CHAPTER

18

STRUCTURAL AND FUNCTIONAL DIVERSITY IN TEMPERATE FORESTS

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Temperate zones, including their Mediterranean subzones, are the regions of the world most uniformly and extensively altered by human activities. Settlement and development of these productive and hospitable regions have a long history and have had dramatic impacts on biological diversity. Many ecosystems and organisms have been entirely eliminated, and most remaining examples of natural ecosystems are fragmented and highly modified. Intensive human activities, including the relatively recent addition of environmental pollutants, provide continuing threats to biota.

Preserving biotic diversity in temperate zones therefore represents a major challenge. Restoring some of the lost biodiversity is an element of this challenge as is protecting what remains. Positive factors in preservation include the general resilience of temperate forests, the relatively high level of relevant knowledge, and the wealth and educational level of temperate-zone nations and inhabitants. A resurgence of temperate forests on abandoned agricultural and cutover forest lands, such as in the northeastern United States, also contributes to the potential for restoration of biodiversity.

This chapter contains my views on some major needs in preserving and enhancing biotic diversity in temperate forest regions. These needs are to maintain, or, where absent, to create a complete array of forest successional stages, including old-growth forest conditions; to maintain structural and functional diversity throughout the forest landscape, e.g., by retaining standing dead trees and fallen logs; to protect aquatic diversity in the streams, lakes, and rivers associated with temperate forests; and to develop effective stewardship programs that can maintain (and create, when necessary) natural area preserves within intensively utilized landscapes. There is also a critical need to integrate biodiversity objectives into management of all our landscapes because preservation of selected tracts of land, even at the largest scale possible, will not by itself achieve the desired goal of maintaining Earth's biodiversity.

MAINTAINING SUCCESSIONAL STATES

Preserving biodiversity in temperate regions requires the maintenance of all successional stages. Since early successional stages are typically well represented, a major concern is preserving or recreating old-growth forests. Such old-growth forests typically contrast sharply with early successional stages in composition, structure, and function.

Most forests in the temperate zone are secondary forests that developed after logging of primeval forests or abandonment of agricultural lands. In the United States, these forests are typically young, having originated during the last 100 to 150 years. The composition and structure of these forests are different—often drastically different—from those they have replaced. We see, for example, forests of birch (*Betula* spp.) and aspen (*Populus* spp.) in the Great Lakes states, where the forests were originally dominated by long-lived pioneer species, such as red and eastern white pine (*Pinus resinosa* and *P. strobus*), and late successional species of hardwood.

Old-growth temperate forests dominated by coniferous species still cover substantial acreages in the western United States; research in these forests is clarifying the contrasts between young- (e.g., <100 year) and old-growth (e.g., >200 year) forests (see, e.g., Franklin et al., 1981). For example, old-growth forests of Douglas fir and western hemlock (*Pseudotsuga menziedii* and *Tsuga heterophylla*) (Figure 18-1) provide essential habitats for a set of highly specialized vertebrate species, including the northern spotted owl (*Strix occidentalis*). Research presently under way will provide a definitive list of old-growth-dependent species within these temperate conifer forests. This list may include several other birds, several mammals (bat species may be notable), and several amphibians (particularly salamanders). Such forests are also very rich in mosses, lichens, and liverworts, of which at least one species—a lichen—is strongly related to old-growth forests. That species, *Lobaria oregana*, is an important nitrogen-fixing foliose lichen that grows in the crowns of old-growth Douglas-fir trees. Research will almost certainly show that some of the rich invertebrate community is also old-growth-dependent; more than 1,000 species have been identified within a single old-growth stand, the upper bole and crown providing particularly rich habitat. The old-growth forests obviously have a high genetic content and are far from the biological deserts that some game biologists and foresters once suggested.

Functional differences between old-growth and younger forests are often qualitative rather than quantitative. That is, forests at all stages fix and cycle energy or carbon, regulate hydrologic flows, and conserve nutrients. Some stages carry out these activities more efficiently than others, however. Old-growth forests in the Douglas-fir region are particularly effective at regulating water flows and re-

FIGURE 18-1 Old-growth forests are an important successional stage that needs to be protected in any overall scheme for protection of temperate zone biodiversity; 500-year-old *Pseudotsuga menziesii-Tsuga heterophylla* forest on the H. J. Andrews Experimental Forest in the central Oregon Cascade Range. Courtesy Glen Hawk.

ducing nutrient losses. Nutrient losses from old-growth watersheds in the Pacific Northwest are, for example, extremely low (Franklin et al., 1981), although this is not always true in other regions (see, e.g., Martin, 1979). Old-growth forests may contrast with younger forests in their influence on some important hydrologic processes. Old-growth coniferous forests present a very large crown surface and occupy an extensive volume of space, because dominant trees are commonly taller than 75 meters. Such forests are particularly effective at gleaning moisture from clouds and fog, which can substantially increase precipitation (Harr, 1982). These forests may also influence the amount and spatial distribution of snowfall thereby minimizing the potential for the damaging rain-on-snow floods that are characteristic of the Pacific Northwest. In addition, the old-growth Douglas-fir forests provide several important sites for nitrogen fixation (e.g., epiphytic lichens and rotting wood), which are more limited or absent in earlier stages of succession.

Old-growth coniferous forests contrast most visibly with earlier successional stages in their structure (Franklin et al., 1981). Old-growth stands obviously have a greater range of tree sizes and conditions than do younger stands and generally have a more heterogeneous forest understory. Large live trees, large standing dead trees (or snags), and large fallen logs are the most conspicuous structures that distinguish old-growth forests. Furthermore, these structures are often the key to the unique compositional and functional attributes of the forest, such as habitat for the northern spotted owl and its prey. Early successional forests developing after natural catastrophes, such as wildfires or hurricanes, often contain large standing dead trees and fallen logs because most catastrophes kill trees but do not consume the wood structures. Young forests developing after timber cutting or agricultural abandonment do not have snags and woody debris, however, because the boles are removed.

Although these examples are all drawn from the temperate coniferous forests of the Pacific Northwest, old-growth forests in other temperate regions probably exhibit similar distinctions of composition, structure, and function. Ecological investigations of old-growth forests in northeastern North America are just beginning, but differences between early and late successional stages in composition and structure are already apparent. Old-growth-dependent wildlife species have not yet been identified, but some of them may already have been eliminated; at present, no investigations of lower plants or invertebrates have been undertaken. Ongoing investigations of remnant primeval forests in northeastern North America, China, South America, New Zealand, and Europe should clarify the distinctive characteristics of old-growth forests throughout the temperate zones.

Old-growth forests and the organisms and processes that they represent are an essential aspect of the global biodiversity at risk. Thus, preserving or recreating old-growth temperate forests should be a key objective of any conservation program. Such efforts would be timely, since there are still opportunities to retain examples of old-growth ecosystems in northwestern North America and eastern Asia and to allow areas of maturing woodlands in northeastern North America to develop into old-growth forests. Additional research on the characteristics of old-growth hardwood and hardwood-conifer forests is critical as a basis for conservation efforts.

MAINTAINING STRUCTURAL AND FUNCTIONAL DIVERSITY

We tend to be intent on preserving genetic diversity as represented by species, but ecosystem simplification and loss of biodiversity is proceeding rapidly in other ways. Maintaining structural and functional diversity in temperate regions is an important need, particularly in intensively managed landscapes. Unfortunately, such efforts run contrary to our cultural tendencies to simplify ecosystems, even when such simplification is not essential to our objectives. Large snags and fallen logs are examples of structural diversity (Figure 18-2). Retaining nitrogen-fixing organisms exemplifies a functional aspect of biotic diversity within an ecosystem or landscape.

FIGURE 18-2 Coarse woody debris, including standing dead trees and downed boles, are an important structural component of forests. An important goal in preserving ecological diversity is to maintain such structures within managed forest ecosystems. This rotting log is serving as habitat for a large variety of heterotrophic and autotrophic organisms. (Goar Marsh Research Natural Area, Giffort Pinchot National Forest, Washington.) Courtesy U.S. Forest Service.

Standing dead trees and fallen logs are essential to many organisms and biological processes within forest ecosystems (Harmon et al., 1986); yet, such structures have rarely been retained within managed forests. For example, Thomas (1979), in his compilation of the wildlife of northeastern Oregon forests, found that 178 vertebrates—14 amphibians and reptiles, 115 birds, and 49 mammals—used fallen logs as habitats. Elton (1966, p. 279) recognized the broad importance of dead wood structures for biotic diversity: "When one walks through the rather dull and tidy woodlands [of England] that result from modern forestry practices, it is difficult to believe that dying and dead wood provides one of the two or three greatest resources for animal species in a natural forest, and that if fallen timber and slightly decayed trees are removed the whole system is gravely impoverished of perhaps more than a fifth of its total fauna." In addition to its role as a habitat for land animals, woody debris also provides habitats, structure, energy, and nutrients for aquatic ecosystems (Harmon et al., 1986). Furthermore, it provides sites for nitrogen fixation, sources of soil organic matter, and sites for the establishment of other higher plants, including tree seedlings (Harmon et al., 1986). Maintaining deadwood structures should be a regular objective of silvicultural activities within the forests of the temperate zone and other zones, quite apart from any program for maintaining old-growth-forest conditions.

Maintaining nitrogen-fixing organisms within our forest landscapes is an example of maintaining functional diversity. Many nitrogen-fixing species of plants, such as ceanothus (*Ceanothus* spp.) and alder (*Alnus* spp.), are associated with early stages of succession. Others, such as the lichen mentioned earlier, are associated with old growth; still others (microbial) are associated with woody debris. Forest management activities have tended to eliminate these sources to minimize competition from noncrop species and speed development of a closed canopy of crop trees.

Efforts to conserve structural and functional diversity are often linked; for example, by maintaining woody debris, one of the sites for nitrogen fixation is retained within the ecosystem. Another example is maintaining large volume, complex crown structures that are especially effective at scavenging moisture and particulate materials from the atmosphere.

Obviously, maintaining structural and functional diversity is an objective that is broadly applicable to temperate landscapes and not just to forests. For example, continuous efforts are under way to convert complex shrub-steppes or savannas to grasslands or even monocultures of seeded grasses by eliminating woody plants such as sagebrush (*Artemisia* spp.) or junipers (*Juniperus* spp.). Such programs are capable of causing great damage to structural, functional, and genetic diversity over large areas.

PROTECTING AQUATIC DIVERSITY

Protecting aquatic diversity, including that of the riparian zones, is one of the most difficult tasks within the temperate zone. Streams and rivers have been dammed, diverted, and polluted. Organisms have been extirpated and many new organisms introduced, either purposely or accidently. Control of large land areas (watersheds) is required to provide complete protection for many bodies of water (Figure 18-3). Legal problems are often overwhelming in view of the large number of jurisdictions involved and, at least in the United States, the peculiarities of water rights and law.

The risk to aquatic biodiversity within temperate regions is great and has not received much effective attention, despite the attention given waterfowl and fisheries and the recognized importance of wetlands. Loss of diversity in river ecosystems may be particularly serious and certainly affects invertebrates (e.g., insects and molluscs) as well as vertebrates (e.g., fish). One need only be reminded of the loss of anadromous fish from many river systems after dams were built to realize that these changes involve loss of other important compositional, structural, and functional features from these ecosystems as well.

Developing effective programs to protect aquatic biodiversity is a priority of the highest order. Even the initial step—an adequate analysis of the problem—will require additional research as well as syntheses of existing information. Creative new approaches to conservation will be required, such as acquisition of water rights and licenses for dam construction. The Nature Conservancy has pioneered development of such creative approaches in their recent wetlands initiative.

Protecting aquatic biodiversity is a problem in all segments of the temperate zone—from forests to deserts. The most critical problems in protecting aquatic

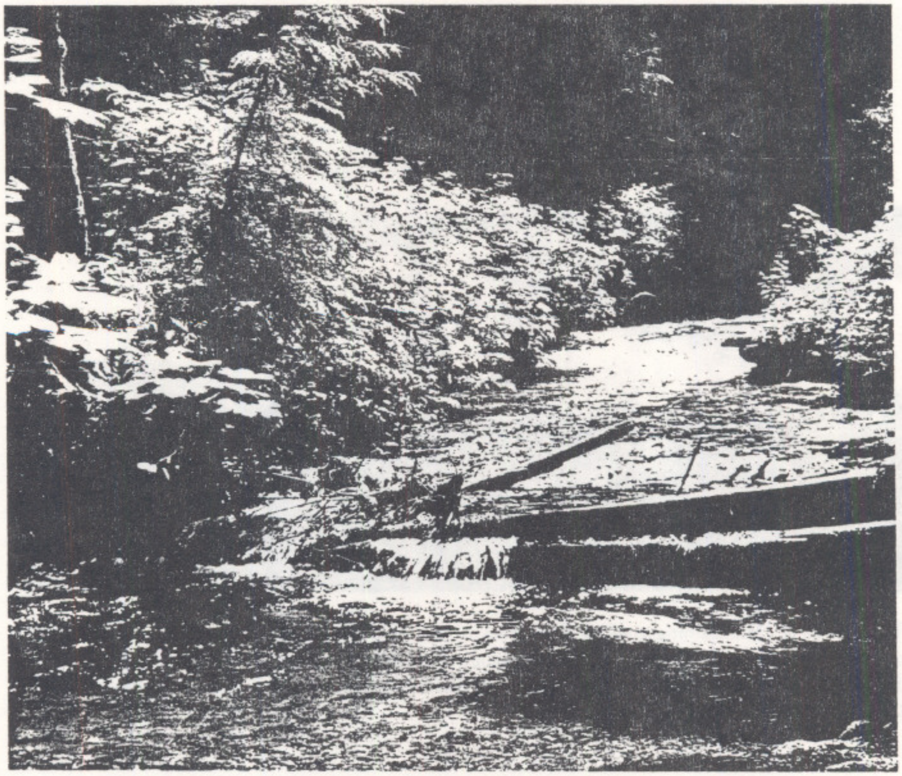

FIGURE 18-3 Maintaining examples of natural river and stream ecosystems is one of the most challenging tasks facing society in temperate as well as other biotic zones. (San Juan Mountains, Colorado.) Courtesy U.S. Forest Service.

biodiversity are probably associated with bodies of water in arid regions where they are a critical and often overallocated resource.

DEVELOPING EFFECTIVE STEWARDSHIP PROGRAMS

Maintaining biodiversity is a continuing and multifaceted task. It cannot be permanently accomplished by a single action, such as establishing a national park or biological preserve. Indeed, we often forget that establishing a preserve is only the first step in the infinite responsibility that we have assumed for keeping many organisms and ecosystems afloat (Figure 18-4).

Fulfilling our stewardship responsibility will require a great deal more attention than it has been receiving. Maintaining a viable biological preserve in the densely settled and intensively used temperate zones requires sophistication and dedication. Large amounts of information about the ecology of the target ecosystems and organisms and about environmental conditions in and around these preserves will be required. This means intensive research and monitoring programs, often of long

FIGURE 18-4 Maintaining ecological reserves in the heavily settled temperate zone will require extensive knowledge and sophisticated technology. Prescribed burning is one of the methodologies already commonly utilized in both prairie and forest reserves in North America. (Konza Prairie Biosphere Reserve, Kansas.) Courtesy U.S. Forest Service.

duration. Trained personnel will have to develop and implement complicated management programs. To meet all these needs will require large and stable financial support and the development of professional cadres trained and experienced in stewardship.

The key to such a large and long-term commitment can ultimately come only from society at large. Resolving the risks to biodiversity in the temperate zones and developing the philosophy and technology of stewardship can provide an essential example for tropical regions.

INCORPORATING BIODIVERSITY OBJECTIVES INTO MANAGEMENT

We cannot accomplish our objectives simply by creating preserves; the objectives of maintaining biodiversity must be incorporated into intensively managed temperate landscapes. The bulk of the temperate landscape will be used for production of commodities and for human habitation. We must therefore develop management strategies for forestry, agriculture, water development, and fisheries that incorporate the broader diversity. Most intensive management strategies currently do not take biological diversity into consideration; rather, they emphasize simplifying and sub-

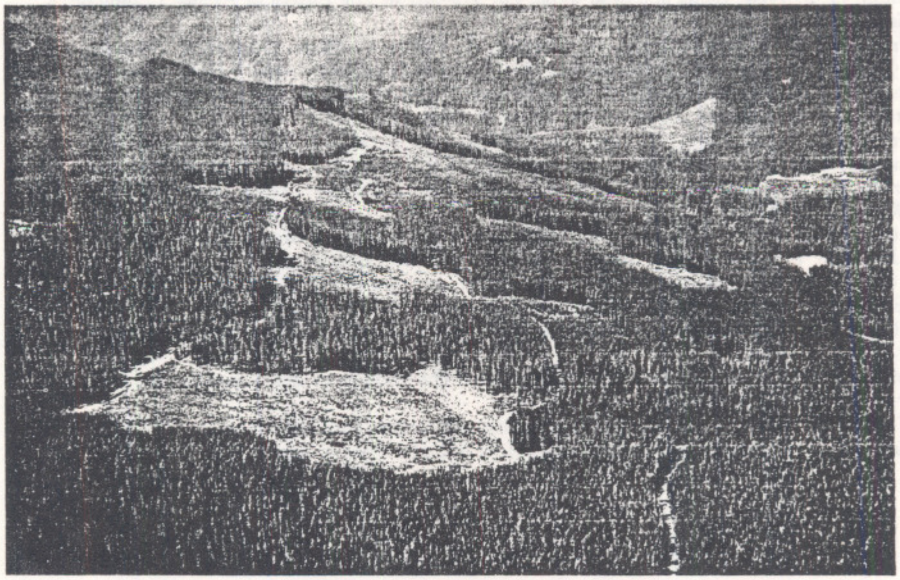

FIGURE 18-5 It is essential that the objective of preserving ecological diversity be incorporated into management programs on lands used for production of commodities; reserves or "set-asides" on the public lands will not adequately accomplish the essential goals. This will have to include considerations of landscape ecology, such as the effects of patch patterns on biota. (Dispersed patch clearcutting on the Gifford Pinchot National Forest, Washington.) Courtesy U.S. Forest Service.

sidizing ecosystems, i.e., organismal, structural, successional, and landscape homogenization (Franklin et al., 1986).

In forestry practices, we can see this emphasis on simplification from the level of the tree, where great efforts are being expended to create genetically uniform material, through the geometrically arranged stand to the landscape, where multiple age classes of conifer monocultures are sometimes cited as evidence of commitment to biological diversity. We must modify our treatments of forest stands and arrangements of forest landscapes to incorporate the objective of protecting biodiversity (Figure 18-5). This can be done with very little reduction in the production of commodities. Failure to do so will result in immense losses of genes and processes within the temperate zone.

Biodiversity is abundant in the temperate zone, and it, too, is worth saving.

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