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Ecological Applications, Volume 3, Issue 2 (May, 1993), 202-205.

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Ecological Applications

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PRESERVING BIODIVERSITY: SPECIES, ECOSYSTEMS, OR LANDSCAPES?¹

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Abstract. Efforts to preserve biological diversity must focus increasingly at the ecosystem level because of the immense number of species, the majority of which are currently unknown. An ecosystem approach is also the only way to conserve processes and habitats (such as forest canopies, belowground habitats, and hyporheic zones) that, with their constituent species, are poorly known. Continued concern with species is essential, however. Landscape-level issues also need much greater attention. Designing an appropriate system of habitat reserves is one landscape-level concern. Understanding and appropriately manipulating the landscape matrix is at least equal in importance to reserves issues, however, since the matrix itself is important in maintaining diversity, influences the effectiveness of reserves, and controls landscape connectivity.

Key words: belowground habitats; design of conservation reserves; forest canopies; heroic megafauna; hyporheic zones; landscape connectivity; landscape matrix; National Parks and Wilderness Areas; vertebrates and vascular plants vs. invertebrates and small organisms.

The vast majority of past and current efforts to preserve biological diversity have focused upon species, subspecies, and populations. This is certainly true of actions that have been taken under the Endangered Species Act (ESA). Yet, for several decades we have discussed the need for alternative approaches to the maintenance of biological diversity, most commonly an approach oriented toward ecosystems rather than species. With the pending debate over reauthorization of ESA, proposals to shift emphasis from species to ecosystems have taken on new intensity.

In this forum I outline some of the reasons why ecosystems, and even landscapes, need to receive more attention in efforts to preserve biological diversity. Included is the fundamental impossibility of dealing with more than a small fraction of existing diversity on a species basis, as well as the need to move beyond conservation strategies based upon reserve and corridor concepts. It is not my contention that we should abandon species-based efforts but, rather, that we should understand the limitations of this approach as we grapple with the immense and pressing task of preserving as much biological diversity as possible. In developing these views I have been strongly influenced by my experiences with research natural areas, old-growth forest ecosystems and landscapes, and conservation of interior forest species, such as the Northern Spotted Owl (*Strix occidentalis*), and most recently as a member of the Congressionally chartered Scientific Panel on Late Successional Forest Ecosystems (1991).

THE NECESSITY FOR AN ECOSYSTEM APPROACH

I contend that we cannot even come close to attaining our goal of preserving biological diversity, let alone sustainability, if we continue to focus our efforts pri-

marily on species. Why? First and foremost, for practical reasons—there are simply too many species to handle on a species-by-species approach. Such an approach will fail as it will quickly exhaust (1) the time available, (2) our financial resources, (3) societal patience, and (4) scientific knowledge. This will happen long before we have even begun making serious progress on this task.

Larger-scale approaches—at the levels of ecosystems and landscapes—are the *only* way to conserve the overwhelming mass—the millions of species—of existing biodiversity. Specifically included is that large array of what are sometimes called “lesser” organisms but might better be referred to as “smaller” organisms—such as invertebrates, fungi, and bacteria (Wilson 1986). It is these physically smaller but overwhelmingly more numerous elements of diversity that carry out critical ecosystem functions, such as decomposition and nitrogen fixation. Based upon a very conservative estimate of 5,000,000 species, vertebrates make up <1% and vertebrates and vascular plants together only ≈5% of the total array of species, while invertebrates will probably compose 90% of the total. Yet the vast majority of these taxa are unknown and, in a practical sense, unknowable. They will be conserved only as ecosystems are conserved.

These smaller organisms are the greater measure of diversity, yet we have largely ignored them. I suspect many of us assume that, somehow, most such organisms are either tolerant of human activities or readily capable of recolonizing eliminated habitats, logic and considerable evidence to the contrary.

Organisms such as insects and fungi are *not* necessarily more resistant to human impacts or more effective dispersers than vertebrates and vascular plants. We can and *do* lose such species from disturbed sites and these losses have negative consequences for sustainability (see, e.g., Perry et al. 1989). We must pay

¹ Manuscript received 24 July 1992.

more attention to these smaller organisms if our efforts to maintain biodiversity and conserve ecosystems are to have the desired result.

The ecosystem approach is also the *only* way to conserve organisms and processes in poorly known or unknown habitats and ecological subsystems. There are many examples from ecological science of the richness of previously unappreciated habitats, such as forest canopies, belowground subsystems, and the hyporheic zones.

Canopies of natural forests in both tropical and temperate regions are proving to be incredibly rich in species, as shown by scientists such as Erwin (1986) and Schowalter (1989). Indeed, Erwin's collections of invertebrates following the gassing of tropical forest canopies have led to greatly expanded estimates of the number of species. Schowalter has shown how old-growth *Pseudotsuga menziesii* forest canopies not only have many more invertebrate species but also a very different functional balance than exists in adjacent plantations; invertebrate predators and parasites are extremely abundant in the old-growth forest, while plant herbivores overwhelmingly dominate the invertebrate communities in the plantations.

Belowground eco-subsystems are proving to be intensely dynamic and extremely diverse in species (Harris et al. 1980). They are also rich assemblages of spatially complex communities—anything but the homogenous habitat that many imagine. These subsystems are highly dependent upon copious, continuing energy supplies from the photosynthetically active vascular plants. It is increasingly understood that it is not just the soil that supports the vascular plants but, at least equally, the plants that function as the life support system for the soil. Maintenance of the belowground elements of diversity requires an ecosystem approach that provides for a healthy and diverse aboveground energy source.

The hyporheic zone is the saturated zone below and adjacent to stream and river channels—within the alluvial materials of the stream channel and floodplains (Naiman 1992). This eco-subsystem has direct functional links to the associated river or stream. The hyporheic is the site of critical processes—carbon and nutrient transformations—and habitat for a large array of aquatic organisms, many of which are poorly known to science.

So, how could we propose to maintain biodiversity using only, or even primarily, a species approach? I do not think we could. Nor could we do so without a species approach, given our objectives and interests as humans. Often the vertebrates provide useful indicators of the overall health of our ecosystems and, with varying degrees of success, as serve as "umbrellas" for protection of other organisms and ecosystems. We humans also relate well to fur, feathers, and, sometimes, scales; so the vertebrates are biodiversity attention-

getters and legal levers. Further, the heroic megafauna provide us with inspiration and enrich our lives.

But if we truly intend to maintain a significant component of existing biological diversity, we should not allow this concern for species, especially heroic and beautiful species, to obscure our larger task. Nor should we let approaches relevant primarily to vertebrates confuse us as to what strategies are essential to conserving the bulk of biological diversity.

Finally, I have one additional comment on the species approach. I find it fascinating that conservation biologists who would not for a moment consider a species approach to the conservation of biological diversity in tropical rainforests will defend such a strategy for the temperate regions. Once the "smaller" organisms are considered, diversity in temperate regions is probably not that much different than it is in the tropics—it is quite simply overwhelming in both regions, at least in the near term.

NECESSITY FOR A LANDSCAPE AND REGIONAL VIEW

To achieve our objective of conserving the vast majority of biological diversity, it is critical that we plan and assess at the level of landscapes and regions as well as ecosystems. This is a complex issue that includes the development of an appropriate system of habitat preserves with greatly expanded attention to conditions in the landscape matrix—the complex of semi-natural and domesticated lands within which most reserve systems will be embedded.

Habitat reserves are an essential element in any comprehensive program to conserve biological diversity for the foreseeable future. The objective in designing a reserve system is to try to ensure that the reserves are sufficient in number and size and appropriately distributed over the landscape in terms of geography and ecosystem type.

The focus and accomplishments of conservationists with regard to reserve systems leave much to be desired, and academic scientists have significantly contributed to suboptimal approaches, in my opinion. Conservation biology has focused primarily upon large reserves to accommodate wide-ranging species, and not enough on the need for small- and medium-sized areas at much closer spacings. Many elements of diversity are not capable of responding to a coarse-textured reserve system of large but widely spaced reserves. The SLOSS (single large or several small) debate over appropriate reserve systems is proving to be not only irrelevant, but also misleading, as we turn from the heroic megafauna to considering the dominant components of biological diversity—the smaller organisms. At least this has been our experience in the Pacific Northwest.

Furthermore, reserve efforts have focused too heavily on wild and aesthetically pleasing landscapes, which

probably do not do a good job of serving the bulk of biological diversity. For example, in the Pacific Northwest the diversity of forest vertebrates is strongly associated with elevation (Harris 1984) and, probably, ecosystem productivity. Yet, most reserved forests are at middle and high elevations and not in the productive lowlands. Our system of National Parks and Wilderness Areas is a beautiful one, but it does not appear to be the functional centerpiece of a strategy designed primarily to protect biological diversity; a much better geographic distribution and far higher representation of productive habitats and ecosystems would be required.

Much of the emphasis on reserves for maintenance of biological diversity is appropriate. Native habitats are disappearing at a rapid rate. Saving some pieces has a high priority if we are to retain the species and the processes dependent upon them. In the Pacific Northwest it is highly probable that there are species and processes that depend upon old-growth forest as habitat. Over the short term, existing old-growth forests are our only source of reserves. Hence, decisions about the amount and distribution of late successional forest habitats have high priority.

A comprehensive strategy for the conservation of biodiversity is going to require reserves—areas where human disruption is minimized. And recent scientific judgements in the Pacific Northwest indicate that we are going to need more and better-distributed reserves, generally of medium size, than previously believed. This is clearly reflected in recommendations by scientific panels to establish several million acres as Habitat Conservation Areas (HCAs) for the Northern Spotted Owl (Interagency Scientific Committee 1990) or Late-Successional/Old-Growth reserves for late-successional forest ecosystems and species (Scientific Panel on Late Successional Forest Ecosystems 1991).

IMPORTANCE OF THE UNRESERVED MATRIX

However, reserves cannot be the only or even the primary strategy for maintaining biological diversity. There are many reasons for this, including the fact that we will never have enough large, well-distributed reserves. Distribution—particularly representation of the most productive ecosystems that we have converted to towns, farms, power generation, tree farms, etc.—is a particular problem.

In fact, most of the temperate landscape is subject to alterations and consumptive uses by the human species. This unreserved portion of the landscape can be broadly referred to as the landscape matrix, in the sense that it is the matrix within which any system of reserves is embedded. J. H. Brown (*personal communication*) has referred to this as the "semi-natural matrix." This matrix obviously varies greatly in its characteristics, since the degree of human use varies from minimal to both intensive (agricultural, urban, and surface mining)

and extensive exploitation of natural resources (much forest harvesting, fishing, and domestic livestock grazing on native grasslands). But it is the semi-natural matrix that is really dominant in most inhabited regions of the world, that occupies the most productive locales and, probably, contains the majority of biological diversity (Pimentel et al. 1992). Hence, the matrix is a critical locale for conserving biological diversity; but, unfortunately, it has largely been ignored.

The landscape matrix plays at least three critical roles in the conservation of biological diversity: (1) providing habitat at smaller spatial scales; (2) increasing the effectiveness of reserved areas; and (3) controlling connectivity in the landscape, including movements of organisms between reserves.

The provision of habitat at smaller spatial scales is a primary function of the matrix. Conserving biological diversity requires the maintenance of habitat across a wide array of spatial scales. Many species do not require reserves in the traditional sense; their habitat requirements are at the scale of individual structures, such as dead trees, logs, hedgerows, gravel beds, large soil aggregates, etc. The maintenance of such habitats in the matrix is determined by the management prescriptions that are applied. Many elements of biological diversity can be lost if human activities eliminate essential habitat features. Conversely, management practices can be designed to retain essential habitat features and dependent species. Furthermore, far more is involved here than simply the maintenance of biological diversity for its own sake; many of the organisms, such as fungi capable of forming mycorrhizae, carry out critical ecosystem functions and are directly related to the sustained productivity of these ecosystems. There are many ways in which management practices can be modified to maintain higher levels of biological diversity including both the maintenance of critical structures (e.g., snags and down logs in forested areas) (Franklin 1992) and less-intensive manipulations (e.g., no-till agriculture) (Pimentel et al. 1992).

The importance of the matrix in buffering reserves is well known. If a reserve is imbedded in a matrix that is highly dissimilar—has a high contrast—a much larger reserved area is going to be required to achieve the same level of protection. In the forest landscapes of the Pacific Northwest, for example, a reserved patch of old growth will have to be much larger to provide an unmodified interior environment if it is located within a clearcut landscape than it will if it is surrounded primarily by partially cut forest. Harris (1984) suggests that conserving an intact old-growth patch might require 10 ha if it is surrounded by comparable forest, but 100 ha if it is surrounded by a clearcut. Whether this proportion is precisely correct is not the point. What is important is recognizing that edge influences can be extensive, and that the higher the contrast between patch types, the greater the effects.

The role of the matrix in providing for connectivity in the landscape, including connectivity between reserves, is in drastic need of attention. The focus in connectivity has been on corridors. While we intuitively expect that corridors are important, their effectiveness has not been proven and there is almost certainly a large proportion of the species for which corridors are not likely to be very useful. Perhaps our obsession with corridors again reflects our bias toward vertebrates. I specifically want to note, however, that I view riparian corridors as having intrinsic merit for the services and protection they provide to aquatic ecosystems, regardless of their potential value as connectors for upland species.

Management of the matrix offers us alternative approaches to corridors for facilitating connectivity in the landscape. Depending upon our management we can either "soften" the matrix, making it less hostile for the dispersion of organisms, or enhance its lethality. In island-biogeographic terms, we can think about making the sea between habitat islands "shallower," perhaps providing stepping stones or haul-out areas or, alternatively, "deeper, full of sharks and deadly currents."

In the Pacific Northwest we are beginning to propose serious strategies for matrix modification in our forest landscapes, both to enhance connectivity for old-growth organisms and to maintain critical habitat on smaller spatial scales. An outstanding example of the matrix modification approach is the "50-11-40 rule" designed by the Interagency Scientific Committee (1990) in their plan for conserving the Northern Spotted Owl. In order to improve prospects for successful dispersion between major reserves ("habitat conservation areas") the committee required, as part of their strategy, that at least 50% of the matrix be maintained in trees 11 inches (28 cm) in diameter or larger, and with a 40% canopy cover. The Scientific Panel on late Successional Forest Ecosystems (1991) in their report to Congress went even further in recommending that minimal numbers of large trees, snags, and down logs be maintained in the matrix between old-growth reserves in addition to 50-11-40 conditions.

It should be apparent that the condition of the matrix is absolutely critical to overall landscape connectivity and, in most cases, will be the primary controller. Human activities can either produce very hostile conditions in the matrix—deep seas full of sharks, barren of food, lethal temperatures, etc. Or activities can be designed to enhance dispersion and in-place survival of organisms. I emphasize the matrix because of its importance and the fact that it has been largely ignored in conservation biology.

CONCLUSIONS

In this paper I have tried to indicate why we must increase our emphasis on ecosystem- and landscape-

level approaches over species-based approaches if we truly intend to maintain the majority of existing biological diversity. Once we see beyond vertebrates and vascular plants to the far more numerous "smaller" organisms, the necessity for taking an ecosystem approach becomes apparent. The critical role of the landscape matrix in maintaining diversity—and the reciprocal role of diversity in the sustained productivity of the lands and waters used by man—also becomes apparent. Biodiversity is not a "set-aside" issue that can be physically isolated in few, or even many, reserves. All parties to the biodiversity debate—environmentalists and utilitarians—have had this same narrow view and have disagreed only on how much to reserve and where! I think that we need to put reserves and corridors and heroic megafauna in perspective. We must see the larger task—stewardship of *all* of the species on *all* of the landscape with every activity we undertake as human beings—a task without spatial and temporal boundaries.

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