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SESSION OVERVIEW

Ecosystem and Habitat Conservation: More Than Just a Problem of Geography

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As more and more species become extinct or come under the protection of the U.S. Endangered Species Act (ESA; 16 U.S.C. §§ 1531 to 1544), public pressure mounts to stem the widespread loss of biological diversity. At the same time, implementation of recovery plans for threatened or endangered species may cause economic hardships that are translated into job losses and accompanying social problems. Perhaps nowhere have recent collisions of conservation with economic interests been more apparent than in the Pacific Northwest, where protection and management of the northern spotted owl *Strix occidentalis caurina* and Pacific salmon *Oncorhynchus* spp. have resulted in a scientific, economic, and political turmoil to which terms like "gridlock" and "train wreck" have been applied (FEMAT 1993), and which promises to be a major battleground relative to ESA reauthorization (Volkman and Lee 1994). Conditioned by this controversy, scientists from the region have questioned whether conventional use of natural resources is sustainable (Ludwig et al. 1993) and whether the ESA is the appropriate regulatory tool to protect biological diversity (Franklin 1993). Both of these topics have provoked lively debate in recent issues of *Ecological Applications* (1993, 3:547–589; 1994, 4:205–209), and the debate is likely to continue for some time.

The ESA requires critical habitat for threatened or endangered species to be identified and protected. For species with very small populations and limited geographic distribution, critical habitat may be measured in square meters. For anadromous salmonids, critical habitat is much more problematic. Chinook salmon *O. tshawytscha* spawning in Idaho, for example, may migrate thousands of kilometers from their natal spawning grounds to the Gulf of Alaska and back over the course of their life cycle. For most aquatic vertebrates, the geographic range of potentially critical habitat is somewhere between these two extremes. Critical habitat designations for species undertaking migrations usually include areas where important life history phases occur such as reproduction or overwintering.

It is useful to review some key concepts applied to ecosystem management. *Biotic integrity* is "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981). *Biological diversity* includes the variety and variability among living organisms and the ecological complexes in which they occur. It is divided into four levels (Temple 1991): genetic diversity (genetic variation within a species), phenotypic and morphological diversity (physical and life history variation within species), species diversity (species richness within an ecosystem), and community–ecosystem diversity (variability in habitats and ecological processes extending over a region). *Critical habitat*, according to the Endangered Species Act, includes areas that contain physical or biological features that are essential to the conservation of the species and that may require special management consideration or protection. These include areas important for population growth, food and water resources, shelter, and breeding and rearing sites, as well as areas representative of the species' historical distribution.

In practice, the protection of endangered species and the ecosystems upon which they depend has been based on identifying remaining patches of ecologically intact habitat and preventing these areas from being adversely altered by human activity, although some human use of the areas typically is allowed. Conservation of harvestable natural resources is, in effect, approached as a matter of zoning in space and time, the tools being spatial preserves and closed harvest seasons. For spotted owls, salmon, and other inhabitants of late-successional forests on federally owned forest lands in the Pacific Northwest, this exercise required the intervention of a U.S. President and the combined efforts of many scientists over many months to delineate a highly complex system of forest reserves and management areas (FEMAT 1993). Although the mobilization of scientific effort for the Forest Ecosystem Management Assessment Team (FEMAT) was unprecedented in conservation history, many questions remain about the project's ultimate success in preventing extinctions related to anthropogenic disturbances. For example, the forest management option preferred by FEMAT was believed to have only a 65% likelihood of achieving aquatic habitat of sufficient quality, distribution, and abundance to allow anadromous fishes to become well distributed across federal lands over the next century, even though it provided for wide buffer strips along all streams and designated key watersheds where conservation of salmonid habitat would receive top priority (FEMAT 1993). Part of the reason for this somewhat pessimistic assessment was that FEMAT authors realized protection of streams on federal lands would typically influence only parts of river basins inhabited by anadromous salmonids: other land owners might not be subject to such stringent environmental requirements.

This example illustrates a widespread problem in conserving evolutionarily significant units (ESUs): the scales at which conservation efforts are currently focused may not match the spatial, temporal, or geological scales appropriate for the protection of species with highly dynamic life cycles and complex metapopulation structures. In a wide variety of areas scattered across the landscape, aquatic habitat receives special protection and some degree of naturalness is retained (Figure 1). At very large landscape scales, often termed ecoregions because they possess characteristic biogeoclimatic conditions, large blocks of land (usually federally owned) such as national parks, wilderness areas, or (in the recent FEMAT example) key watersheds may encompass whole drainage systems and contain relatively pristine habitats. At the somewhat smaller landscape scale of a river basin, sizable blocks of land may occur in state parks, wildlife refuges, or extended reaches of main-stem rivers designated as wild and scenic. These patches tend to be smaller than major wilderness areas, but they can include habitats that are buffered against anthropogenic disturbance. The next smaller landscape division, the subbasin or watershed, contains a major tributary system within the river basin. Habitat conservation areas often found within subbasins include county parks, greenway belts, and privately owned reserves (such as those maintained by The Nature Conservancy). Finally, small habitat conservation areas may occur at the scale of individual streams or standing water bodies, or even of reaches within a stream. Examples include municipal parks, conservation easements, and habitat restoration projects. The latter may consist of areas with previously degraded habitat or with new habitat created as mitigation for land or water development projects.

There is no question that preventing the degradation of remaining areas where biotic integrity is high must be a cornerstone of any program to conserve an ESU or a cluster of ESUs threatened with extinction (Reeves and Sedell 1992). These areas will serve as refuges and sources of colonists as environmental improvements are realized elsewhere. But the current system of habitat patches set aside in wilderness areas, parks, and various natural reserves may not provide all the habitat requirements of many fishes and other aquatic species. The majority of habitat reserves have boundaries dictated by land ownership patterns that rarely coincide with drainage divides, natural landscape units, and ecological boundaries. The size of habitat reserves may not encompass the migratory range of individuals within populations, and some patches may not be large enough to provide the full range of environmental conditions to which local populations are adapted and that are necessary to support all life history phases. The question, Which is better, many small refuges or a few large refuges? likely has different answers for different species. Habitat reserves may be managed for the benefit of one or a few species to the detriment of others, especially when management activities cause changes that depart from the natural range of conditions, leading to a decline in biological integrity. Furthermore, areas such as parks may be protected from the impacts of normal land uses but are often managed for human recreation, and this may simply mean the substitution of one type of anthropogenic disturbance for another.

There are additional, and in some ways even more daunting, problems with the current patchwork of large and small habitat refuges arrayed over the landscape. The arrangement of habitat refugia may not be favorable to the dispersal of organisms from one patch to another, which could have important genetic consequences for a population (Harrison 1991). Patch location and size may influence the vulnerability of patches to catastrophic disturbances, and their ability to recover from natural disturbances. Boundary conditions may facilitate the invasion of nonnative species or upset the structure and function of native assemblages. All these conditions, together or separately, can in-

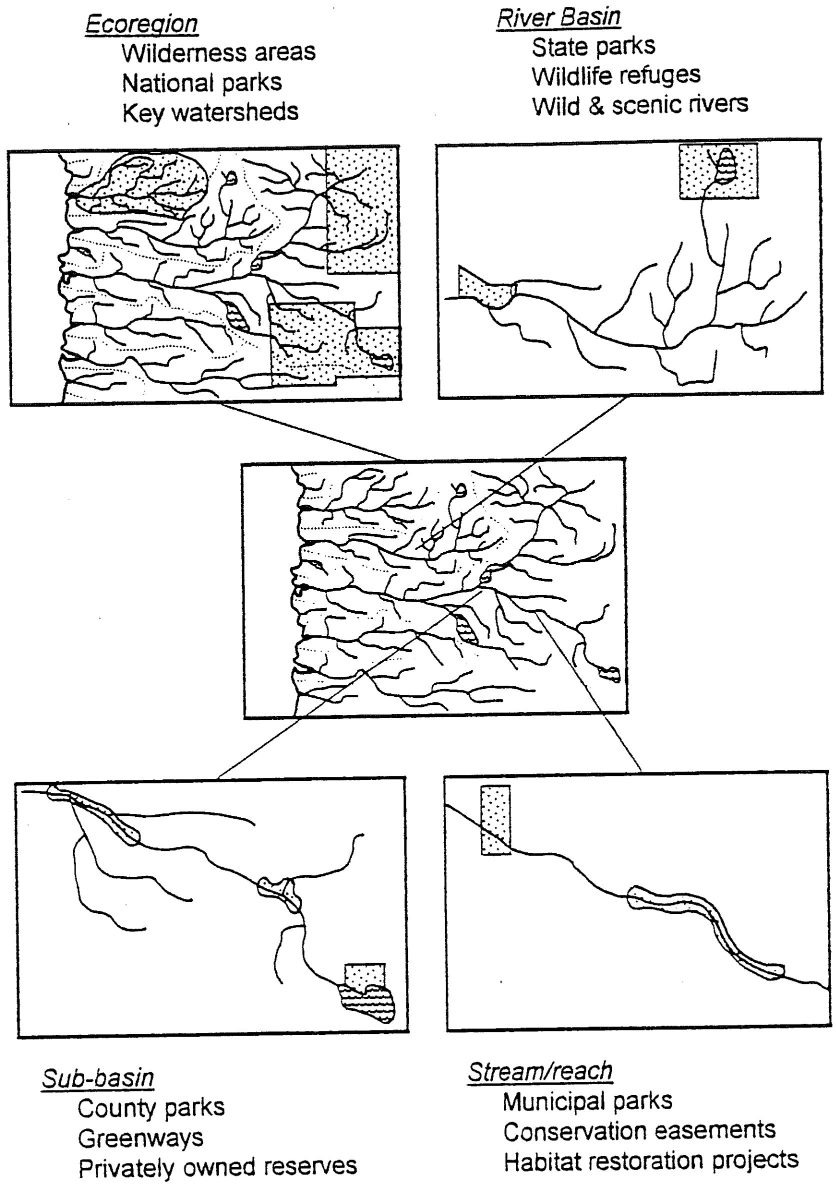

FIGURE 1.—Examples of habitat conservation areas (stippled) at different landscape scales.

crease the risk that small, fragmented populations will become extinct (Sheldon 1987).

The development of geographic information system (GIS) technology has provided a powerful tool for landscape-level planning. Using a GIS, resource managers can examine the juxtaposition of landforms, plant and animal distributions, local climatic regimes, land uses, and other mappable factors in a way that facilitates efficient management decisions and long-range forecasting. Although GIS technology has revolutionized landscape planning, similar to the way in which DNA analysis has contributed to the understanding of phylogenetic and taxonomic relationships, it is still just a tool. The creation of more patches, even with the aid of GIS, will not guarantee the conservation of biological diversity. There should be a sound conceptual and empirical basis for the location and arrangement of protected habitat areas in space and time, as well as a long-term strategy for the restoration of key ecological processes where habitat has been degraded (Karr 1991).

Two recent approaches to conserving aquatic ecosystems and biodiversity at a variety of landscape scales have been put forward by Sedell et al. (1994) and Moyle and Yoshiyama (1994). Both proposals encompass a hierarchical system of habitat conservation and management strategies for land-

TABLE 1.—Key elements of two recent proposals for landscape-based conservation of aquatic biodiversity: a habitat-oriented approach (Sedell et al. 1994) and a taxon-oriented approach (Moyle and Yoshiyama 1994).

Component	Description
	Habitat orientation
Riparian reserves	Portions of the landscape where riparian dependent and stream resources receive primary emphasis, including all permanently flowing streams, lakes, wetlands greater than 0.4 ha, and intermittent streams; riparian reserves protect all bodies of water, inner gorges, all riparian vegetation, 100-year floodplains, and landslide-prone areas
Key watersheds	May contain at-risk fish stocks or serve as sources of high-quality water; key watersheds receive no new roads in roadless areas and no net increase in roads elsewhere, and they receive the highest priority in restoration programs
Watershed analysis	Systematic procedure for characterizing watersheds, providing management prescriptions, and developing restoration strategies and monitoring programs
Watershed restoration	Procedures that restore watershed processes to recover degraded habitat; principal focus is on road removal and upgrading, silvicultural rehabilitation of riparian zones, and restoration of channel complexity with short-term use of in-channel structures
	Taxon orientation
Endangered species listing	Immediate listing under the Endangered Species Act of all species likely to be extirpated within the next 20 years
Management clusters	Implementation of management strategies for clusters of declining species that inhabit the same habitats or drainages, an assumption being that simultaneous protection of coexisting species will improve ecosystem health
Aquatic diversity management areas	Creation of a system of drainages and unique habitats that provides systematic regionwide protection of aquatic biodiversity; most of these water bodies, for which the first priority is to maintain local biodiversity, will be relatively small (<50 km^2) and managed by one governmental agency or landowner
Key watersheds	Representative watersheds more than 50 km^2 in area that are still dominated by native organisms and natural processes, or that have high potential to be restored to such a condition; the management goal for key watersheds is to ensure natural processes are allowed to continue with minimal human interference
Landscape management	Large-scale bioregional planning with the goal of protecting biodiversity and natural processes

scape units ranging in size from small to large (Table 1). Both proposals emphasize protection or restoration of ecosystem processes and natural assemblages of plants and animals rather than restoration measures directed at single species.

These two examples, based on principles of conservation biology, suggest new approaches that go beyond simply setting aside areas of unaltered habitat as preserves or refuges for endangered species. Investigations of physical and biological interactions controlling the structure and function of aquatic ecosystems have shown that drainage systems and the organisms within them are often highly dynamic and influenced by processes operating over several spatial and temporal scales (Naiman et al. 1992). These processes, which include disturbance–recovery cycles, synergistic interactions between environmental components, and biophysical linkages and feedback mechanisms, cause systems to be evolutionary. Such systems are not easily modeled, may rarely conform to steady-state assumptions (Gregory et al. 1991), and will never be fully understood (Holling 1993). Faced with inevitable uncertainty, natural resource managers have begun to explore alternative approaches to the protection of habitat and ecosystems and to the conservation of biodiversity (Angermeier and Williams 1993). New approaches place less emphasis on individual species and more emphasis on natural assemblages and evolutionary history, less emphasis on creating or maintaining certain habitat types in fixed locations and more emphasis on restoring ecological processes leading to the conditions created by natural disturbances, less emphasis on the total number or area of habitat preserves and more emphasis on the spatial and temporal relationships of preserves to one another.

It might be possible to undertake a risk analysis of particularly valued ecosystem resources, such as those we harvest or those at risk of extinction, by determining how well the current "zoning" scheme is working to protect different elements of the "space–time path" of the taxon(s) of interest. Are human uses of resource taxa or their ecosystems compatible with long-term conservation objectives? If not, can more careful selection of space–time windows for managing natural resources significantly reduce extinction risk? How can the overall risk of extinction be distributed more evenly throughout all elements of the space–time path so that all resource users share in conservation responsibility? These questions will be explored more fully in the papers that follow.

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