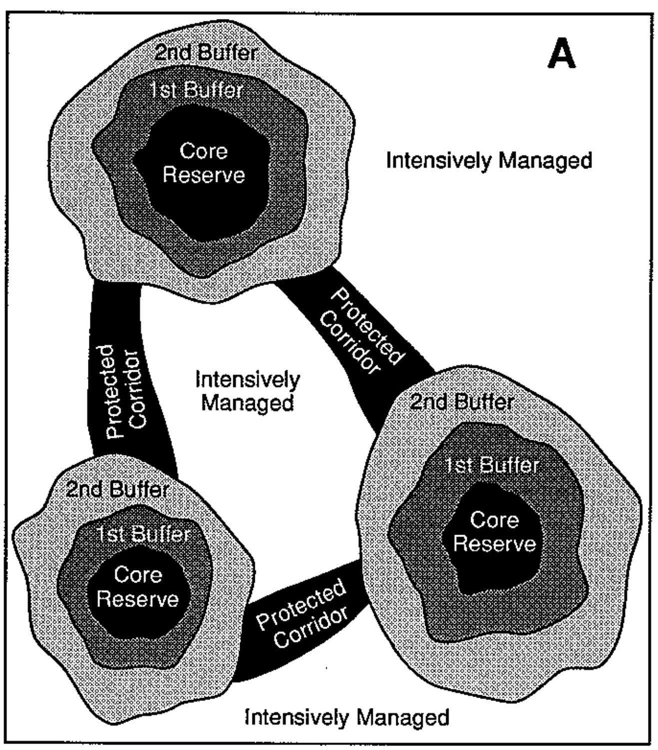
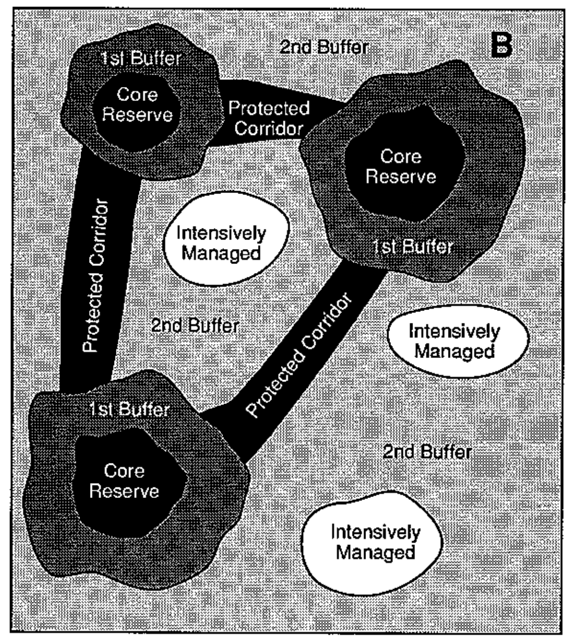
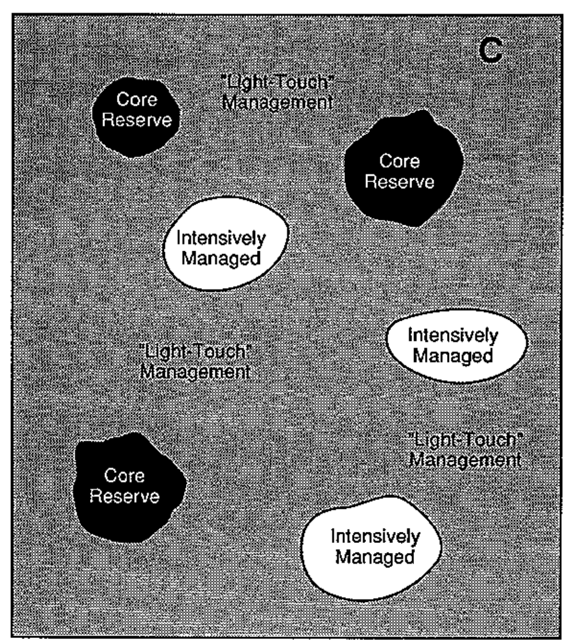


Figure 1 (from Perry 1994; after Noss 1983; Harris 1984) shows schematic diagrams of three possible multiple use landscapes (MUL's; i.e., reserves plus multiple use lands). These simple diagrams are not intended to reflect the real world, which consists of complex political, ownership, and natural boundaries not reflected in the figures. Rather, by illustrating a range of possibilities for landscape patterns as affected by management actions, they are intended as reference points for the discussion to follow in this and succeeding sections.

All three scenarios shown in Figure 1 include relatively lightly managed lands within the matrix that serve as buffers around core reserves and corridors (as proposed by Harris 1984). The two levels of buffer represent increasing utilization as one moves further away from the reserve boundaries. First, buffers might consist of single-tree or group selection harvests, or perhaps





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rotations sufficiently long to keep a majority of forests within the buffer dominated by relatively large, fire resistant trees. Second, buffers might consist of green-tree retention cuts, or moderately long rotations (or both). In Figure 1a, reserves and their buffers are embedded within a matrix consisting largely of forests managed intensively for wood products, the situation that characterized the Pacific Northwest prior to FEMAT (and still does outside of FEMAT areas). This scheme results in relatively high production of wood fibre, at least in the short-run—stability of such a landscape has been questioned because of low diversity and fire hazard (Perry 1988; Perry and Maghembe 1989; Franklin et al. 1989). The ecological tradeoffs include restricted dispersal for species associated with older forests, risk to reserves from fires propagating through plantations (Perry 1993), and no development of older forest habitat to replace losses within reserves.

In Figure 1b, second buffer lands are expanded, and intensively managed lands exist as islands within less intensively managed lands, improving dispersal opportunities and habitat for older forest associates within the matrix. Figure 1c takes protection a step further by expanding the first buffer treatments to cover most of the matrix.

Ignoring the complexities of natural and human boundaries, landscape patterns similar to Figures 1b and 1c can be produced using various combinations of New Forestry cuts (e.g., green tree retention) and long rotations. Long rotations are increasingly seen as not only workable but desirable in western Oregon and Washington, especially when coupled with periodic commercial thinning (N ewton and Cole 1987; Curtis and Marshall 1993). If stands are periodically thinned, Douglas-fir has the capability to maintain good rates of growth well past 150 years. The resultant stands, characterized by relatively large trees, provide good habitat for some old forest associates, and, if fuel buildups are avoided (e.g., through periodic controlled underburns), are relatively resistant to crown fires.

The form a "Multiple Use Landscape" (MUL) might take in any one region would depend on land-use constraints, such as human population density or the degree of private vs. public ownership. A mix of various MUL's might be appropriate for any given region. An approach somewhere between Figures 1a and 1b may be most realistic in areas with a large amount of private land, whereas areas of mostly federal ownership are better candidates for the more active species and landscape protection represented by Figures 1b and 1c. Regardless of the type of MUL that is employed, allocation of land to different uses should be based on biology and ecology, as well as ownership. Gap analysis or a similar approach should be used to site core reserves and their buffers, and marginal lands (steep slopes, fragile soils) should be left untouched or, at most, lightly managed (Terborgh 1992).

Deciding what landscape patterns are most likely to achieve certain goals requires knowledge of relationships among landscape patterns, habitats, and ecological processes within a given area. It also requires some understanding of the basic principles of two relatively new disciplines, landscape ecology and conservation biology. These principles are briefly discussed in the following sections, however, it is beyond the scope of this paper to go into detail (see Walters 1986; Turner et al. 1987; Bormann et al. 1993; Jensen and Bourgeron 1993; Maser et al. 1993; Noss and Cooperrider 1994; Perry 1994).

HABITATS AND CONNECTIVITY

Conserving species means conserving and, where necessary, restoring habitats (also see Noss and Cooperrider 1994; Perry 1994; DellaSala et al. 1995, this volume). Two aspects of habitat are relevant at the scale of landscapes: the relative amounts of different types, and the degree interconnectedness (or, conversely, fragmentation and isolation). The habitat template within a forested region comprises: a) different major forest types, b) different successional stages within a given forest type, and c) unique communities such as riparian zones, natural meadows, and wetlands. Species that typify different habitats—particularly different seral stages—often differ in life history characteristics in ways that are significant for conservation strategies. It is not true, as one sometimes hears, that all early successional species are weeds. Many are opportunistic generalists whose populations grow rapidly and disperse widely, and exotic weeds <u>are</u> most likely to successfully invade communities following disturbance. Compared to early successional communities, a higher proportion of old-growth associates have one or more characteristics that make them vulnerable to extinction (Henjum et al. 1994; Noss and Cooperider 1994; Perry 1994). This includes, in particular, vertebrates, that require large amounts of territory and cover from hunters and poachers, and species using habitats such as large dead wood and closed canopy forests that are vulnerable to logging. Terrestrial vertebrates of concern in the Interior West include goshawks, flammulated owls, boreal owls, grizzly bears, wolves, American martens, fishers, wolverines, and white-headed, pileated, black-backed, and three-toed woodpeckers. (See Henjum et al. 1994 and Perry et al., this volume).

The relative proportion of old to young and middle stage forests has reversed from what it was in the pristine state in most, if not all, managed landscapes in the United States. One hundred years ago, 60% to 70% of eastern Oregon and Washington forests were old growth; today, less than 25% are (Henjum et al. 1994). Two caveats are necessary here. The first is obvious, but bears repeating: "old-growth" is not some homogeneous thing that is the same everywhere, an old subalpine forest may be significantly younger and structured quite differently than an old-growth ponderosa pine forest. Second, landscapes dominated by older forests are generally heterogeneous with regard to the age classes and species that they comprise. In other words, all forested landscapes are mosaics, though the grain of the mosaic may differ widely among forest types.

The transition from natural to managed forests has been accompanied by increasing isolation of remaining natural blocks, and deterioration in the quality of habitat that they provide. Much of the old-forest habitat remaining in eastern Oregon and Washington is fragmented into small islands and permeated by roads (Henjum et al. 1994; Perry et al. this volume), which diminishes the quality of interior habitat in various ways. Clearly, a fragment that contains less than the minimum area requirements of a family

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group of a given species is unsuitable for that species (e.g., 100 ha of suitable habitat doesn't do much for a pair of pine martens, which requires several hundred ha). But even those interior forest species that find enough space within a forest that is fragmented and/or permeated with roads may become more vulnerable to predators and parasites. Moreover, the fragment itself may be vulnerable to destruction by fire or wind.

In addition to being vulnerable to various disturbances, habitat fragments that are too widely scattered result in isolated populations, which means that lost populations may not be replenished from the metapopulation pool. How much separation is too much depends on species, but generalizations are possible. Early successional species have evolved in ephemeral, widely scattered habitat patches, hence can be assumed to disperse successfully through "hostile" territory (i.e., nonhabitat). Old-growth associates have evolved in relatively stable habitats and may be less mobile, hence, more vulnerable to fragmentation.

Impacts of fragmentation on migration and dispersal can be reduced or eliminated by providing suitable interconnectance among reserves, or older forest habitat within the multiple use matrix (Noss 1983). What constitutes "suitable interconnectance" is a matter of debate and varies depending on species (Noss and Cooperrider 1994). Attention has focused on movement corridors, with riparian zones often mentioned as the logical choice (Harris 1984; Harris and Gallagher 1989). Riparian zones are critically important habitats and clearly serve to link landscapes (Thomas et al. 1979; Harris and Gallagher 1989; Knopf and Samson 1994), however, some species disperse through upslope habitats. Such species are unlikely to benefit from landscapes with riparian zones as the sole connectors (such as depicted in Figure 1a)(McGarical and McComb 1992; McComb et al. 1993). Moreover, fragmented stands linked by narrow corridors (what I like to call the "dumbbell" model) may be vulnerable to pests, pathogens, fire, and wind.

An example of a more dispersed interconnectance was provided in the spotted owl recovery strategy by the 50-11-40 rule, which required that a minimum 50% of the landscape outside of reserves be maintained in stands, with at least 40% canopy cover, and an average tree diameter no smaller than 11 inches (Thomas et al. 1990). This rule was designed specifically for spotted owls and should not be taken as a general recipe, however, the principle behind 50-11-40 is generalizable: connectance can be improved by proper management of matrix stands. In terms of the abstract landscapes of Figure 1, 50-11-40 would probably best fit under 1b. A landscape in which the majority of matrix lands are managed on long rotations (Figure 1c) would provide the best interconnectance for old-growth associates. At the regional scale, such landscapes might also appear as corridors, albeit kilometers wide, and their highest priority locations would be as interlinks among core reserves such as wilderness areas and parks (Bader 1992; Noss and Cooperrider 1994). The ecological principles that underpin species conservation lead to three recommendations for protecting and restoring terrestrial habitat in the inland northwest.

1. Use GAP analysis or other techniques to identify and protect representative community types and forest age classes that are now poorly protected (Scott et al. 1993). This includes riparian zones, wetlands, and low elevation forest types (which are currently under-represented in the reserve system; Henjum et al. 1994). The eastside scientific societies committee, of which I was a member, recommended a moratorium on logging old-growth in eastern Oregon and Washington, at least until more is known concerning the status and habitat requirements of species of concern (Henjum et al. 1994; Perry et al. this volume). The only exception, in my opinion, is underthinning to reduce fire hazard, a point I return to in a following section.
2. Reduce fragmentation of mature and old-growth forests by restoring the landscape to a higher proportion of these types.
3. Use controlled fire and appropriate silviculture to reduce vulnerability of critical habitats to catastrophic disturbance. It goes without saying that measures designed to reduce the vulnerability of habitats should not, themselves, harm those habitats, nor should they create new problems by degrading soils or streams.

The last point warrants further discussion. The scientific debate about landscape management has generally focused on either wildlife or disturbance, with distressingly poor communication between the two camps. The fact is that managers must account for both. A landscape that provides suitable interconnectance for wildlife, but is highly vulnerable to disturbance (e.g., fire) is unlikely to provide either interconnectance or older forest habitat for long; nor are ecosystem goals achieved where reduced risk to catastrophic disturbance comes at the cost of critical habitat. Finding balance between these potentially conflicting goals is the central challenge, both ecologically and politically.

FOREST PROTECTION

From the landscape perspective, the strategy for protecting forests is to create (or maintain) landscapes that buffer and absorb disturbances, rather than magnify them. Whether a particular landscape pattern is absorbing or magnifying depends on the types of disturbances likely to move through it (Forman 1987; Perry 1988; Turner et al. 1989). Once again, each case must be analyzed on its own merit. I will not belabor the current situation in the Inland West other than to reiterate what has been said many times before: the widespread replacement of old-growth ponderosa pine forests by younger grand fir and Douglas-fir has converted the regional landscape from one that absorbed and damped, to one that magnifies the spread of fire, pathogens, and defoliating insects. In result, these native agents, which at one level of activity play beneficial ecological roles, now operate in a milieu of relaxed ecological constraints that create the potential for destruction of critical habitats and degradation of ecosystem integrity (e.g., through impacts of frequent, severe disturbance on soils). While this is an undeniable fact in my opinion, it is nevertheless important to avoid overgeneralizing the risks. Some of the insect kill seen over the past few years may be part of a longer term natural cycle—spruce beetle being the most obvious

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example. Even spruce budworm, which has clearly behaved quite differently in this century than the last (Wickman et al. 1993), may be viewed as a natural restoration agent that has begun the process of land healing by killing tree species that had themselves been released from historic natural controls (frequent ground fires) and spread beyond their historic bounds. Unfortunately, the natural healing process is threatened by the increased potential for catastrophic crown fires—which have clearly increased in the Inland West over the past few decades (Covington et al. 1994). Once again, it is important to avoid overgeneralizing. While recent fires in the dry forest types of the Interior West have been more destructive than the historic norm (Mutch et al. 1993; Covington et al. 1994; Auclair and Bedford 1994), those in higher elevation forests (e.g., Yellowstone NP) were probably much closer to the historic norm (Romme and DeSpain 1989).

Various people have argued that restoring historic disturbance patterns will require restoring dry forest types to a higher proportion of relatively open forests dominated by early successional trees (primarily ponderosa pine in interior forests, but also larch and Douglas-fir depending on site)(Mutch et al. 1993; Covington et al. 1994; Oliver et al. 1994). Most authors are silent on the issue of tree size and/or age, hence rotation length, however there is no doubt that big, thickbarked trees are the most resistant to fire, and foresters have noted since the early decades of the century that plantations were particularly vulnerable to fire (Buck 1934; Cowlin et al. 1942). Susceptibility was reduced with the advent of aggressive slash disposal (often with significant negative impacts on soils; Childs et al. 1989; Harvey et al. 1989; Powers 1989). However, even with slash disposal, densely stocked plantations are more vulnerable to fires than healthy old-growth (i.e., old-growth in which the majority of overstory trees are healthy there are no unnatural levels of understory fire-ladders)(Van Wagner 1983; Perry 1988; Franklin et al. 1989). For example, following the 1987 wildfires in the dry forest types of southwest Oregon, 65% of submerchantable conifer stands had less than adequate stocking, whereas two-thirds of old-growth stands escaped with fewer than one-quarter of tress being killed (U.S. Forest Service 1988). I emphasize that this pattern of relative fire resistance cannot be extrapolated to low and midelevation old-growth with significant numbers of young trees that act as fire ladders.

The relative susceptibility of younger stands means that converting healthy old-growth to plantations is likely to increase landscape vulnerability to crown fires at some point in the future. Following an initial phase when fuels are low and stands open, plantations will grow into a highly vulnerable phase. A commitment to active density management and periodic fuel reduction will reduce hazards, but done properly these actions will be expensive and time consuming. In the long-run, the most effective and least expensive strategy for reducing the probability of large, catastrophic fires in the dry forest types is a system of partial cutting on long rotations, coupled with periodic underburning to reduce fuels. Economically, this represents a shift from maximizing timber volume to maximizing timber value (e.g., high quality logs) and forest value (Oliver 1992). Additionally, by lowering risk of stand loss to fire managers the potential long-term volume production is increased.

SCALES OF PLANNING AND COORDINATION

One of the central challenges of ecosystem management is to address objectives at the proper spatial and temporal scales. What scale of planning is appropriate if the objective is to maintain or restore biological diversity? Two factors are involved: 1) the area needed to maintain viable populations of umbrella species (i.e., those requiring large areas of habitat to maintain viable populations, and whose protection is assumed to de facto protect others that require similar habitat, but less of it), and 2) the scale of disturbances.

Viable Populations of Umbrella Species

Maintaining viable populations of typical umbrella species, which are usually large predators, requires regional coordination. Consider goshawks, the only true forest-dwelling hawk in North America. Based on radio-telemetry studies, Austin (1993) concluded that one goshawk pair requires, on average, 4700 continuous ha, at least 20% of which is in closed canopy mature or old-growth, and 40% in closed canopy small sawtimber stands. It follows that five thousand breeding pairs (a possible viable population) would require somewhat more than 23,000,000 ha. By way of comparison, all USFS, NPS, and forested lands administered by BLM in Oregon, Washington, and Idaho total approximately 21 million ha (Jackson and Kimerling 1993). This simple example is not intended as a guideline for goshawks, but rather to illustrate the need for thinking regionally when planning for viable populations of wide ranging species. Other large predators require similar areas. For example, Noss and Cooperrider (1994) estimate that roughly 60% of the area of the U.S. northern Rockies will be necessary to maintain viable populations of grizzly bears.

Few, if any, conservation biologists argue that maintaining populations of umbrella species requires locking up lands on a regional scale; that is generally recognized as impractical and probably unnecessary. What will be required is a) explicit recognition that conservation at a regional scale is a goal of ecosystem management, b) a reserve network based on ecological as well as aesthetic needs, c) multiple use lands managed with an eye to species requirements for migration, dispersal, and protection (e.g., from poachers), d) scientifically reliable information on the habitat needs of species of concern, and e) in order to achieve the preceding, greatly improved communication among landowners and administrative units.

Scale of Disturbances

Where factors such as infectious disease or wildfires have the potential to sharply reduce population sizes, populations need to be buffered by keeping them large. This is of particular concern in the Pacific Northwest, where large fires, and in some areas windstorms or large insect outbreaks, are common, and where

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fragmentation, years of fire exclusion, and drought have left forests especially vulnerable to one or more of these disturbances. Small populations do not contain sufficient individuals to be buffered against catastrophic losses. A particular threat is the possibility that two or more events that reduce population size may occur in quick succession, not allowing the population time to recover before it is further reduced. In today's world the probability is growing that two or more forces that stress populations might occur simultaneously—catastrophic wildfire plus abnormal drought, for example—a fact that makes the buffering power of large, well-distributed populations even more vital.

Figure 2 shows the qualitative relationships among specialized habitat needs, the risk of losing that habitat, and the need for population buffering (i.e., redundancy in protected areas and/or maintenance of habitat on multiple use lands). As the scale of disturbances increases, so does the risk of losing mature and old-growth habitat. As risk increases, more area is needed to buffer late-successional species against excessive habitat loss. Where natural disturbances are operating beyond their historic range, appropriate actions aimed at reducing the scale of natural disturbance are an important conservation tool. Implications for the Inland West are obvious; perhaps less obvious are the caveats implied by the condition "appropriate", to which I return a bit later.

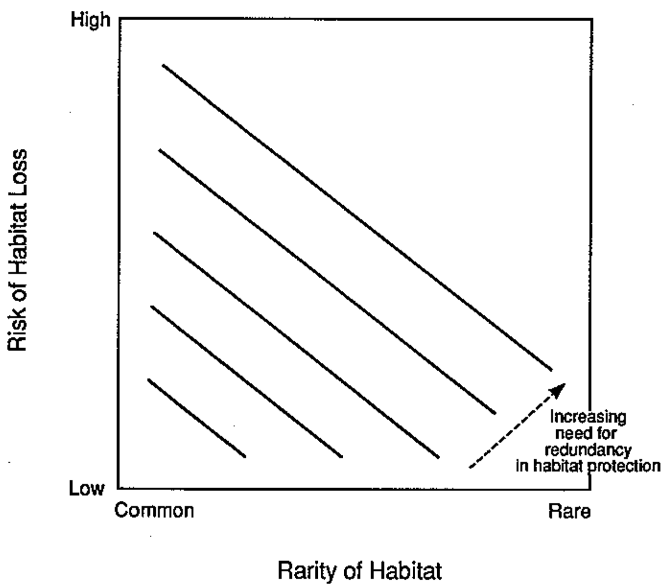

Figure 2.—A hypothetical relationship among habitat rarity, risk of habitat loss, and need for population buffering through redundancy in habitat protection. Need for buffering increases with habitat rarity and risk of habitat loss.

The probability that greenhouse effects will significantly alter climate in coming decades introduces new considerations for landscape and regional planning. The disruptive potential of possible climatic changes should not be underestimated. On the east slopes of the Cascades, for example, Franklin et al. (1992) calculate that a 2°C change in average temperature would reduce the extent of forest and alpine by 50% and double the cover of juniper savanna plus shrub-steppe. With a 5°C change, alpine would disappear, the area suitable for forest would decline to about 15% of what it is now, and three-quarters of the east slopes would fall within the shrub-steppe zone. These temperature changes are plausible over the coming decades, emphasizing the need to maintain pathways of migration for plants and animals. (At the end of the last glacial maximum, average temperature changed as much as 7°C within 50 years at high latitudes, and evidence suggests that areas which are now the western United States also experienced this extremely rapid change; Allen and Anderson 1993). If native plants cannot keep pace with the changing climate, there is a high probability that sites will be taken over by those accomplished migrants, weeds (Perry et al. 1990). Because natural disturbance regimes are predicted to become more severe (Overpeck et al. 1990), the risk of losing already limited habitat and of weeds spreading is likely to increase in the future. This will increase the need for: 1) buffering populations by maintaining abundant, well-distributed habitats,(2) active landscape protection (e.g., reducing fire hazard), and 3) maintaining biological diversity to protect soils and other aspects of ecosystem resiliency (Perry et al. 1990).

CHOOSING A LANDSCAPE PATTERN: LANDSCAPE PROCESSES AND HISTORIC RANGE OF VARIABILITY

Once an appropriate spatial scale is identified, the question arises as to what spatial and temporal patterns are most likely to meet the objectives. Three general types of pattern occur within landscapes and regions: a relatively permanent pattern imposed by topography, elevation, soils, and macroclimate; variable patterns of succession due to fires, wind, insects, and pathogens; and variable patterns of succession (or stand structure) due to management (e.g., logging, controlled fire). By definition, choice of management directly affects the latter through factors such as reserve siting, harvest intensity, and rotation length. As is clear from forest health problems in the semiarid west, management may also indirectly affect forest and landscape structure by altering the susceptibility of forests to non-human disturbances. It follows that management strategies aimed at producing a given landscape pattern must account for both direct and indirect effects.

There are two ways to decide which landscape patterns will provide the proper mix of habitats and reduce the chance of abnormally destructive "natural" disturbances: 1) the direct approach of understanding functional relationships between landscape pattern and processes such as hydrology, maintenance of habitat, and propagation of disturbances, and 2) the indirect approach of documenting historic patterns of variation, under the assumption that landscapes maintained within the bounds of historic patterns are also likely to maintain historic processes (e.g., viable populations of indigenous species). These two approaches are not mutually exclusive, in fact they are quite complementary and should be used together.

I briefly discussed relationships between landscape patterns and processes in earlier sections. A number of papers and books published over the past few years deal with the relatively new

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scientific discipline of landscape ecology (e.g., Weins 1978; Weins et al. 1993; Forman and Gordon 1981; Romme and Knight 1982; Noss 1983; Noss and Cooperrider 1994; Franklin and Forman 1987; Turner 1987; Turner et al. 1989 a, b, 1993; Urban et al. 1987; Perry 1988, 1993, 1994; Pielke and Avissar 1990; O'Neill et al. 1992; Chen et al. 1992). The sometimes daunting complexity of natural patterns and processes has led to increasing use of Historic Range of Variability (HRV) to guide management. According to Morgan et al (in press), "The historical range of variability characterizes fluctuations in ecosystem conditions or processes over time....(its) essential function...is to define the bounds of system behavior that remain relatively consistent over time".

The move towards understanding the forces that have shaped ecosystems, and designing management strategies that reflect natural patterns, is a significant step forward and will hopefully continue. Unfortunately, however, HRV is being applied in some cases without clearly identifying the goals it's addressing, the scales of HRV necessary to meet goals, or the clear limitations of applying the idea to management. Moreover, determining HRV within the relevant time scales (at least 2 or 3 centuries prior to settlement by EuroAmericans) requires a level of study that has been conducted in relatively few areas around the region, raising the possibility that HRV will be invoked with little or no reliable information about what historic patterns actually were. Misuse of the concept not only creates the potential for bad management decisions, it fosters mistrust of agency motives (especially when HRV is used incorrectly to justify cutting in relatively pristine areas, which has happened in at least one case).

The following steps are essential for proper use of HRV in guiding management.

1. Acknowledge that natural disturbances killed trees but did not remove logs from sites. Indigenous people rarely removed logs, therefore timber harvest is not equivalent to historic disturbances. In terms of relevance to HRV, there are basically two types of logging: a) restoring historic forest structure, which involves thinning grand fir and other species that invaded dry forest types following fire exclusion, and b) everything else. Any approach that falls under the latter category is clearly outside of HRV, and the relevant question regarding its use is how far from HRV can management depart without compromising objectives? This means that one must have clear objectives, and they must be specific enough to be evaluated with regard to proposed landscape patterns.
2. Once objectives have been stated, identify at what spatial scales they must be addressed. Applying HRV at too small a scale is one of the major problems with the way the concept is being used. Maintaining viable populations of wide-ranging vertebrates requires areas encompassing much or all of the region. Applied at that scale, the message of HRV is clear: there are far fewer old-growth forests than during the previous several hundred years, and moving toward HRV means restoring old-growth to its original structure rather than replacing it with young stands.
3. Gather reliable information about disturbance and succession patterns reaching as far back as possible <u>prior to settlement by EuroAmericans</u>. This is neither easy or cheap.
4. Use HRV guidelines appropriate to the forest type in question, particularly with regard to distinguishing successional stages. This has been a problem in some instances on the east-side, where definitions of forest structure more appropriate to west-side forests were applied. (The situation was greatly confused by FEMAT which, unfortunately, lumped old-growth and late-successional forests together). <u>Old-growth is not necessarily the same as late-successional, and should not be treated as the same successional stage in HRV guidelines</u>. This is an especially important point in the dry forest types of the west. When EuroAmericans first arrived, approximately two-thirds of eastern Oregon and Washington forests were dominated by ponderosa pine, 90% of which was old-growth with few or no late-successional trees. Old-growth pine forests were structurally (and probably ecologically) quite distinct from mid-aged pine forests, yet in some instances old-growth and mid-aged stands have been lumped together for HRV purposes. This means that a landscape with 70% cover of mid-aged stands would be considered equivalent to the historic landscape dominated by old-growth. From the standpoint of ecology and conservation biology, this is a gross misuse of HRV.

To summarize this discussion, understanding historic patterns is not only good, but a necessary part of ecosystem management. However HRV has little use as a management tool without clearly defined objectives and an understanding of the basic ecological principles that relate those objectives to landscape patterns.

An Aside on the Question of Balance

Before moving to the next section, which addresses achieving balance among competing human wants and needs, I want to speak briefly to the issue of dynamism and balance in ecological systems. There has been much recent hoopla among ecologists about nature being dynamic and some would purge the very idea of balance from our notions of how nature works (e.g., Botkin 1990). I won't get into the semantics of the word balance other than to point out that there are, without doubt, moving balances. This is to say that dynamic systems evolve to move within certain bounds, and when they exceed those bounds their subsequent behavior may change radically. Organisms and populations clearly evolve to constrain their dynamics (if they did not they wouldn't persist); whether that is also true of ecological communities and ecosystems is a hypothesis to be tested, however the evidence suggests it is (e.g., Perry et al. 1989, 1992). This is not some esoteric scientific debate, but crucial to the task of ecosystem management. In systems that are dynamic and changing, what are the bounds of change beyond which the system may change radically and unexpectedly? Pickett et al. (1992) express the concern of some environmental scientists that managers may wrongfully interpret the so-called "New Paradigm" (nature is dynamic) as saying that anything goes:

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"The new paradigm in ecology can, like so much scientific knowledge, be misused. If nature is a shifting mosaic or in essentially continuous flux, then some people may wrongly conclude that whatever people or societies choose to do in or to the natural world is fine. The question may be stated as, 'If the state of nature is flux, then is any human generated change okay?'....The answer to this question is a resounding 'No!'...Human generated changes must be constrained because nature has functional, historical, and evolutionary limits. Nature has a range of ways to be, but there is a limit to those ways, and therefore, human changes must be within those limits."

A central challenge facing scientists and managers is to better understand and protect the mechanisms which keep populations and ecosystems away from threshold changes (e.g., extinctions, diseased landscapes, degraded soils). This leads to a more detailed consideration of forest health, and particularly the role of biological diversity in maintaining ecosystem health.

ECOSYSTEM HEALTH

A healthy system is one that retains the integrity of its basic structure, processes, and functional interactions among its parts (Karr and Dudley 1981; Rapport 1989; Karr 1991). Note this definition includes not only the health of trees, but the viability of indigenous populations. Some level of disease and tree death is normal and beneficial in forests. Ecosystem health is not so much the absence of disease and death, it is the ability to contain these natural forces within certain bounds and the robustness to resist or recover quickly from environmental stresses. As I will discuss below, the system properties of "resistance" and "resilience" are associated with species diversity and the multiplicity of interactions among species that compose the system. Although healthy trees are a prerequisite to healthy forest ecosystems, health encompasses much more than trees, and forest health correlates much more closely with structure and processes than with how fast trees are growing.

Because ecological systems seldom have clear boundaries, ecological health spans spatial scales. A central point of this paper has been that the structure of landscapes shapes processes (e.g., hydrology, propagation of disturbances) which influence the integrity of stands and streams. The integrity of streams depends, additionally, on the integrity of riparian forests and of upslope forests that control sediment yields. Species, stands, streams, landscapes, and regions compose an interlinked system in which the health of the parts cannot be considered separately from the health of the whole.

As all foresters know, ecosystem types differ in their structure and, to some degree, their processes. It follows that what is "unhealthy" in one type may be normal in another; large crown fires, for example, were rare in low elevation forests, and threaten the integrity of those forests, but the same threat cannot be extrapolated to higher elevation forests, where crown fires were historically more common. Given the diversity of nature, are generalizations possible about what is required to restore and protect ecosystem health?

I will offer two pieces of advice that I believe apply to any system: protect soils and protect indigenous species. The entire system is underpined by the integrity and health of the soil ecosystem (Perry et al. 1989), and in our new-found fascination with large scales we must not forget "the little things that run the world" (Wilson 1987), many of which live below ground. Regarding indigenous species, the relationship between diversity and stability has been a contentious topic in ecology. However, accumulating evidence indicates that diversity contributes to healthy ecosystem function (Franklin et al. 1989; Perry et al. 1989, 1992; Amaranthus and Perry 1993; Frank and McNaughton 1991; Tilman and Downing 1994). Ultimately, any question about the relationship between diversity and stability must address the functional role of individual species or groups of species, an area in which scientific knowledge is frankly abyssmal. Once again, however, evidence is accumulating that individual species influence processes in many ways that feedback to help maintain ecological health. One of the more notable examples in eastside forests is the regulatory role played by birds and predatory insects in consuming tree-eating insects (e.g., Torgersen et al. 1990). These natural enemies of insect pests require habitats such as large dead wood, linking the health of stands and landscapes back to their own structures (Torgersen et al. 1990). To give another example, inability to reforest high elevation clearcuts in the Siskiyou Mountains has been linked to reduced populations of soil invertebrates, which slows the nutrient cycle (Colinas et al. 1994). What about large predators such as mountain lions, wolves, and bears, do these animals significantly influence ecosystem function? This has been yet another contentious issue among ecologists (e.g., Leopold 1943; Caughley 1970; Wilcove 1985; Botkin 1990; Perry 1994), largely because of the complexity of the subject and the difficulty of doing experiments. However, recent research shows that in some instances large mammals at the top of the food chain do exert significant control over lower-level system processes (Lindstrom et al. 1987; McLaren et al. 1994). Perhaps the most striking example comes from Isle Royale National Park, where McLaren et al. (1994) found a significant positive correlation between tree ring width and populations of wolves. Presumably wolves benefit tree growth by controlling moose populations.

The stabilizing role of diversity may manifest only during certain stressful periods, such as drought (Tilman and Downing 1994) or recovery from disturbance (Franklin et al. 1989; Perry et al. 1989; Frank and McNaughton 1991). In southwest Oregon and northern California, certain species of hardwoods are relatively inflammable and, when intermixed with conifers, protect the conifers from fire (Perry 1988). The degree to which similar interactions might occur between conifers and hardwoods in the Interior West is unknown, however, the general point is valid nonetheless: evaluating the influence of hardwoods on conifers would yield quite different results depending on whether the evaluation was done before or after the fire. The fact that stabilizing factors may operate only at certain critical times underscores the point made earlier, that rate of tree growth by itself may be a poor indicator of ecosystem health. Something that reduces tree growth under some conditions may promote it

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under others. Discarding pieces of a complex system because they have no obvious value (other than aesthetic) can be risky.

ACHIEVING BALANCE AMONG VALUES

To recapitulate some well known facts, forests of the Interior West have been significantly altered over the past century; the amount of old-growth has declined, the spread of shade-tolerant tree species has increased susceptibility of the drier forest types to catastrophic disturbance, and degraded habitat has raised serious concerns about the viability of a number of vertebrate species. Fortuitously, restoring low and midelevation landscapes to their historic cover of large, older, early seral trees (ponderosa pine and western larch throughout much of the region) serves the dual purpose of lowering the risk of catastrophic disturbance and recovering some lost habitat. Why then are conservation biologists and environmentalists so concerned about "forest health logging"? The primary reason will surprise no one—it is the very real issue of lack of trust. This distrust takes two forms: 1) skepticism concerning the ability of managers to protect other values while "restoring health", and 2) outright mistrust of motives.

Protecting All Values

The major challenge facing management is to heal one set of problems without exacerbating others or creating new ones. The basic strategy is to plan carefully at both the stand and landscape scale, paying particular attention not only to improving tree health, but also to protecting critical habitats, soils, and residual trees. Change in the structure of dry forest types during the past century has eliminated habitat for some species and created habitat for others (Covington et al. 1994). The latter includes some closed forest associates (e.g., goshawks, spotted owls) whose overall regional habitat has probably been reduced (Henjum et al. 1994). Similarly, salvage of dead trees currently proceeds in a virtual information vacuum about the viability of the numerous species that use dead wood. In my opinion, these uncertainties do not justify doing nothing; however, they do argue strongly for prudent action. Salvage or other logging to improve forest health should proceed with an eye to the needs of sensitive species, lest we inadvertently push them into what Gilpin and Soule (1986) termed the extinction vortex.

Thinning can be an excellent tool for reducing fire hazard as well as insect and pathogen spread, however, it must be used judiciously. I recommend the following guidelines:

1. Plan at the landscape scale. Thinning programs should take into account the needs of species that require closed canopy forests. One way to accomplish this is to determine where on the landscape these needs exist and thin those areas either very lightly or not at all. In fact, not all forests are likely to need thinning to improve tree health; higher elevations and moist north slopes naturally had lower fire frequencies and greater tree densities than lower elevations and dry south slopes, hence, are less likely to be overstocked than the drier forest types. The important point is that not all forest types, nor individual stands within forest types, are the same, nor will they require the same treatment to restore health. Even within stands, some areas will be overstocked and other areas will not. Thinning strategies need to recognize differences both between and within stands and treat them accordingly. Where heavier thinning is necessary, excessive impacts can probably be avoided by dispersing thinnings in time, so that no one area (e.g., a single watershed) is opened within a short time. Such dispersing allows thinned forests to close canopies before the area is reentered to thin other stands. Entry into areas that are especially sensitive, such as roadless areas, should either be avoided or delayed until possible impacts and techniques for mitigation are better understood. Given the large area of potential thinnings, delayed entry into sensitive areas is unlikely to delay the thinning program as a whole.

2. Avoid building new roads. Road densities throughout much of the National Forest land in eastern Oregon and Washington already exceed 2.5 mi/mi^2, which is a concern because roads facilitate the entry and spread of any number of potentially disruptive agents (Henjum et al. 1994). In the Pacific Northwest, logging roads have facilitated the spread of at least five pest species (Strang et al. 1979; Hansen et al. 1986; Daterman et al. 1986). Roads also directly impact habitat quality. Most fisheries biologists agree that sedimentation from roads has significant impacts on salmonids and some species of resident trout, and point to the fact that the healthiest populations of sensitive species (e.g., bull trout) are consistently found in streams draining roadless areas (Henjum et al. 1994). Road densities greater than 1 mi/mi^2 are considered detrimental to elk and wolf populations, although wolves may tolerate higher densities when large unroaded areas are nearby (Jensen et al. 1986; Mech 1989; Henjum et al. 1994). Recent advances in helicopter logging and the current high market value of small wood combine to make logging without roads much more feasible than in the past.

3. Thin from below, taking small trees and leaving larger ones. Many of the larger pine and larch were high-graded from interior forests decades ago; those that remain are the building blocks of the future forest and as such should be retained. In the moister forest types, large firs and spruces also represent unique habitats for numerous species. There is no shortage of smaller trees to log and, in terms of forest health, one gains much more from cutting these than from cutting the larger trees. Moreover, there are markets for small trees and there are new engineering options for ecologically-sensitive harvest.

4. Avoid compacting soils and damaging residual trees. Soil compaction is a particularly insidious problem that is difficult or impossible to cure, and that will without doubt reduce forest health (Childs et al. 1989). Compaction can be minimized or avoided altogether by using the proper equipment and techniques.

5. Reintroduce fire as a management tool. This is an important part of restoring drier forest types to a condition that better

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resists crown fires. However, it will not be easy given current fuel loading. Controlled underburns will be more feasible once underthinnings have reduced ladder fuels, but some manual labor may be required to lop and scatter logging slash and rake fuels away from the bases of residual trees.

6. Remember that some tree death and disease is ecologically beneficial. Snags and logs, large firs infected with heart rots, and trees with mistletoe or dead tops provide habitat for numerous species, including some that help regulate pest populations. Retaining appropriate amounts of these components and providing for future supplies is an important part of managing for forest health.

7. Make sure the proper resource specialists are fully involved in planning thinning operations.

The Issue of Motives

It is probably beyond my charge to discuss mistrust of motives. On the other hand, considering the human connection in all its aspects is central to the spirit of ecosystem management (ecstasy), and the hard fact is that the trust issue bears directly on what can and should be done by land managers (laundry). I don't have any easy solutions, but I do have some observations that have grown out of my involvement in conservation and land management issues over the past several years. What follows deals with the inability of management agencies to effectively communicate with environmentalists and many environmental scientists. It does not follow that I think managers bear complete responsibility; all parties have a duty to speak clearly, listen carefully, and judge fairly.

Many of those who mistrust motives see the whole issue of forest health as a scam designed to get the cut out. Rhetoric is not going to solve this problem, especially when the rhetoric is so vague that no one can discern the intent behind the words. Managers want and need flexibility, however, they must also be willing to clearly articulate bounds on flexibility and, most importantly, back up words with action. Mistrust of motives has been fueled by incidents such as cutting healthy old-growth trees under the guise of "improving health", when many environmental scientists agree that cutting healthy old trees has exactly the opposite effect.

Mistrust of motives is also fueled by signals that are either obscure or contradictory to the goals of ecosystem management. A prime example of the latter being agency budgets that still reflect old rather than new priorities.

Some, including myself, find a great deal of obscurity in the way humans are being invoked as parts of ecosystems. A prime example is the definition of forest health, now enjoying great popularity, which holds forest health to be a condition that "sustains...complexity while providing for human needs" (Sampson et al. 1994; O'Laughlin et al. 1994). This definition is not scientifically valid, because it leads to the absurd conclusion that ecosystems not providing something to humans are unhealthy. Moreover, in the minds of some, it is yet one more thinly veiled attempt to maintain timber primacy within the context of ecosystem management. Finally, it takes a clear position in the old and still very active debate about whether nature exists solely for humans or has intrinsic value quite separate from human needs (Booth 1994). A definition of ecosystem health that takes either position muddles philosophy and biology, hence confusing the political decision-making process and unnecessarily alienating stakeholders.

As society moves toward explicit recognition of humans as part of nature, it is important to keep clearly in mind that the relationship is not symmetric: i.e., humans cannot persist with out healthy ecosystems, but healthy ecosystems do quite well without humans. Humans may be part of nature, but we also have far more power than any other organism to either purposely or inadvertently alter habitats and processes. This power is limited, however, as nature is increasingly understood to comprise a highly complex set of relationships that may exhibit unexpected threshold changes that are difficult or impossible to reverse. Examples include species extinction, soil degradation, changes in regional ecosystem health, and rapid, significant changes in climate. The possibility of threshold change in system level properties raises the conservation stakes from ethics to enlightened self-interest.

While from an ecological standpoint it seems self-evident that humans are part of nature, this will be a point of mistrust and contention until the roles and responsibilities of humans vis-a-vis nature are more clearly articulated. It is necessary to recognize that we are unique animals with no top predator to control our consumption, and with enormous power to alter the patterns of nature, sometimes in ways we wish we hadn't. The question is not what this generation can do, but what we cannot or should not do if our goals include passing to the future a better world than we found. Clearly articulating ecological potentials, constraints, uncertainties, tradeoffs, and risks is the role of scientists and managers. Once the ecological sideboards are clearly stated, the democratic process and the enormous ingenuity of humans can turn to the task of what can be done within those sideboards.

Institutional Support

Finally, I will briefly mention four areas where institutional support would significantly aid managers in restoring and protecting forest health.

1. Support research and development of ecologically-sensitive harvesting techniques. These include helicopters and low-impact ground equipment, both of which are being successfully used in various areas of the Pacific Northwest.

2. Support conversion to small-log milling and value-added industries within local communities.

3. Direct funds from fire-fighting to fire prevention. The economics of logging aimed strictly at improving forest health is unclear and will probably vary widely depending on circumstances. It seems likely, however, that some of these operations will not pay for themselves. One option in such cases is to fund deficit sales with money from the large

accounts set aside for fire-fighting. Considering the cost of fighting a major wildfire, such an action is likely to be cost effective for the nation in the long run.

4. Inventory the status of sensitive species and, in the spirit of adaptive management (Walters and Holling 1990), install large-scale management experiments that address both the short- and long-term effects of thinning and salvage. Any sensible management requires an inventory of stocks, which in the case of ecosystem management includes the species composing the system. Little is known about the status of many forest species in the inland west, and even less is known about how these species tolerate different levels of forest management. Providing the information necessary to truly manage ecosystems will be expensive, but I see no choice if we are to use resources wisely and avoid future crises.

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