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Scientific Basis for New Perspectives in Forests and Streams

JERRY F. FRANKLIN

Abstract

New perspectives that involve development of management approaches that integrate ecological and economic values are especially important in riparian zones because of the numerous ecological linkages between terrestrial and aquatic ecosystems. The scientific bases for alternative management regimes for forests and associated streams lie primarily in expanded knowledge of the importance of ecosystem complexity, of biological legacies in reestablishing ecosystems following major disturbances, and of landscape perspectives (larger spatial and temporal scales). Each of these three areas of knowledge is reviewed and then applied in developing some alternative approaches to managing forests and associated riparian zones. Maintenance or re-creation of structurally diverse managed forests is an important principle of New Perspectives concepts at the stand level. Structures such as large trees, snags, and down logs are focal points in management, because they can act as surrogates for organisms and functions that are often difficult to quantify. Important considerations at the landscape level include special attention to riparian habitats (including headwaters), creation of an interconnected system of reserved areas, and selection of appropriate patch sizes for managed areas. Substantial progress is occurring in development and field trials of New Perspective concepts at both stand and landscape levels. A high level of collaboration between scientists, managers, and public interest groups is essential for this process to be successful.

Key words. New Forestry, riparian, biological diversity, biological legacies, landscape ecology, fragmentation, cumulative effects.

Introduction

Today, conflict provides the context for natural resource management. We are faced as a society and as resource managers with ever-increasing and increasingly diverse demands upon a limited resource base. The inevitable conflicts are epitomized by such extraordinarily difficult issues as preserving northern spotted owl (*Strix occidentalis caurina*) habitat versus cutting timber in the old-growth forests, and sustaining anadromous fish runs versus generating power or using water for irrigation from our major river systems.

The traditional approach to resolving conflicts over resource values has been to allocate lands and waters among apparently incompatible uses. Some areas are designated as wilderness, national parks, or national scenic rivers for retention in a natural state, while other lands are committed to the production of commodities such as timber. While both commodity and wild lands are generally recognized as providing a variety of benefits to society, physically separating management activities on these lands by allocation has been the primary approach. This emphasis has impeded efforts by agencies, such as the U.S. Forest Service, to develop and apply a "multiple use" concept.

Allocation is proving to have less and less value as an approach to resolving resource conflicts, due to the decreasing resource base and the increasing demands of a growing and more affluent population (see Lee, this volume). There is also greater recognition that various ecological processes, such as those associated with sustainable productivity and biological diversity, permeate our lands and waters, regardless of their actual or designated uses (Amoros et al. 1987).

The development of alternative approaches to resource management—approaches that better integrate maintenance of ecological values with commodity production—is one response to the dilemma (see Lee et al., this volume). These approaches are known by many labels, including "ecological" or "new" forestry and the Forest Service's New Perspectives Program. They are more often conceptual than prescriptive, pointing to the need for specific management activities to be in concert with the multiplicity of resources, environments, and landowner goals. New knowledge and technology are combined with old tools and experience to provide a broader spectrum of management tools (Franklin and Maser 1988). Most important, these approaches have a sound scientific basis in ecological science, although some of the applications or proposed practices can be viewed as working hypotheses or experiments (Hopwood 1991, Oliver and Hinckley 1987, Walters 1986).

I explore the relevance of New Perspectives to riparian zones in this chapter, beginning with a brief review of the ecological roles played by riparian environments; I take the broader view of the riparian area as the streamside influence zone. Then follows an overview of recent scientific research relevant to the design of ecologically oriented management practices—ecosystem complexity, biological legacies, and landscape ecology. I conclude with a section on key issues in the integration of ecological and commodity values and some specific practices—at the stand, stream reach, and landscape levels—that might be used to address those issues. My purpose is to illustrate the potential contribution of alternative management practices in

managing for a mix of resource values in both upland and riparian environments.

Ecological Benefits Provided by Riparian Environments

Riparian portions of our northwestern forest landscapes provide numerous ecological links between the forest and the aquatic ecosystem (Gregory et al. 1991*a*, Agee 1988, Heede 1985, Naiman 1990, Naiman et al. 1988, 1989). Riparian vegetation controls much of the environmental regime of stream ecosystems; this is less true of larger streams and rivers which greatly influence the nature of the riparian vegetation. Quantity and seasonal timing of light levels are most often determined by type and amount of streamside vegetation along small- and medium-size (up to fourth-order) streams. Light levels are critical to a variety of ecological processes as diverse as primary productivity, which is light-limited in heavily shaded streams (Gregory et al. 1991*b*), and feeding by fish (Wilzbach et al. 1986, Cummins 1974). Stream temperature is also strongly influenced by riparian vegetation; shading to maintain stream temperatures below lethal levels for fish was an early justification for preserving forest corridors and remains an important factor in warmer parts of the region (Hunt 1988, Agee 1988).

Riparian zones are the source of extremely important structural components of the aquatic ecosystem. Woody debris is often the dominant element in the physical structure of streams (Bisson et al. 1987); specifically, providing coarse woody debris for the stream channels is a particularly critical role of the riparian forest (Maser et al. 1988, Swanson et al. 1976, 1984; Keller and Swanson 1979, Harmon et al. 1986). The structural complexity resulting from woody debris is important in determining such stream-reach characteristics as ability to retain allochthonous inputs, store sediments, and detain water (Harmon et al. 1986, Sullivan et al. 1987, Bisson et al. 1987, Bilby 1981). Large woody debris can be directly responsible for the creation of stepped stream profiles and a variety of habitats, such as debris jams and sediment accumulations (sand or gravel bars); wood and wood-related materials may account for 50% or more of the habitats in small, densely forested stream reaches (Franklin et al. 1981, Harmon et al. 1986, Gregory et al. 1991*b*, Grant et al. 1990). These materials are important invertebrate resources (Anderson et al. 1978, 1984). Furthermore, large woody debris can strongly influence habitat diversity in large streams and small rivers through its effect on their hydraulic characteristics (Grette 1985, Bilby and Likens 1980).

Riparian vegetation provides important nutritional substrate for aquatic ecosystems (Gregory et al. 1991*b*, Triska et al. 1982). The allochthonous inputs that dominate small streams are the main source of energy and an important source of nutrients for the aquatic ecosystem. Research is making us increasingly aware of the large variety of species and life-forms that are present, as well as the high degree of spatial heterogeneity in natural streamside and riparian vegetation (Oliver and Hinckley 1987, Nilsson et al. 1989, Gregory et al. 1991*b*). One direct consequence of this richness is allochthonous inputs with higher levels of compositional and temporal diversity (Conners and Naiman 1984, Melillo et al. 1984). For example, herbaceous components of riparian vegetation typically senesce earlier in the season, contain higher nutritional content, and are more readily processed by the aquatic community than inputs from deciduous trees and shrubs which, in turn, are of higher quality and are more readily processed than needles and litter from coniferous trees (Gregory et al. 1991*b*, Melillo et al. 1983, Conners and Naiman 1984). Therefore, streamside zones that have a diversity of herbaceous, shrub, and tree communities generate more diverse allochthonous inputs qualitatively and temporally than those dominated by a single vegetation type.

Streamside zones also provide important and specialized habitat for many elements of biological diversity, a function that is disproportionately high for the area they occupy. Many plant and animal species are known to have their primary habitat requirements met within riparian environments (Raedeke 1988, Décamps et al. 1987, Rochelle et al. 1988). The existence of vascular plant species dependent on the special moisture and temperature of the streamside zones is well known; some of these may be equally dependent on the pattern of chronic disturbance associated with floodplain environments. Many species of both vertebrate (Murphy 1979) and invertebrate (Lattin 1990) animals are identified as riparian species. Other animals, including many invertebrates, divide their life cycles between riparian and upland habitats (Merritt and Cummins 1978) and still others, including many species of bats, make essential daily use of both conditions (West 1988, Cross 1988). In addition to direct use of riparian habitats, streamside corridors are hypothesized to be routes for the movement or migration of various animal species (Raedeke 1988), although this use has not been well documented.

Disturbance regimes in stream ecosystems are important in maintenance of both species and processes; furthermore, the roles of chronic events (e.g., annual flooding) and episodic ones (e.g., debris flows and high intensity floods) are different (Gregory et al. 1991*b*, Lamberti et al. 1991). Episodic disturbances are most important in shaping the riparian zone and its vegetation. Substantial import, movement, and export of woody debris and sediments occur during major storm episodes. Shifts in channel morphology and woody debris are more limited with chronic flooding, although annual events do provide for the regular creation of freshly disturbed habitats for plant colonization. In any case, both chronic and episodic disturbances are important elements of riparian zones, and their contrasting roles need to be recognized in New Perspectives management.

One conclusion based on existing ecological research is that the structurally and compositionally diverse streamside zones are well suited to produce the desired mixture of "ecological services" for the associated aquatic ecosystems. It also appears that natural streams or reaches—those free of major human influences—are more likely to have high levels of complexity than those that have been managed (Bryant 1983, Triska et al. 1982). This translates into more diverse, productive, and resilient ecosystems. These conclusions are similar to those for upland areas, which are addressed in the next section.

The Scientific Basis for Alternative Management Regimes

The expanding ecological knowledge of terrestrial and aquatic ecosystems, particularly in the Pacific Northwest, is a major factor both in identifying problems with existing practices and in offering solutions. Therefore, a discussion of the scientific underpinnings of New Perspectives is a good place to begin (Hopwood 1991). Any proposed management practice, however, including most current approaches, must be considered a working hypothesis until its effectiveness is verified.

Only recently have we begun to examine natural forests and associated streams as ecosystems. Although there has been a long history of silvicultural, autecological, and fisheries research, studies of natural forest ecosystems started just a little over two decades ago, with National Science Foundation support of the International Biological Program's (IBP) Coniferous Forest Biome Project in 1969 (Edmonds 1982). This project and subsequent ecosystem research programs, including the Long-Term Ecological Research (LTER) project at H. J. Andrews Experimental Forest (Franklin et al. 1990), have yielded a wealth of information. Other programs, such as the Old-Growth Wildlife Habitat Program (Ruggiero et al. 1991), have greatly expanded our knowledge of biological diversity and its requirements. I will review some of this information under three topical headings: (1) ecosystem complexity, (2) "biological legacies," or aspects of ecosystem regeneration following catastrophic disturbances, and (3) landscape ecology perspectives. While these subject areas are not new, the richness of the scientific information base is, as well as its relevance to forest management issues.

Ecosystem Complexity

Scientific studies have shown that the natural forests and streams are far more complex than we had imagined in terms of their composition, function, and structure (Franklin et al. 1981, Edmonds 1982, and Gregory et al. 1991*b*). In particular, the natural mature and old-growth forests are far more than just young forest stands grown senescent. Such forests have distinctive properties and functions.

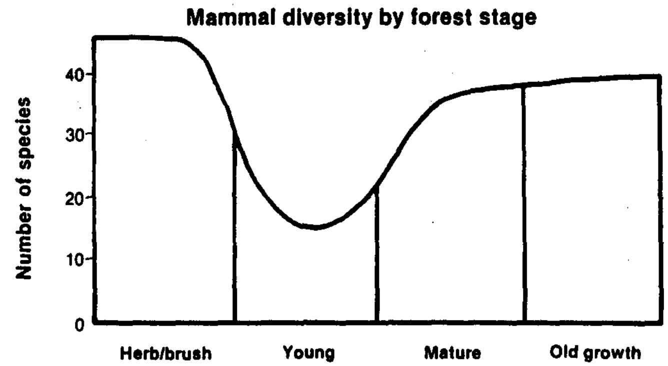

FIGURE 3.1. Number of species of mammals associated with different successional stages in Douglas-fir forests (data based on Harris 1984). Young forests are typically 20 to 80, mature 80 to 200, and old-growth 200 years old.

Compositional Diversity

Natural forests and streams are rich in species, but this varies greatly with successional stage. Mammalian species provide an example of successional changes in species diversity in Douglas-fir (*Pseudotsuga menziesii*) forests (Figure 3.1) (Harris 1984, Brown 1985*a*, *b*). Species richness is highest early in succession, drops to much lower species numbers following forest canopy closure, and then recovers to intermediate levels of diversity in the mature and old-growth stages. This is a common pattern for many groups of organisms, including birds (Brown 1985*a*, *b*; Thomas 1979), fishes, and many classes of invertebrates. Vascular plant species behave similarly. High levels of plant species richness occur in the open ecosystem prior to tree canopy closure; this diversity is a mixture of surviving forest species and weedy pioneer species (Schoonmaker and McKee 1988, Halpern and Franklin 1990, Franklin 1990*a*).

Although the early successional (precanopy closure) stage typically has more total species, many of the species found in the mature and old-growth forests have specialized habitat requirements. These species appear to require conditions that are found primarily in later stages of forest succession; consequently, they are found primarily in those forests. The northern spotted owl (*Strix occidentalis caurina*) is a well-known example (Thomas et al. 1990). In his research on old-growth Douglas-fir forests of the Pacific Northwest, Carey (1989) has identified five vertebrate taxa that are dependent on these forests, seven that are closely associated with them, and eight that are possibly associated. Many are also found in low abundance in natural young forests (Ruggiero et al. 1991) for reasons that will be discussed later.

Of equal or even greater importance is the high diversity of so-called lower organisms (such as invertebrates, fungi, and microbes) present in natural forests and streams. This "invisible," or "hidden," diversity involves groups of organisms that are poorly known and—except for pests and pathogens—receive little attention from the public and resource managers. Yet there are far more species of these organisms than the vertebrates (Schowalter 1989, Moldenke 1990). Knowledge of these lesser organisms is limited, but available evidence indicates that their diversity is high in natural forests (at least older forests) and significantly reduced in managed forests. For example, Schowalter (1989) found 61 species of arthropods in the canopy of an old-growth forest and only 16 species in an adjacent young stand (e.g., plantation). Furthermore, most of the old-growth invertebrates were species that prey upon or parasitize other kinds of invertebrates; in terms of total arthropod numbers (not species), the ratio of predators + parasites to herbivores was 1:4 in the old-growth stand and 1:1,000 in the young stand.

Natural forests and streams, including old-growth forests, then, appear to be biologically diverse ecosystems. High levels of species diversity are characteristic of organismal groups that have been studied. Many of these appear to be specialized in their habitat requirements. Many, especially the lower organisms, provide for important ecosystem functions, including maintaining the vitality of the forest and stream ecosystems they inhabit.

Functional Characteristics

Investigations of ecosystem functions such as productivity, nutrient cycling and retention, and regulation of hydrologic cycles reveal a richness of process as well as organisms in natural forests and streams (Franklin et al. 1981, Gregory et al. 1991*b*, Triska and Cromack 1980). Productivity is the most basic ecosystem process. Studies have documented that mature and old-growth forests in the Pacific Northwest are particularly productive biologically (Grier and Logan 1977, Fujimori et al. 1976). The large leaf areas found in these forests (Franklin and Waring 1980) confirm the high levels of gross production, since trees do not retain leaves that lack a net benefit in terms of photosynthesis. The difference between young and old forests appears to be that in older forests much of the productivity is utilized in respiration (estimated, in Grier and Logan 1977, at greater than 90%) rather than for production of additional wood. Furthermore, much tree growth is offset by tree mortality, although most old-growth stands in the Douglas-fir region probably continue to gradually accumulate wood (DeBell and Franklin 1987) and, almost certainly, total organic matter (stored carbon) for at least five to eight centuries (Spies et al. 1988).

Streams associated with old-growth forests typically have less primary productivity than those in open areas because of low levels of sunlight (Gregory et al. 1991*b*, Triska et al. 1982). However, total carbon inputs are typically higher in the old-growth, due to allochthonous inputs.

The nitrogen (N) cycle, particularly as a source of N inputs, provides another example of the richness of processes within natural forests. Thirty years ago it was thought that most inputs of N in coniferous forests were contributed by free-living cyanobacteria. Now at least four locales for N-fixation have been revealed by ecosystem research. An early discovery by the IBP was N-fixation by large foliose lichens, such as *Lobaria oregana*, that occur in canopies of old-growth Douglas-fir (Denison 1979, Carroll 1980). Current estimates place annual N-fixation at 5 to 9 kg/ha in a typical old-growth forest. Other sites that can experience significant N-fixation include rotting wood (e.g., large logs) (Cornaby and Waide 1973, Sharpe and Milbank 1973), the rhizosphere (regions immediately adjacent to tree roots), and leaf litter (Heath et al. 1987). Levels of N-fixation within intact coniferous stands are substantially less than those that can occur within stands of red alder (*Alnus rubra*) or other trees with N-fixing symbionts; annual N-fixation in such stands can exceed 200 kg/ha (Trappe et al. 1967).

Complexity is particularly evident in the numerous linkages revealed by ecosystem research—the richness of food and material webs and flows, or functional relationships. The below-ground portion of the forest provides an excellent example. Although only 20% of the biomass is below ground, 25 to 70% of the photosynthate produced by the plants may be required for below-ground maintenance because of high rates of turnover in fine roots and mycorrhizae (Harris et al. 1980). Such findings underline the importance of green plants as energy sources fueling the soil subsystem, and consequently the reciprocal dependence of trees and soils (Perry et al. 1989)—something typically not appreciated by foresters. The mycorrhizae and mycorrhizal relationships also provide direct linkages among trees and between forest overstory and understory. Through fungi and other organisms, the soil subsystem is in fact a highly interlinked living system.

The forest canopy is a second subsystem illustrating the complex relationships of forest ecosystems. The canopies in old-growth Douglas-fir forests represent immense surface areas; leaf areas of 8 to 14 m^2/m^2 of ground surface are typical (Franklin and Waring 1980), perhaps 50 to 100% more than young stands on comparable sites. Documented foliar surface areas of over 4,000 m^2 (all sides) have been measured on individual old-growth Douglas-fir (Pike et al. 1977, Massman 1982). Large and diverse amounts of habitat are provided by the forest canopies, which are typically continuous from the top of the crown to the ground; hence canopies are capable of providing niches for a very large array of organisms.

Canopies also represent the major interface between the forest and the atmosphere. From one perspective they are giant atmospheric scavengers which condense large amounts of moisture and precipitate dust and other atmospheric particulates, bringing these materials into the ecosystem. In some forest areas condensation from fog and low clouds adds significantly to moisture inputs, and consequently to streamflow. For example, Harr (1982) found that fog drip from old-growth forest canopies produced a net 882 mm increase in precipitation over that experienced in adjacent open areas at a mid-elevation site in the northern Oregon Cascade Range. Of course, in other localities lacking abundant fog and low clouds, forest removal may result in increased streamflow as evapotranspiration is reduced.

Structural Characteristics

Structural complexity and diversity in natural forests provide the key to much of the richness of organisms, habitat, and processes (Franklin et al. 1981). Some of this complexity can be defined in terms of individual structural features, as in many current definitions of old-growth forests (Old Growth Definition Task Group 1986, Franklin and Spies 1984, 1991*a*, *b*). These individual structures include large old-growth trees, large snags or standing dead trees, and large down logs.

Large individual old-growth trees are not only dominant visual elements of the old-growth forest but also carry out critical processes and provide diverse and essential habitat (Franklin et al. 1981). Old-growth Douglas-fir trees will attain diameters of 1 to 2 m and heights of 50 to 90 m; furthermore, they are highly individualistic, having been shaped over centuries by their genetic heritage, site conditions, competition, and the effects of various kinds of disturbances. They function as primary producers, and the canopies and boles provide habitat for a large number of epiphytic organisms, including nitrogen-fixing lichens, and for a large and diverse community of invertebrates (Franklin et al. 1981, Lattin 1990, Moldenke 1990, Schowalter 1989). The large old trees are also the source of two other key structural components on the forest floor: the large standing dead trees and large logs.

Intermediate-size trees of the shade-tolerant species, such as western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and Pacific silver fir (*Abies amabilis*), are also important structural components of the old-growth forest (Franklin et al. 1981, Spies and Franklin 1991). These species provide a range of tree sizes from seedlings to large individuals which are canopy codominants, producing a many-layered or continuous canopy from the ground to the top of the crown. In fact, light levels at the old-growth forest floor are typically controlled by the density and size of shade-tolerant trees rather than by the dominant Douglas-fir trees.

Large snags and down logs (>10 cm diameter), collectively known as coarse woody debris (CWD), represent two other important structures found in natural forests (Maser and Trappe 1984, Harmon et al. 1986, Maser et al. 1988, Franklin et al. 1981). The importance of snags to wildlife has been recognized by biologists for some time (Brown 1985*a*, *b*; Thomas 1979), but recognition of the ecological benefits of CWD on the forest floor and in the streams has emerged more recently. These benefits range all the way from geomorphic functions, in influencing erosional processes; to biological diversity, in providing habitat for a broad array of animal and plant organisms; to providing long-term sources of energy and nutrients for these systems.

The change in attitude toward CWD reflects a dramatic recognition that dead trees are as important to ecological functioning in a forest as live trees (Franklin et al. 1987). Moreover, the dead tree structures may perform terrestrial and aquatic functions for many centuries because of their slow rates of decay or disappearance from ecosystems (Harmon et al. 1986). And those functions change throughout the "lifetime" of a dead log.

Overall structural heterogeneity is also an important feature of almost all natural forests and, of course, related riparian habitats; spatial heterogeneity is particularly notable in old-growth forests. So while the individual structural components of the forest—large trees, snags, and down logs—are important, a natural forest cannot be reduced simply to those individual structures: the forest as a whole has both vertical and horizontal critical structural attributes. One important component of stand-level structural diversity is related to canopy density. There are locales within the stand where light levels are higher (canopy gaps) and there is rich development of the understory. There are also areas where a dense overstory, such as of western hemlock and western redcedar, produces heavily shaded locales essentially barren of understory plants. This variability in light conditions, as well as below-ground competition for moisture and nutrients, contributes to the incredible complexity and richness of understories in old-growth forests. These diverse understories can be critical for some organisms; for example, the old-growth forests provide essential winter habitat for the Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in the coastal Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) forests of southeastern Alaska (Alaback 1984, Schoen 1990, Schoen and Kirchoff 1990). Research by Alaback and others is showing that the development and maintenance of diverse understory plant communities in forest stands is very complex, not simply a matter of manipulating crown density or light levels.

Riparian habitats associated with natural forests are, if anything, even more heterogenous than the upland areas (see, e.g., Triska et al. 1982, Franklin et al. 1981, Gregory et al. 1991*b*, Pringle et al. 1988, Bisson et al. 1982). There are high levels of environmental heterogeneity (e.g., light) associated with the location and activity of the stream channel, and both coniferous and deciduous tree species are typically present. Coarse woody debris is much more aggregated in the riparian habitat than in the adjacent uplands (Harmon et al. 1986). As in the uplands, the structural heterogeneity of the riparian is very important in providing for many microhabitats or niches, which in turn sustain a greater diversity of organisms and functions.

Biological Legacies

The processes by which ecosystems recover from catastrophic disturbances—particularly the living organisms and dead organic materials that are "passed on" from the original, destroyed ecosystem to the new, regenerating ecosystem—provide an important key to understanding how nature perpetuates complexity and richness (Franklin 1990*a*). When Mount St. Helens (Washington, USA) erupted on May 18, 1980, it provided scientists with a unique object lesson and a grand experimental area to study pattern and process in ecosystem recovery. At first they assumed that the area had been essentially sterilized and would recover through primary succession processes.

In fact, most species of organisms survived within the Mount St. Helens landscape (Franklin et al. 1985, 1988). Within two weeks of the eruption, scientists encountered in the devastated zone large numbers of organisms that had survived using a wide variety of strategies. Those living below ground, or which could regenerate from parts protected below ground, or those that were buried in a snowbank or in the mud at the bottom of a lake, or in any of several other environments, were able to survive. Surviving seeds, spores, and full-size organisms were important elements in the early recovery at Mount St. Helens. In addition to the living legacy, there was an immense legacy of dead organic matter, much of which was in those biologically derived structures so important for ecosystem function: snags, logs, and large soil aggregates.

The importance of biological legacies, both living and dead, stimulated several groups of scientists, including the H.J. Andrews Forest Ecosystem Group, to consider ecosystem responses to other catastrophic events. What happens in forests following fire, windstorm, flood, avalanche, or outbreaks of pests and pathogens? While most natural catastrophes kill trees and other organisms, they typically leave behind most of the carbon in the form of snags and down logs. These disturbances also leave behind large legacies of living organisms, including trees, because most disturbances are patchy.

It is apparent, because of these biological legacies, that most natural forest ecosystems do not start "from scratch" following a major disturbance. Young natural forests typically exhibit substantial structural diversity and species richness. Evidence of these legacies is found, for example, in 80- to 145-year-old stands of Douglas-fir regenerated following catastrophic wildfires in the mid-1800s and early 1900s; these natural stands included scattered large old trees, large snags, and abundant down logs as structural components (Spies et al. 1988, Spies and Franklin 1991). Many such naturally regenerated forest stands are actually forests of two or more ages, or mixed structure stands, not the even-aged and -sized stands often described. Long-term patterns in quantity and quality (decay state) of CWD following catastrophic disturbances are also well understood for Douglas-fir forests; young and old stands alike will have high levels while the mature stands (100 to 200 years old) will have minimal levels (Figure 3.2) (Spies and Cline 1988).

The concept of biological legacies is not new, but it has been nearly ignored in the ecological and silvicultural textbooks. Ecological science has emphasized the need for migration and reestablishment of individual species in barren areas; so while scientists knew about biological legacies, their significance was not appreciated. Perhaps one reason for this is the historical

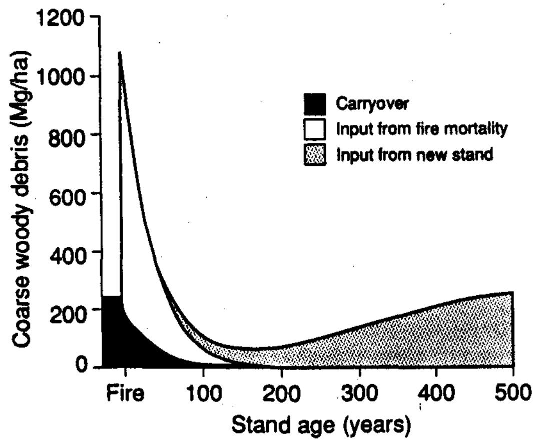

FIGURE 3.2. Levels of coarse woody debris in relation to forest age for Douglas-fir and western hemlock forests The high levels in young forest are the result of the legacy of dead trees from the preceding stand (from Maser et al. 1988).

emphasis on old-field succession in ecological research. Such environments offer minimal levels of legacies compared with other types of secondary forest seres, such as those that follow fire, windstorm, insect epidemic, flood, or avalanche. Another reason may be the forester's traditional orientation to the reforestation of devastated areas (see Oliver et al., this volume). Rapid restocking of sites with trees is one approach where human intercession often does assist nature; this result can also be seen at Mount St. Helens, where tree planting has reestablished forests more quickly than natural reseeding.

Comparisons of biological legacies do make clear some critical differences between natural disturbances and traditional even-aged harvest cutting methods. For example, the effects of clearcutting are not ecologically comparable to the effects of most natural disturbances, including wildfire. Levels of biological legacies are typically high following natural disturbances, leading to rapid redevelopment of compositionally, structurally, and functionally complex ecosystems. Traditional approaches to clearcutting purposely eliminate most of the structural and much of the compositional legacy in the interest of efficient wood production.

Catastrophic disturbances to upland areas typically lead to creation of significant biological legacies in associated riparian and aquatic habitats. At Mount St. Helens, streams received major inputs of large woody debris within areas of blown-down forest (Franklin et al. 1985, 1988). Similar effects in riparian habitats—such as high loadings of woody debris—can be seen following wildfire, windstorms, and insect outbreaks. However, significant time may elapse between the death of standing trees and their delivery to adjacent

streams; for example, Engelmann spruce (*Picea engelmannii*) killed in bark beetle (*Dendroctonus rufipennis*) outbreaks in Colorado typically stood for several decades before falling over.

Some disturbances—such as debris torrents or landslides—leave little in the way of biological legacies, and disturbances of this type are more common within riparian areas than in the uplands (Leopold et al. 1963). The materials removed may become a legacy (deposit) somewhere else in the landscape, but a relatively barren site is typically created.

Landscape Ecology Perspectives

Landscape ecology is the third area of science underpinning a new perspective on forest and stream management. The landscape perspective refers to the need to consider larger spatial and temporal scales than have traditionally been considered in forestry. It means thinking beyond the individual stands or patches or reaches of streams to drainages, mosaics of patches, and long-term changes in these mosaics. Many of the critical issues facing forest managers today must be approached at these larger scales, as outlined below in a discussion of the cumulative effects and forest fragmentation issues. Some foresters have thought on larger spatial and longer temporal scales, as is reflected in the forestry logging plans developed in the 1950s (Ruth and Silen 1950, Silen 1955), but the issues addressed had to do with logging rather than ecology. What is needed now is a more comprehensive approach to managing forest and stream resources, using concepts and tools from the emerging discipline of landscape ecology (Forman and Godron 1986; see also Pastor and Johnston, this volume, and Swanson et al., this volume).

Early examples of landscape-level perspectives in natural resources typically dealt with management of large game animals. Managers who worked with grizzly bear (*Ursus horribilis*) and elk (*Cervis elaphus*) quickly recognized the need to consider areas covering thousands of hectares and a mix of habitats. The "greater ecosystem" concepts associated with Yellowstone National Park provide one current example of this perspective (Agee and Johnson 1988).

Unfortunately, in forestry we are learning much about landscape ecology from experiences with dysfunctional landscapes—landscapes that are not working very well—rather than from studying healthy ones. Landscape disfunction includes the phenomena commonly referred to as cumulative effects and forest fragmentation.

Cumulative Effects

Cumulative effects are diverse phenomena resulting from the collective impacts of management activities (Geppert et al. 1984, Peterson et al. 1987, Sonntag et al. 1987). These are negative or undesirable consequences that can involve the additive effects of a repeated single activity, such as forest harvest, or the synergistic or additive effects of two or more activities. Cumulative effects may show threshold behavior: the cumulative impacts are minimal up to some critical point, after which major changes occur—through time at a particular site or through time and across space.

In the forest landscapes of the Pacific Northwest, cumulative effects most often concern impacts of forest harvest and road building on hydrology (e.g., frequency and intensity of flood events) and on fisheries (e.g., sediment production and destruction of spawning habitat). Roads and recent clearcuts tend to be particular problems because of a much higher probability of undesirable hydrologic or geomorphic events in these areas, such as landslides (Sidle et al. 1985) or higher peak flows associated with rain-on-snow flood events (Harr 1986).

Mass soil movements of various types are primarily management-related sources of sediment impacting streams and rivers in many watersheds of the Pacific Northwest (Naiman et al., this volume). Damage to fish habitat, particularly spawning and rearing habitat for anadromous fisheries, is of particular concern (Cederholm and Reid 1987, Bisson and Sedell 1984). Road systems are a primary source of mass soil movements (Sidle et al. 1985, Swanson et al. 1987). Although improved road location and construction methods and reconstruction of older roads reduce the probability of mass soil movements, the potential remains much higher than in unroaded areas (Sidle et al. 1985, Swanson et al. 1987). Similarly, recently clearcut areas in mountainous topography have a significantly higher probability of landslides than unlogged areas, quite apart from roads (Sidle et al. 1985, Swanson et al. 1987, 1989). An important contributing factor is that the root systems of the logged forest, which function as soil binders, decompose before full replacement by the regenerating forest. The period following clearcutting when mass movements are most likely to occur varies across the region (Table 3.1) (Sidle et al. 1985, Swanson et al. 1987). The regional differences shown in Table 3.1 reflect differences in the decay rate of the old root systems and the regeneration rate of the new root system in these contrasting forest environments. Therefore, both the extent and the types of roads and cutover areas at vulnerable ages raise significant issues regarding cumulative effects in the mountain landscapes of the Pacific Northwest.

The frequency and intensity of floods resulting from rain-on-snow events create another cumulative effects issue in the Pacific Northwest (Harr 1986). Much of the Cascade Range and the Olympic Mountains lies within a "transitional" or "warm" snow zone, largely within an elevational belt (350 to 1,100 m in western Oregon; Harr 1986) that develops a snowpack during winter cold periods. A subsequent warm front with warm air and rain can melt much of this snowpack. High streamflows, commonly known as rain-on-snow flood events, sometimes result from the combined runoff from rainfall and the melting snowpack; the snowpack can contribute over a third of the water under some weather conditions (Harr 1986). Many of the major

Table 3.1. Relation of landslides to time since clearcutting (percentage of inventoried slides).

Time since Clearcutting (years)	Location: Oregon Coast Range* (%)	Oregon Cascade Range† (%)	Idaho Batholith‡ (%)
0 to 3	63	46	24
4 to 10	29	42	41
≥11	8	12	35
Total	100	100	100

*Gresswell et al. (1979) for Mapleton, Oregon, USA, area.
†F.J. Swanson, unpublished data for H. J. Andrews Experimental Forest, on file at the Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon, USA.
‡Megahan et al. (1978).

flood events along the northwestern coast of North America, from northern California to southeastern Alaska, are of this type. These meteorological events also trigger major episodes of landslides and channel erosion (Harr 1986).

Clearcutting often increases the size of peak flows during rain-on-snow events relative to flows from areas of mature and old-growth forest (Harr 1986, Berris and Harr 1987, Harr et al. 1989). Old-growth forests typically intercept a large portion of the snow in the canopies. Much of this intercepted snow melts and drips to the ground, infiltrating the soil; additional snow is lost to sublimation and evaporation. The snowpack that does form is protected by the forest canopy from direct exposure to the atmosphere. In contrast, deeper accumulations of snow (and much greater amounts of water) may occur on recently cutover areas; in one study, water equivalents were two to three times greater in a clearcut than in an adjacent old-growth plot (Berris and Harr 1987). Furthermore, the snowpack in the clearcut is fully exposed to turbulent warm air and rain; it is actually latent and sensible heat transfer from the warm, moist air mass to the snow surface during a storm that produces most of the melting (Berris and Harr 1987). Consequently, melting can occur more rapidly in open areas than in forested areas where wind speed and turbulence at the snow surface are low.

The contribution of recent clearcuts to rain-on-snow flood events can be considerable. Measured water outflow was 21% greater from a clearcut than from an old-growth forest plot in the central Oregon Cascade Range during the largest rain-on-snow event studied by Berris and Harr (1987). In the northern Washington Cascade Range, clearcut plots produced 84 and 90% more runoff than paired areas in mature forest (Harr et al. 1989). Clearcutting also decreases the return interval for a water input event of a given size; in other words, it increases the frequency for a flood event of a given magnitude (Harr 1986, Harr et al. 1989). Finally, hydrologic recovery for clearcut areas appears to be longer than the 20 to 25 years originally hypothesized. For example, preliminary results from a study in northern Washington suggest that hydrologic recovery is only about 50% complete in 25-year-old forest plantations (Harr et al. 1989).

Increased frequencies of high flood flows, debris torrents, and dam-break floods can dramatically affect aquatic environments, simplifying some stream reaches (especially those with steeper gradients) and burying low-gradient reaches in debris. An important management implication is recognizing that such events can degrade stream and river ecosystems even where riparian forest corridors are maintained. Hence any overall management strategy must consider not only riparian corridors but other activities, such as road density and construction and maintenance standards, that generate channel disturbances.

Cumulative effects of clearcutting and road systems on hydrologic and sediment regimes are therefore a serious landscape issue in the Pacific Northwest. The cumulative area of clearcuts and the early successional forest during a given period need to be carefully considered if managers wish to avoid high probabilities of specific geomorphic and hydrologic events. Cumulative impacts have, in fact, forced the U.S. Forest Service to limit timber sales in portions of the Mount Baker-Snoqualmie National Forest (United States Forest Service, Pacific Northwest Region 1990).

Forest Fragmentation

Extensive forest fragmentation provides another example of landscape disfunction, hence a stimulus to consider larger spatial and temporal scales. Fragmentation results when a large area of continuous forest becomes a mosaic of high contrast, small forest patches. Such forest fragments often lack the habitat conditions found in larger areas of intact forest and are more vulnerable to disturbances such as windthrow and wildfire (Franklin and Forman 1987, Perry 1988, Hansen et al. 1990, Gardner and O'Neill 1991).

The dispersed patch clearcutting system selected for cutting Douglas-fir forests on federal lands in the 1940s is a major factor in the fragmentation of the northwestern forest landscape (Franklin and Forman 1987). This approach to creating forest pattern is sometimes known as the "checkerboard" system because of its appearance halfway through a cutting cycle in an idealized application (Figure 3.3). The detrimental effects of dispersed patch clearcutting include the fragmentation of the forest matrix early in the cutting cycle (at about the 30% cutover point) and the creation of a large amount of high contrast, forest-cutover edge.

Edge effects are a major problem when a forest matrix is broken into small patches surrounded primarily by cutover areas. Such patches of residual forest have a modified environment throughout, lacking true interior forest conditions. For example, in the Douglas-fir region, the patch size selected for management is typically 10 to 15 ha. Recent studies show that the more extreme environmental conditions of a clearcut extend into the forest, in-

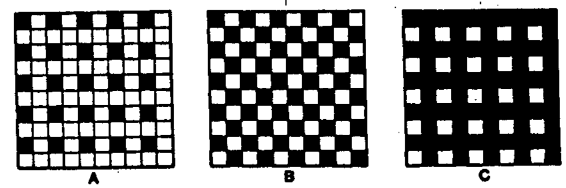

FIGURE 3.3. Dispersed patch clearcutting is sometimes referred to as the "checkerboard" system because the direction for dispersion of cutting areas produces a checkerboardlike pattern at around the 50% cutover level.

fluencing the microclimate of the old-growth forest for 200 m or more in the case of sensitive parameters such as relative humidity and wind. In extreme cases, such as a southerly exposed forest edge, influences may penetrate for more than 300 m (Chen et al. 1990, 1991; Chen 1991). Biotic processes are also influenced by the modified microenvironment; for example, rates of tree mortality increase dramatically (Chen et al. 1990). Forest patches have to attain sizes of 50 ha or more before a significant amount of unmodified interior forest condition is created (Figure 3.4).

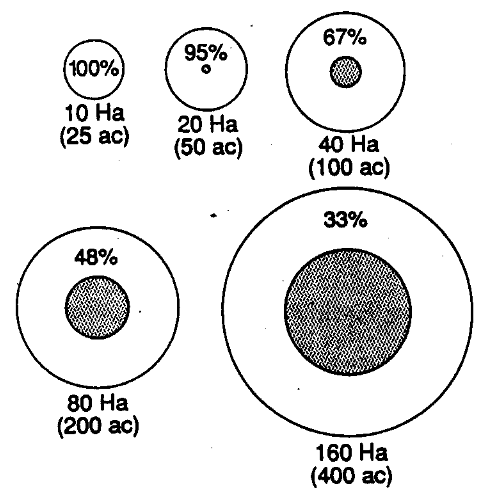

FIGURE 3.4. Edge effects can drastically reduce the amount of interior habitat within a forest patch surrounded by cutovers. Microclimatic measurements in Douglas-fir forests suggest that edge influences often extend 200 m or more into a forested patch. Illustrated here are the percentages of interior habitat associated with various forest patch sizes based on a 240 m area of influence.

Dispersed patch clearcutting has created comparable problems in the forests of the Lake States (Great Lakes region, USA), primarily because of the large amount of clearcut-forest edge that is created (United States Forest Service, Eastern Region 1991). In this case the extensive areas of edge environment produce high populations of white-tailed deer (*Odocoileus virginianus*), which, in turn, heavily browse the understories of the forested patches. Regeneration of tree species can be drastically affected, as can population levels of several other plant species of special interest (United States Forest Service, Eastern Region 1991).

Effects of fragmentation on riparian habitats appear to be more complex and have not, in any case, received as much study as in upland areas. One major question has to do with the relative cumulative effects of dispersed versus concentrated forest cuttings on hydrologic and geomorphic events (Grant 1990). Dispersed cutting is often proposed as a management strategy that minimizes cumulative effects. However, the answer to the question of dispersed versus aggregated cutting appears to be highly dependent on scale—that is, what sizes of watershed and cutover are under consideration (Grant 1990). Negative impacts of fragmentation on aquatic environments relate to the way it tends to chronically disturb essentially all drainages in a landscape in perpetuity and to require maximum densities of active roads.

In summary, fragmentation is a generic problem whereby an area is divided into patches lacking sufficient size to produce suitable habitat for interior-forest species or lacking viability (an ability to persist in the face of windthrow) or both (Franklin and Forman 1987). In the Pacific Northwest, fragmentation occurs when a landscape of small forest patches interspersed with cutovers is created, effectively eliminating interior forest conditions. This is a serious problem for the species and ecological processes dependent on interior forest environments. The extreme alternative—large continuous clearcuts lacking any residual forest areas—is, of course, equally inappropriate for interior species and processes (as well as many other organisms), even though these clearcuts are not fragmented landscapes. Effects of fragmentation on riparian habitats are complex and poorly understood.

Summary of Scientific Underpinnings

Recent scientific findings regarding ecosystem complexity, biological legacies, and landscape ecology make up a large and rapidly growing body of knowledge that is substantial, quantitative, and provides some fundamental principles that can be used to create alternative forestry practices. These findings show that natural forest ecosystems are much more complex than foresters and scientists believed them to be. As each piece and process has been identified and studied, its significant and sometimes essential role in the functioning of the forest has also become apparent. This makes clear that organisms, structures, or processes generally cannot be discarded without ecological consequences. Hence forest simplification—the basis for most current commodity management—needs to be approached with caution and humility.

Nature provides for the rapid recreation of ecologically complex young forests through the mechanism of biological legacies. These carryovers of live and dead organic materials and the processes associated with them help ensure that natural young forests are structurally and compositionally diverse. In effect, nature perpetuates ecosystems rather than simply reforesting with stands of trees. This finding suggests that management of forests should give greater attention to what is retained on the site at the time of harvest. Much larger land areas—landscapes—and time periods must be considered in forest planning. Without these grander perspectives, forest resources will almost certainly experience undesirable cumulative impacts.

What Are Some Alternatives Under New Perspectives?

How well have foresters and other resource managers incorporated this new knowledge into philosophy and practice? Some concepts, such as maintenance of coarse woody debris in forests and streams, have been accepted relatively rapidly, particularly on public forest lands. However, professional managers have been much slower to incorporate other ecological concepts, probably partly because of a general reluctance to accept the idea that traditional practices have significant environmental costs.

Traditional forest practices are based on principles of simplification and homogenization of the forest resource at the tree, stand, and landscape levels in order to achieve economical wood fiber production (Franklin et al. 1986). Approaches based on these principles were consistent with the state of forest science as it existed at midcentury. Consequently, foresters developed a management paradigm for Douglas-fir in the 1940s based on clearcutting, broadcast slash burning (including the disposal of large woody debris), and planting of conifer monocultures. These approaches also reflected a midcentury societal emphasis on production of wood fiber.

Circumstances have changed. As partly outlined in the preceding section, our understanding of forest ecosystems and landscapes has improved dramatically. We are learning that what enhances efficient production and harvesting of wood fiber in the short term does not always enhance other forest values and long-term productivities. Society has become concerned with many other forest values, including the maintenance of biological diversity.

With expanded knowledge and objectives, the goal becomes one of using ecological knowledge to create alternative forest management systems (Perry and Maghembe 1989). That is what New Perspectives (*sensu* this conference), the Forest Service's New Perspectives Program, and New Forestry are all about (Franklin 1989, 1990*b*). Management approaches must be developed which better integrate the maintenance of ecological values with production of commodities (see Lee et al., this volume, and Stanford and

Ward et al., this volume). These approaches must incorporate the best ecological science as well as accurately reflect societal values and objectives. They should also provide feedback mechanisms so that new technical information and societal objectives are continually incorporated.

Two additional philosophical points on New Perspectives should be made before discussing specific practices. First, there is no intent here of throwing out the old tools of forestry, such as traditional clearcutting, slash burning, and tree planting techniques. The idea is to add new knowledge and techniques to the existing approaches, thereby generating more management options. Second, some "new" practices resemble older, traditional forest practices. Logging systems that maintain mixed-structure stands have been utilized by foresters in both Europe and North America for over a century. They have not, however, been widely advocated or applied in western North America, partly because there has been little scientific rationale for using more complicated silvicultural systems.

Moreover, it is important to recognize that the new forestry practices being advocated differ significantly from traditional forestry in their philosophical and scientific roots, regardless of any superficial resemblances. Management of forests as whole ecosystems, rather than as collections of trees, is the basis for New Perspectives. For example, the retention of green trees in a cutting program, discussed below, is far different in objectives, application, and consequences from a partial cutting program that emphasizes the economically valuable trees in a stand. To suggest that foresters have previously tried and discarded New Forestry practices is nonsense, since the ecological knowledge to even conceptualize them is of such recent origin (Hopwood 1991).

Management systems are needed at both the stand and landscape levels that incorporate the new knowledge and the added societal objectives for forest lands and associated waters. Hence the following discussion is divided into stand and landscape approaches. Riparian habitats are relevant at both levels.

Stand-Level Approaches

In forest stands managed for some level of commodity production there is a general New Forestry principle: maintain or create stands that are structurally and compositionally diverse. Within the constraints of objectives and stand conditions, maintain as much diversity as possible rather than simplify the stand. Structural diversity is usually the goal, because structure is normally closely correlated to organisms and processes; that is, the structure provides the necessary conditions for organisms and ecological processes. The general principle of maintaining structural diversity should be kept in mind during the following discussion; this will reduce the tendency to have difficulty with specific practices being inappropriate to a particular stand or region. The exact set of silvicultural practices—the treatments developed to create or maintain structural diversity—will vary with forest type and condition, environment, and specific management objectives (see Oliver et al., this volume).

Young Stand Management

Through management practices, young stands provide many opportunities or pathways for developing elements or attributes that are important in enhancing diversity. An initial step would be aggressive efforts to create stands of mixed composition. Although natural reseeding of multiple species ordinarily reduces the potential for forest monocultures, intensive management tends to force the ecosystem toward a single favored species. Maintaining a mixture of species can greatly enhance ecological values, such as the ability to provide habitat for a broad array of organisms. For example, occasional hardwoods, such as a bigleaf maple (*Acer macrophyllum*), add significant structural and species diversity (e.g., in epiphytes, Coleman et al. 1956) to a conifer-dominated stand. Hardwoods such as alders (*Alnus* spp.) bring an additional benefit of nitrogen-fixation (Trappe et al. 1967).

Richer mixtures of conifers can also be valuable. The cedars, such as *Thuja* and *Chamaecyparis*, help improve site quality in addition to producing valuable wood products. All Cupressaceae are foliar calcium accumulators (Kiilsgaard et al. 1987) and produce high quality litter. In turn, the litter contributes to higher base saturation and rates of nitrogen mineralization, reduced acidity, and production of more biologically active mull humus conditions (Alban 1967, Turner and Franz 1985).

Foresters need to think much more seriously about species mixtures in designing managed forests both for ecologic and economic objectives. Prescriptions for precommercial and commercial thinning increasingly reflect a new appreciation for the maintenance of "minor" species. Continuing attention to species mixtures in both reforestation and stand improvement prescriptions will be important.

Delaying the process of canopy closure can also be of value in some young stands. Intensive forest management has traditionally sought rapid canopy closure (early full occupancy of the site by commercial trees). In fact, some foresters clearly favor instant canopy closure—the year following broadcast slash burning—and consider the open period of early succession wasted from the standpoint of tree productivity! Yet the period prior to tree canopy closure is an important one ecologically. This stage is rich in plant and animal species, as noted earlier, and many of these organisms are valued by humans. For example, many game species use the precanopy closure stage (Brown 1985*a*, *b*). Nitrogen-fixing vascular plant species tend to be most common at this time. Canopy closure is probably the most dramatic and, in terms of some processes, most traumatic single event in the life of the stand, other than its ultimate destruction by some catastrophe. Many aspects of the forest, including its composition and functioning, change rapidly and significantly at the time of canopy closure.

Canopy closure can be delayed by maintaining wider tree spacings to obtain more of the ecological values associated with precanopy closure stages of forest succession. Reduced tree planting densities and heavy thinning (mostly precommercial) can be used to achieve this objective. Furthermore, spacing studies show that wide spacing can be maintained in young stands with little or no sacrifice in commercial wood volume production (Reukema 1979, Reukema and Smith 1987). Tree pruning can be utilized in order to produce high quality wood in these more open-grown stands. Interestingly, New Zealand foresters use the cost-effective approach of widely spaced young stands and pruning in their management of Monterey pine (*Pinus radiata*) plantations.

All of the above young-stand management concepts have direct application to riparian habitats if riparian zones are committed to wood fiber production. Streamside forests of mixed composition are almost always preferable to forests of a single species from the standpoint of most aquatic ecosystem functions. For example, they produce a more diverse stream environment by virtue of inputs of allochthonous materials that vary in nutrient quality and timing of delivery to the aquatic system. A coniferous component that produces persistent large woody debris, such as Douglas-fir or western redcedar, is clearly desirable. Alternatives to dense, uniform coniferous canopies in riparian forests are also desirable (Salo and Cundy 1987, Raedeke 1988, Naiman and Décamps 1990). Again, these comments apply to riparian areas managed for wood production.

Maintaining Coarse Woody Debris

Practices that provide for a continuous supply of CWD—including large standing dead trees and logs on the forest floor—are important in maintaining stand-level structural diversity. There can be no question about the value of these structures for many species and ecological processes in both terrestrial and aquatic systems; this has been documented in many studies (Harmon et al. 1986, Maser and Trappe 1984, Maser et al. 1988). Practices that would contribute to this objective include retention of large woody debris at the time of harvest cutting and creation of snags and logs from green trees.

Retention of snags and large logs is a particularly effective practice in maintaining CWD when harvesting in young and mature stands of natural-origin and old-growth forests. Natural stands typically have significant amounts of CWD for potential biological legacies. Retention of large, downed wood is greatly enhanced by eliminating or modifying the practice of removing unmerchantable logs, which has been extensively applied on federal forest lands. Specifications for stream cleanup following logging, which called for channel cleaning in the 1960s, have been drastically altered during the last 10 to 15 years to provide for retention of CWD. Current streamside management on forests such as the Willamette National Forest (Oregon, USA) have used CWD production as a major rationale for retaining streamside forests. Provisions for CWD have also been a major consideration in revision of state forest practice regulations in the Pacific Northwest.

Snag retention is a more controversial practice than the maintenance of logs. There are concerns about worker safety, as well as increased difficulty in logging, which result in increased costs (Atkinson in Hopwood 1991). Snags also create potential problems in fire protection because of their tendency to produce firebrands once ignited. Nevertheless, snag retention on cutover areas is increasing, particularly on federal lands. Two approaches used to reduce the hazards while retaining snags are: (1) clustering snags in groups or patches rather than in a dispersed pattern, and (2) creating snags from green trees following cutting.

Many current forest harvest prescriptions for maintenance of CWD on national forest lands involve retaining green trees as snag sources, some existing snags, and unmerchantable logs (Figure 3.5). A key criterion in these prescriptions is to leave snags and trees sufficient in number to maintain a minimal snag level, such as five snags per ha >53 cm (21 inches) in diameter, during the next 80-year forest rotation. Evidence is already emerging that snag retention on cutover areas does provide wildlife benefits (A. Hansen, pers. comm.). Green trees can also be used as sources for CWD in stands that lack either large snags or logs, as is the case in many intensively managed stands. This is a particularly valuable practice for restoring structure to stands and landscapes that have been simplified by past practices.

Maintenance of CWD in streamside management zones is obviously of direct benefit to riparian habitats, given the central role of large wood in the structure and function of stream and river ecosystems (Gregory et al. 1991*b*, Harmon et al. 1986, Maser et al. 1988). The forest adjacent to live channels is particularly critical in small streams (McDade et al. 1990). River systems have greater ability to entrain large wood by bank cutting processes (Lienkaemper and Swanson 1987), but this assumes that the forested terraces support large trees. Hence it is important to maintain or develop riparian forests as source areas of large CWD for both streams and rivers.

Maintenance of appropriate quantities and qualities of CWD in managed stands is, in fact, much more complex than simply periodically providing for a few dead trees. Different tree species provide snags and logs with different characteristics, and therefore different abilities to provide for various habitat and other functions in both aquatic and terrestrial ecosystems. Tree species are not all equal in terms of CWD roles. Further, CWD typically needs to be present in various stages of decay. Numerous questions exist as to the quantities and spatial distribution of CWD required to achieve specific management objectives. Although a need for some level of CWD is desirable, how much is enough? Refining an approach to CWD will remain a challenge for both scientists and managers for many years to come (Maser et al. 1988).

FIGURE 3.5. Retention of structures from the cutover stand at the time of harvest helps maintain organisms and functions associated with later successional stages in forest development. In the Douglas-fir region such structures typically include the large green trees, large snags, and large down logs illustrated here (Willamette National Forest, Oregon, USA).

Green Tree Retention

Retention of living trees on cutover areas is another practice that can create higher levels of structural diversity in managed stands. This approach may be referred to as partial cutting, partial retention, or green tree retention, in an effort to distinguish it from both clearcutting and selection cutting (Franklin 1990*c*). Green tree retention involves reserving a significant percentage (10 to 40%) of the living trees, including some larger or dominant individuals, at the time of harvest for retention through the next rotation. The density, composition, condition, and distribution of the retained trees vary widely depending on management objectives, initial stand conditions, and other constraints. The general objective, however, is to sustain a more structurally diverse stand than could be obtained through even-aged management. Such partial-cutting prescriptions have not been widely used or recognized in forestry. Silvicultural textbooks discuss related concepts such as "shelterwood with reserves." Partial-cut stands contrast markedly with traditional even-aged stands, which involve only a single age class (Figure 3.6).

Many objectives can be achieved by retaining green trees on harvested areas. They can be used as sources of snags and logs, especially where safety concerns do not allow for retention of snags, and they can also provide desired wildlife habitat.

Green trees can function as refugia and inocula for some of that "hidden," or "invisible," diversity described earlier. For example, many species of the rich invertebrate fauna found in old-growth forests do not disperse well; many are soil dwelling, not canopy or stem species (Lattin 1990). Such organisms typically do not easily recolonize areas once habitat has been altered by clearcutting. Refugia for these kinds of organisms can be provided by leaving host trees which then become an inoculum or seed source in the new stand. The same concept is applicable to mycorrhizae-forming fungal species. At least some of these fungi can disappear in a short time if all potential host species are eliminated (Perry et al. 1987). When some of their hosts are left behind, the fungal communities conserved inoculate the young stands. This concept is a counterpoint to a common complaint about partial cutting: that green trees cannot be retained because they are sources of pests and pathogens. Most of the invertebrates and fungi in forest stands are, in fact, essential components that should be retained; retention of green trees is one tool with which to achieve that objective.

Green tree retention also alters the microenvironment of the cutover area. That is what shelterwood cutting is all about; the overstory moderates microclimate, encouraging tree regeneration where the environment on a clearcut is severe due to heat or frost. Obviously, what works for trees works for other organisms as well; other components of forest ecosystems will certainly survive better on partial cuttings than on clearcuts. Perhaps as important is that many organisms move more readily or safely through a patch or a landscape with green trees than they would through a clean-cut envi-

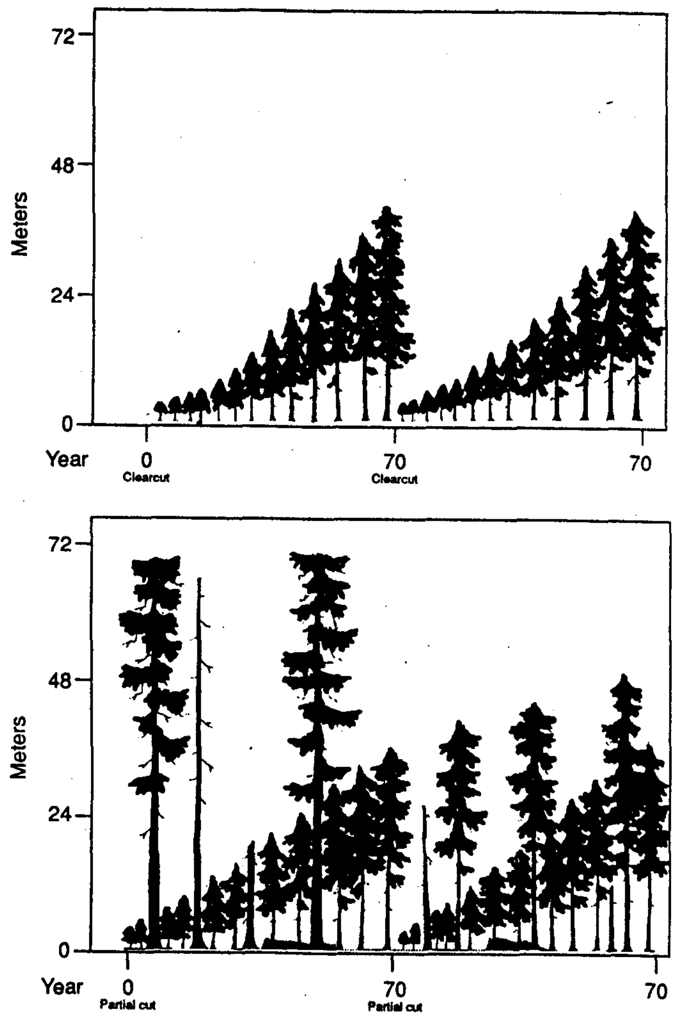

FIGURE 3.6. Idealized contrast in structure between a system based on clearcutting and even-aged management (top) and partial cutting and multi-aged management (bottom). The level of green tree retention under the second scenario can be quite small (10 to 20% of the stand) and still produce a structurally diverse stand.

ronment because of the ameliorated environment, protective cover, or both. Perhaps the connectivity in the landscape matrix can be improved by green tree retention reducing the isolating effects of cutover areas.

Retention of green trees can be used as a strategy to grow large, high quality logs during the next rotation (Figure 3.7). For example, mature (80- to 250-year-old) Douglas-fir can show substantial growth (Williamson 1973). Dominant trees in these age classes that are left behind have significant growth potential. Hence green trees could provide both economic and ecologic benefits in scenarios involving simultaneous management of a stand with a low density of large trees (e.g., western redcedar) on a long rotation and multiple short rotations of a species (e.g., western hemlock) managed for wood fiber production.

Green tree retention may have limited application within riparian zones, since harvest cutting is generally not proposed for these areas. However, if harvest cutting is proposed in a riparian zone, green tree retention is a relevant practice. Tree species that produce larger and more persistent wood, such as Douglas-fir and western redcedar, should be favored where generation of CWD is a concern. Hardwoods produce CWD that persists for a much shorter period (Harmon et al. 1986). Blowdown will typically be a more serious threat in the riparian zone than in the adjacent uplands, due to moister soils and shallow tree rooting; however, a major function of riparian forests is to provide CWD for the stream and floodplain (Maser et al. 1988).

The strategy of green tree retention on upland areas may offer direct benefits to stream ecosystems, although evidence on the following examples is not conclusive. Retention could reduce the potential for landslides through the maintenance of root strength. This concept underlies prescriptions for forest retention on stream headwalls in portions of the Oregon Coast Range (Sidle et al. 1985). Partial cutting might also be utilized to reduce the impact of forest harvest on the intensity of rain-on-snow flood events. This would presumably require sufficient trees for significant snow interception and alteration of the thermal balance on cutover areas.

Partial retention has immediate relevance to the northern spotted owl in the Pacific Northwest. Most natural disturbances, whether wind or fire, leave behind a significant component of green trees as well as a legacy of snags and logs. Even though true old-growth conditions do not develop until after 200 years, many natural stands begin to provide habitat suitable for the northern spotted owl and other late successional species at 70 or 80 years. For example, a large forest area on the Olympic Peninsula (Washington, USA) was blown down in a windstorm in 1921. Today these forests are dominated by 70-year-old western hemlock trees, but many such stands contain large residual old-growth trees, snags, and logs—and provide suitable habitat for the northern spotted owl. There are other examples of predominantly young but structurally diverse forests in the Pacific Northwest that provide suitable habitat for owls.

FIGURE 3.7. The number, species composition, and condition of trees left under partial cutting prescriptions vary widely according to management objectives, stand conditions, and environment. In this cutting, 25 to 30 ha of dominant mature Douglas-fir trees of superior vigor have been retained so as to provide for production of high quality wood during the next rotation while also fulfilling ecological functions (H. J. Andrews Experimental Forest, Willamette National Forest, Oregon, USA).

Partial cutting systems could be used to create similar mixed-structure stands suitable as habitat for owl and other species characteristic of late successional forests (see Oliver et al., this volume). For example, partial cutting using a rotation of 120 years might provide suitable habitat for such organisms for 40 to 50 years. Such an approach has much merit as an alternative to using rotations of 250 to 300 years, which would typically be necessary to recreate old-growthlike forest structures following a traditional "clean" clearcutting operation.

Prescriptions for green retention cutting will vary widely, depending on many factors, including objectives and stand conditions. For example, to provide for a minimal number of snags and logs it may be necessary to retain as few as 10 to 18 green trees 50 cm in diameter per hectare. Creation of mixed-structure forests suitable for late successional species may require retention of 20 to 40 green trees per hectare, depending on the forest age.

The appropriate spatial distribution of retained green trees (e.g., concentrating them in patches or dispersing them throughout the cutover area) is another important issue currently under study. In part, the answer depends on objectives and constraints. For example, green trees retained in patches may function more effectively as refugia for invertebrates and may minimize impacts on logging and other forestry operations (Figure 3.8). On the other hand, well-distributed snags and down logs are desirable from the standpoint of maintaining habitat for some species of wildlife and in contributing to maintenance of soil productivity.

Partial retention may have extensive application to areas adjacent to riparian management zones. Obviously, partial cutting prescriptions could be utilized to maintain a greater structural and compositional legacy when cutting is planned within the riparian zone. Partial retention in such areas can be used to buffer the riparian leave area, improving (1) the ability to provide interior environmental conditions and (2) the viability of the area, such as its ability to resist windthrow. Partial cuts would also provide a more gradual transition between intensively managed upland areas and protected riparian habitats. Aggregated green tree retention can also be used in upland areas to protect critical source areas of water and sediment.

Partial cutting may have applications for enhancing riparian zones even where harvest cutting is excluded. It could be used to release conifers from hardwood competition, for example, where larger conifer trees are desired as structural elements of a riparian stand. It could also be used to increase levels of CWD in and outside of the channel. The value and specifics of such silvicultural practices in the riparian zone are clearly important for New Perspectives research and development programs (Rainville et al. 1985).

Landscape-Level Issues in New Perspectives

The basic principle of New Perspectives at the landscape level is consideration of larger spatial and longer temporal scales while planning management activities. Recent research and experience make clear the need for

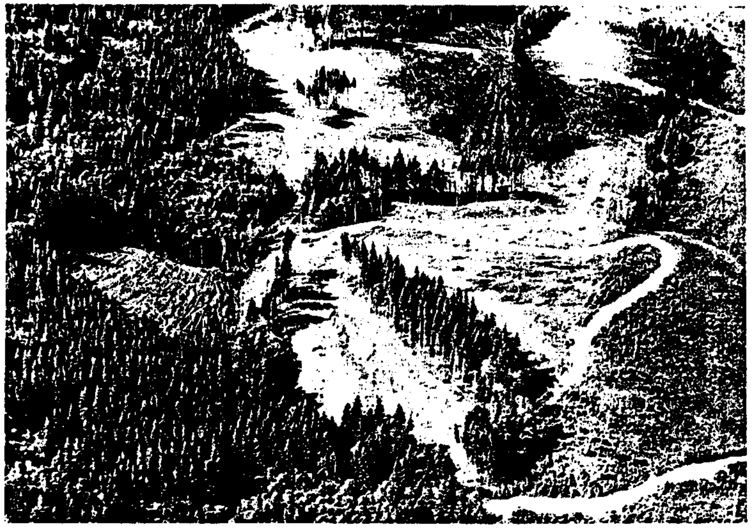

FIGURE 3.8. Green trees and standing dead trees retained on cutover areas can be dispersed or clumped in distribution. There are ecological benefits from both approaches (suggesting a mixed pattern might be in order), but aggregating the structures is often advantageous from the standpoint of logging costs and hazards and overall management efficiency (cutover on Plum Creek Timber Company lands, Cougar Ramp Cutting, Oregon, USA, with 15% of green trees retained).

broadened perspectives in assessing potential ecological consequences of various management alternatives. Managers must systematically think beyond the 10 ha patch, the kilometer stream reach, and planning horizons of 5 to 10 years. This is necessary not only to achieve long-term resource management objectives but to avoid undesirable future conditions, such as those associated with cumulative effects and habitat fragmentation. In considering landscape-level issues it is typically inappropriate to consider the upland or terrestrial and the streamside or aquatic components separately; they are far too interrelated at this geographic scale. But each does have its own distinct structural and functional properties, so a different management paradigm is appropriate for these two major components.

It is important to note in introducing this section that scientists know much less about landscape-level processes than they do about stand- or reach-level processes. Therefore, the following material generally addresses issues rather than offering prescriptions.

Management of Streamside Zones

Managing streamside management zones in their geomorphic and vegetative context is an important, widely recognized landscape-level concern (see Naiman et al., this volume). It involves several issues, including the desirability of matching the width and shape of riparian corridors with landform features rather than using a simple, standard prescription (Swanson et al. 1988, Beschta and Platts 1986, Potts and Anderson 1990). It also means treating different conditions individually. Many different stream types exist in a region such as the Pacific Northwest (Naiman et al. 1991). Most managers, scientists, and regulators would agree that each riparian area needs to be considered individually, and not blanketed under some common prescription.

Explicitly recognizing the longitudinal nature of our riverine ecosystems is essential in placing streamside management in its proper geomorphic context (Leopold et al. 1963). This linkage requires managers to pay close attention to sources and sinks of materials, such as sediments and large woody debris, and the circumstances under which they are generated, transported, and deposited, particularly when they are critical to downstream conditions. For example, areas of high fish productivity in coastal Oregon stream systems are often maintained by periodic debris flows from tributary drainages; these deposits provide the desired stepped profile and sorted gravels in the main stream (Benda 1985; Bisson et al., this volume). In southeastern Alaska large woody debris, an essential component of productive fish rearing habitat in estuaries, comes from mature and old-growth coniferous forest growing on islands and in floodplains along upstream channels and rivers; if all the floodplain forests are logged, the source of this structural material is eliminated, depriving the estuarine rearing habitats of their essential structure (Maser et al. 1988).

Systems of Preserved Areas and Habitats

Designing and implementing a network of reserved or protected areas within a matrix of timber-oriented or commodity lands is another major landscape-level concern. Some protected lands are needed to maintain the full array of ecological values, even within landscapes devoted primarily to timber production. Currently, numerous areas on public lands—riparian corridors, unstable soil areas, habitat areas for specific organisms, and Research Natural Areas—are preserved to achieve specific ecological objectives. Similarly, on state and private lands there are riparian management zones (RMZs) and upland management areas (UMAs) (Armour 1989). Often lacking is a systematic approach to designing these areas, especially with respect to their geographic distribution and connectivity (Naiman et al., this volume). For example, streams could have significant RMZs but if headwater areas lack sufficient protection, debris torrents and related phenomena can damage aquatic values. Basin-scale planning of silvicultural activities is needed to incorporate these kinds of components into a larger, functioning landscape (see Oliver et al., Pastor and Johnston, and Swanson et al., this volume).

Riparian corridors, including RMZs, are critical to this concept (Budd et al. 1987). They contribute directly to the maintenance of ecological processes and biological diversity in aquatic ecosystems and in the landscape as a whole (Naiman and Décamps 1990; Naiman et al., this volume). Furthermore, streamside corridors are geographically the dominant connecting elements in most networks for forested reserve areas, regardless of debates over their effectiveness as movement corridors for upland species.

Developing a comprehensive strategy for preserving biological diversity in our forest and range landscapes is, in fact, a much broader and more difficult challenge, particularly because of the large and diverse array of species requiring special consideration (see, e.g., Cissel 1990). Many of the vertebrate species are reasonably well known in terms of their habitat requirements, which often include late successional forest for some elements of their life history (Ruggiero et al. 1991). Furthermore, the size and spacing of suitable habitat enclaves required for the various plant and animal species, large and small, are highly variable. Some species, for example the northern spotted owl, have large home ranges and superior dispersal ability; therefore, large and widely spaced habitat preserves are appropriate, such as the habitat conservation areas (HCAs) of the Interagency Scientific Committee (Thomas et al. 1990). Other vertebrates, such as the tailed frog (*Ascaphus truei*), appear to have very limited dispersal ability and require smaller, highly localized habitat enclaves in order to maintain well-distributed populations. Invertebrate species exhibit a similar wide range in dispersal abilities; a significant number characteristic of old-growth Douglas-fir forests do have limited mobility (Lattin 1990, Moldenke 1990).

A comprehensive strategy for maintaining biological diversity will, therefore, require an array of habitat preserves of widely varying size and spacing. Large, widely spaced preserves, such as wilderness and other roadless areas, national parks, and HCAs represent the broadest approach. Reserved areas, such as riparian corridors, UMAs, and Research Natural Areas, provide a more closely spaced net of small- to medium-size reserves. Individual structures like large living trees, snags, and down logs, retained on the commodity producing lands, provide the finest net of habitat enclaves, or "preserves," in this multiscale strategy for maintaining biological diversity.

Regardless of the approach, biologists are beginning to recognize that the maintenance of biological diversity will not be achieved solely, or even primarily, using large preserves (J. Brown, University of New Mexico, pers. comm.). Preserved lands are too limited in area and are typically located in the less productive and less diverse parts of our landscape. For example, in the Pacific Northwest, low elevation forests have the highest vertebrate diversity (Harris 1984) and, almost certainly, invertebrate diversity as well. But most preserved forests are at higher elevations. Therefore, any strategy for maintaining biological diversity or ecosystem sustainability has to include modifications of commodity producing lands and stream management that incorporate these concerns.

Patch Size and Geographic Pattern of Management Activities

Other critical landscape-level issues are: (1) patch size, whether for managed or preserved areas; and (2) temporal pattern, whether to disperse or concentrate management activities over periods of a decade or more. These two issues are considered together because they are so interrelated.

Public forest lands within the Douglas-fir region traditionally have been managed using patch clearcuts of 10 to 15 ha in a dispersed landscape pattern. This approach produces a fragmented forest landscape with large amounts of clearcut-forest edge and little habitat suitable for interior forest species (Franklin and Forman 1987). Patch sizes are not adequate to provide for either interior forest conditions or the habitat requirements of some of the old-growth-related vertebrates, such as the pine marten (*Martes americana*) and the northern spotted owl.

The fragmented landscape is also predisposed to some kinds of catastrophic disturbance. For example, in the Bull Run watershed of the northern Oregon Cascade Range, wind damage associated with clearcut boundaries and road rights-of-way resulted in a blowdown of hundreds of hectares of residual forest areas (Franklin and Forman 1987). Dispersed patch clearcutting also requires the creation and maintenance of an extensive, permanent road system with continuing impacts on stream ecosystems, including sustained higher levels of sediments and peak flow alteration by roads serving as extensions of the drainage network (Harr 1982).

The net effect of dispersed patch clearcutting is chronic disturbance of all of the landscape in perpetuity. This human-imposed pattern contrasts with natural patterns of disturbance in the Douglas-fir region, which are usually large but infrequent, allowing extensive disturbance-free periods for ecosystem recovery (Swanson et al. 1982).

Landscape-level approaches to forest cutting patterns which provide alternatives to the dispersed patch clearcutting as currently practiced are now being designed and tested. One approach is to enlarge the patch size for both reserved and cutover areas to reduce edge effects and maintain interior forest conditions. For example, cutting could be concentrated in portions of the landscape—such as subdrainages of a few hundred to a few thousand hectares—over a period of 10 to 20 years. One consequence would be larger cutover areas with higher levels of within-stand structural diversity maintained within the cutover area by retaining green trees and CWD. Alternative approaches to transportation and logging systems could be considered as a part of this strategy. For example, lower-standard roads could be constructed and then eliminated following the period of forest cutting and regeneration. An approach of this type, which concentrates management impacts in time and space, would produce somewhat more intense episodic disturbances of the aquatic environments, and allow long recovery periods free from chronic perturbations.

Of course, there are problems inherent in taking such an approach to management. Creating large continuous clearcut areas lacking compositional and structural diversity, and devoid of preserved areas, is undesirable—particularly taking into account the cumulative effects of concentrated cutting patterns on aquatic ecosystems. Initial research indicates that the spatial scale is of critical importance in assessing the impact of concentrated cutting on cumulative effects (Grant 1990). While a 100 ha cutover may have little impact at the scale of a fourth-order drainage, it will clearly be a major "cumulative" effect for an impacted second-order drainage. It is also clear that recognizing primary source areas for sediments and avoiding them whenever possible is probably more critical than total area subject to cutting. The trade-offs between various approaches to dispersed and concentrated harvest cutting are complex, poorly understood, and currently far from resolved (Grant 1990), making this a critical area of landscape research (see Swanson et al., this volume).

Alternatives to continued dispersed clearcutting are also being considered and sometimes applied on National Forest landscapes that already have a high degree of fragmentation. These approaches, sometimes referred to as minimum fragmentation alternatives, strive to maintain large residual forest patches by placing new cuttings adjacent to existing cutover areas (Hemstrom 1990*a*, *b*). Such alternatives maintain options while long-term landscape designs are worked out.

Larger patch size is also a major consideration in new approaches to management of forest lands in the Lake States. Dispersed patch clearcutting in this region has produced large amounts of edge habitat, high populations of white-tailed deer, and heavy browsing of forest understories in the residual forest areas. Larger patch sizes (for both reserve and harvest areas) and reduced fragmentation are also major considerations in management alternatives being considered in current environmental impact analyses for areas of the Chequamegon and Nicolet National Forests in Wisconsin, USA. In one of the first of these to reach the decision stage, the chosen alternative for the Sunken Camp Management Area on the Chequamegon is one that emphasizes "providing large units of habitat for plant and animal species" (United States Forest Service, Eastern Region 1991).

Decisions on issues such as patch size and the geographic distribution of management activities will vary dramatically with the characteristics of the landscape and organisms of interest. The previous discussion has concerned landscapes in the Douglas-fir region and Lake States; approaches appropriate to these areas are not necessarily applicable to other forested regions. For example, forest landscapes in many areas—large portions of the Klamath Mountains of southwestern Oregon and northwestern California, of the Sierra Nevada Mountains in California, and of the southern Rocky Mountains in Colorado—are often fine-scale mosaics of relatively small (0.5 to 10 ha) and low contrast patches, largely because of their history of frequent, low severity fire. Other landscapes, such as those in eastern Washington, often involve medium-scale mosaics of forested and nonforested patches. Although patches often have high contrast, forest patch edges may be sealed by canopy development, producing interior forest environments in much smaller patches than might otherwise be expected. Still other landscapes, such as those associated with lodgepole pine (*Pinus contorta*) forests and large episodic fire events, resemble Douglas-fir landscapes in patch size and contrast.

Managers can look to the natural landscape and its disturbance regime as one guide to the appropriate design of managed landscapes for a particular area. This is not a proposal to mindlessly adopt nature's design as our model. For example, we would certainly not care to emulate the scale of many of the natural catastrophes that have occurred in the Douglas-fir region, where hundreds of thousands of hectares are "treated" in a single event. However, a study of the natural landscapes does recognize that organisms present in a region are adapted to that landscape and its disturbance regime, and almost certainly will reveal elements that need to be incorporated into the managed landscape.

Overview: Alternative Management Approaches Under New Perspectives

In this article I have outlined some scientific bases for new management approaches to forested landscapes and general principles for New Forestry at the stand and landscape levels, and I have offered some examples of specific approaches that are currently being tested. Clearly, there are several important issues that require careful examination by scientists and managers before major policy changes are adopted. One merit of many proposed New Forestry practices is that, unlike traditional practices of the past few decades, most actually maintain future management options.

At the stand level we are progressing rapidly in developing and implementing alternative management approaches. Extensive research is needed on the effectiveness of various practices in achieving ecological objectives as well as accurate appraisals of their economic impacts. The relationship of attributes of interest to different management practices—that is, how biological diversity responds to various densities of retained trees—is a developing research area. Indeed, a generic question will be the level in structural retention where a harvested area continues to behave like a forest rather than a gap. The answer to this question will vary, of course, with the resource, organism, or function of interest—making the generic question even more interesting!

Some have suggested that many New Perspectives stand-level practices have not been scientifically tested, and should therefore not be widely utilized (Atkinson in Hopwood 1991). These criticisms have some validity, since we have only recently begun to test approaches such as green tree retention. However, there is considerable evidence that supports innovation. First, many examples of structurally diverse stands, created by accidents of nature and man, provide strong direction on how suitable stands for late successional species can be created. Among these is the example of northern spotted owls living in dominantly young, mixed-structure stands. Second, despite current protestations to the contrary, foresters have never done adequate scientific testing of concepts before adopting them as basic professional tenets. In the 1940s, autecological studies of Douglas-fir provided some scientific basis for the development of dispersed patch clearcutting. However, it took nearly two decades to perfect the original concept—that is, to prove it scientifically with regard to regeneration practice. It was another two decades before landscape-level consequences were analyzed and the system was found to have some basic flaws. As another example, there are few sites, if any, where foresters have proved that repeated intensive forest cropping is possible without ultimate reductions in site productivity.

In actuality, the clear failure of traditional intensive forest practices to maintain many forest organisms and values provides the strongest evidence supporting the need for alternative or new silvicultural practices. While we may not know precisely the effectiveness of some of the new techniques, we do know that traditional approaches are not working well for many values, and are no longer socially acceptable (Lee, this volume). If a large segment of our forest fauna is dependent on CWD and CWD is being eliminated from intensively managed forests and streams, then it does not take a detailed scientific study to know that we are not providing for that faunal component. Similarly, it seems obvious that a silvicultural system that maintains at least some level of CWD is going to have a much higher probability of providing for at least some elements of the dependent fauna.

Landscape-level issues are often more complex and less amenable to prescriptive solutions. Our understanding of landscapes and the tools available for their study and design is much more limited than it is for stands and stream reaches. A great deal of research is needed in this area. Equally important is the need for extensive dialogue and collaboration between managers, scientists, and public interest groups on landscape issues. Topics in need of serious attention include: the potential contribution of alternative landscape patterns, larger patch sizes, or longer rotations to cumulative effects; the relative impacts of episodic and chronic disturbances on physical processes, ecosystem health, and biological diversity; and alternatives to the creation of extensive permanent road systems in steep mountainous topography.

Resource managers, scientists, and public interest groups alike must reexamine their basic assumptions about forests, fisheries, biological diversity, and related issues. At the landscape level there are currently no prescriptions, only issues. Furthermore, the unique nature of each landscape makes it likely that management decisions will necessarily be highly individualistic.

At least as a starting point, we can look to the natural landscape for some idea of what patch sizes, edge types, and disturbance regimes might be appropriate.

There are currently many important questions regarding the New Perspectives landscape and the form that it should take. One set of questions involves cumulative effects and the trade-offs between dispersed and spatially concentrated management. A related and extremely interesting question concerns the relative impacts of episodic and chronic disturbances on aquatic ecosystems and organisms, including patterns of recovery and such physical processes as sediment production.

Conclusions

Scientific studies of terrestrial and aquatic ecosystems and landscapes during the last two decades have drastically altered our views on their composition, structure, and function. The natural ecosystems have proved to be far more intricate than we had imagined. Particularly relevant and important elements of this expanded knowledge concern riparian zones: the special importance of riparian habitats as essential habitats for many organisms and processes and the high level of integration or linkage between riparian and upland ecosystems.

The expanded ecological knowledge, in combination with increased societal concerns for ecosystem sustainability, biological diversity, and other ecological values, propels natural resource managers toward making major changes in philosophy and practice. These changes are well encompassed in the New Perspectives approach.

The New Perspectives approach calls for new levels of collaboration between managers, scientists, and public interest groups as we attempt to redesign management methods based on necessarily incomplete information. In many cases, practices will have to precede definitive testing. But, as with current New Forestry practices, they can have a strong base in current ecological science. It is critical that managers and scientists address these questions together, and work to develop a systematic approach to feeding new knowledge back into management practices (Oliver and Hinckley 1987). Only in this way can further traumatic upheaval be avoided.

The future, certainly the near future, will not be a time of rote prescription in resource management. The present is a time for reexamination, innovation, testing, and the building of new working relationships. And, viewing the riparian environment, we can see that the New Perspectives approach does have rubber boots. With additional efforts in research, definition of objectives, and development of innovative approaches to riparian management, it can have a pair of chest waders!

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4

Ecologically Effective Social Organization as a Requirement for Sustaining Watershed Ecosystems

ROBERT G. LEE

Symbiotic relationships mean creative partnerships. The earth is to be seen neither as an ecosystem to be preserved unchanged nor as a quarry to be exploited for selfish and short-range economic reasons, but as a garden to be cultivated for the development of its own potentialities of the human adventure.

René Dubos (1976)

Abstract

The social sciences can make significant contributions to solving watershed management problems. Sustainable watershed management requires knowledge about ecologically effective forms of social organization. Including humans as a component of the ecosystem permits scientists and policy makers to consider how resource management activities affect biophysical processes regulating ecosystems. A major reason for the failure of human societies to develop sustainable resource management activities has been the limitations on their ability to acquire and process ecological information. Difficulty in maintaining adequate information on the state of ecological systems originates in the inability of people to develop an effective cognitive map of their environment. Institutional structure has a major influence on cognitive learning of environments, and institutional arrangements determine the scale of human social organization and the incentives for people to learn and adopt ecologically sustainable practices. Institutionalization of sustainable resource and ecosystem management practices will require better information about the appropriate scale and form of social organization. Small, flexible institutional units may be best suited for the adaptive learning necessary to achieve sustainable resource management.

Key words. Sustainability, resource management, institutions, environmental learning, watershed management, social adaptability.