INTEGRATING BIOLOGICAL DIVERSITY AND RESOURCE MANAGEMENT

An essential approach to productive, sustainable ecosystems

By John R. Probst and Thomas R. Crow

Call for Papers

The *Journal of Forestry* is extending a call for papers in the following areas of biodiversity. All papers will be peer-reviewed prior to publication in the *Journal of Forestry* and may or may not be printed with other articles in the series. Papers are solicited on ecosystem approaches to biodiversity, old-growth ecological processes, biodiversity and ecosystem function, population viability, diverse monitoring strategies for diverse objectives, endangered and threatened species, tropical rainforests, managing for biodiversity on national forests, timber-cutting patterns to optimize biodiversity, evaluation of alternatives in intensely managed forests, and examples of successful biodiversity management in managed forests and human-dominated landscapes.

Submit proposals or completed papers to N. Taylor Gregg, Editor, *Journal of Forestry*, 5400 Grosvenor Lane, Bethesda, MD 20814-2198 (301) 897-8720. Completed papers should follow the guidelines for general scientific papers as presented in "Guidelines for Contributors," May 1990 *Journal of Forestry*, p. 43–44.

It is not uncommon today for foresters to find themselves at the center of controversy. A skeptical public often criticizes forest management activities, especially timber harvesting and road building, and often perceives management as detrimental to many organisms that depend on the forest for their survival. While the forester might argue that an intensively managed forest is likely to be a healthy forest, others call for "natural forests" in which ecological processes are allowed to occur without interference from chain saws and skidders.

Against this background, the issue of conserving biological diversity is receiving increased attention in professional journals, the popular media, and Congress. Growing concerns are being expressed about forest destruction and habitat losses throughout the world, and about the accelerating loss of species due to the cumulative impact of human activities. While the spotlight currently focuses on relatively few species—the spotted owl, the red-cockaded woodpecker, the black-footed ferret—a more comprehensive discussion is developing that deals with biological diversity and its importance to ecosystem health and productivity. The concept of biological diversity serves as a broad framework for considering many of today's important resource issues.

John R. Probst is research ecologist and Thomas R. Crow is project leader, USDA Forest Service, North Central Forest Experiment Station, Rhinelander, WI.

The fact that the total number of species on Earth, even to an order of magnitude, is unknown makes it difficult to know what is being lost. Current estimates of the number of plant and animal species worldwide range from 5 and 50 million, but fewer than 2 million species have been described and catalogued (Wilson 1985, May 1988). Most of this diversity is inconspicuous. Probably only 1–2% of Earth's species are higher plants and less than 0.2% are vertebrates; the remainder are a vast array of invertebrates, algae, fungi, and other microorganisms that, despite being inconspicuous, provide valuable ecological services. Although it is difficult to quantify exact rates of species loss throughout history, scientists generally agree that current extinction rates far exceed the rates documented in geologic records.

But what does this have to do with forestry? Forests, especially public forests, are increasingly viewed as valuable reserves in which large tracts can be managed to protect biological diversity. National Forest Management Act regulations already specify that the USDA Forest Service must consider biological diversity in the planning process, and must monitor and evaluate the effects of implementing any forest plan on biological diversity. Furthermore, concerns about the loss of biological diversity have resulted in draft legislation to make conservation of biological diversity a national goal Foresters should play a role in these policy discussions as well as find practical solutions to the problem. This role, however, will be determined largely by how we perceive the issues and understand the concepts relating to biological diversity.

What Is It?

The first question always is: Can you give me a good definition of biological diversity? Probably the most widely cited definition comes from *Technologies to Maintain Biological Diversity* (Office of Technology Assessment 1987): "Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur" (p. 5).

No matter how well stated, technical definitions rarely make good operational definitions. From a practical viewpoint, it is useful to consider three elements of diversity—genetic, species, and ecosystem. Each is related. For example, it is important in conserving any species to maintain critical ecosystems (or habitats) and retain as much genetic diversity as possible. Each element can operate at a variety of scales in time and space. The time scale can vary from a few hours (the life span of a microorganism) to decades (viability assessments) or even millennia (evolution). Biological diversity occurs at all spatial scales, from local through regional to global. When discussing biological diversity, it is important to consider appropriate elements and scales.

It is also important to view biological diversity as something more than local "species richness." Management to maximize species richness at the local level often favors "generalist" organisms at the expense of "habitat specialists." In the process, species could be lost from large areas or whole regions. Land managers need to be especially concerned about plant and animal species that are habitat specialists, and about species with low population densities, that require large home ranges, with poor dispersal and colonizing abilities, or that are prone to local extinction. In contrast, common species, habitat generalists, or species able to colonize disturbed habitats are more likely to prosper under a variety of land use patterns (*fig. 1*, p. 14).

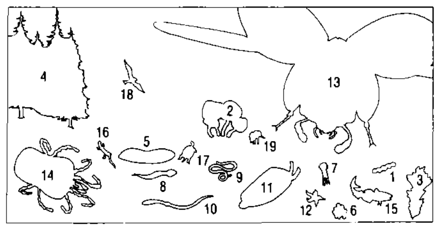
Spatial Considerations

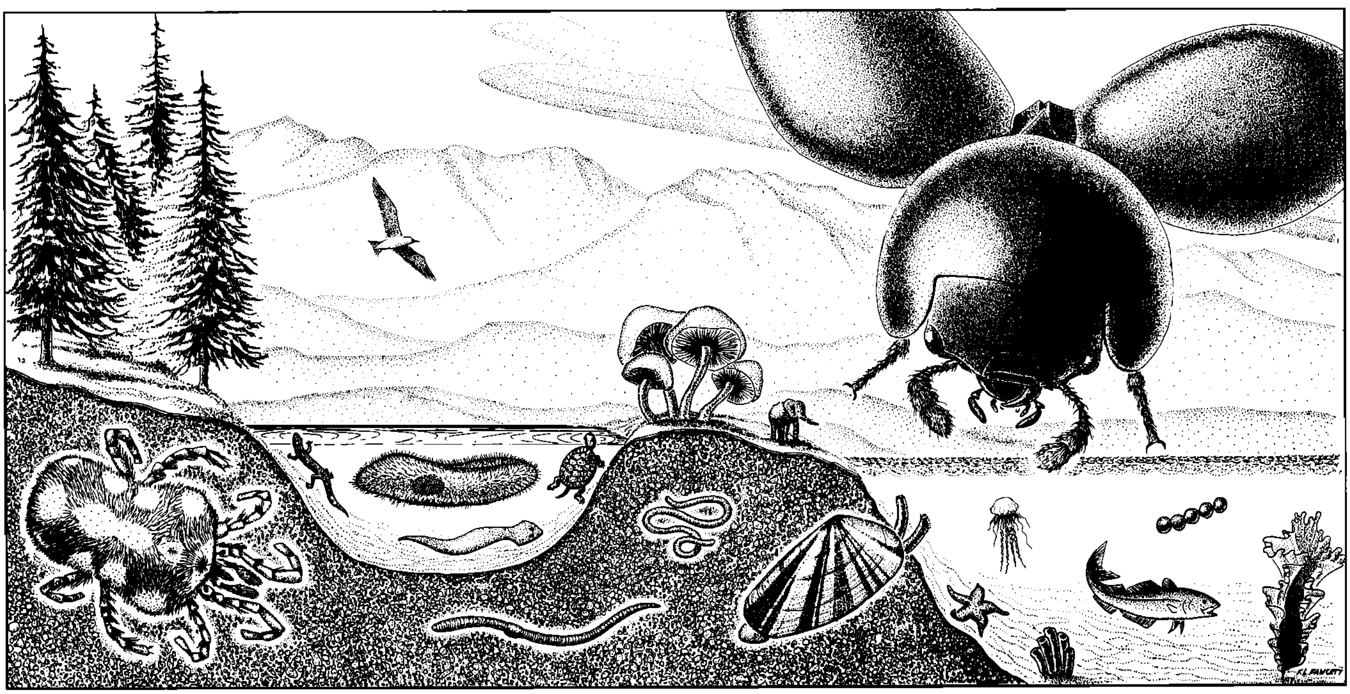
Dividing large and continuous tracts of natural habitat into smaller habitats surrounded by altered or disturbed areas—called habitat fragmentation—is a major concern relating to biological diversity (Harris 1984, Wilcove 1987). The problems of extinction and colonization on habitat fragments are similar to the patterns biogeographers have

Key

	Taxon	*No. of Described Species*
1	Monera (Bacteria, Blue-green Algae)	4,760
2	Fungi	46,983
3	Algae	26,900
4	Plantae (Multicellular Plants)	248,428
5	Protozoa	30,800
6	Porifera (Sponges)	5,000
7	Coelentarata (Jellyfish, Corals, Comb Jellies)	9,000
8	Platyhelminthes (Flatworms)	12,200
9	Nematoda (Roundworms)	12,000
10	Annelida (Earthworms etc.)	12,000
11	Mollusca (Mollusks)	50,000
12	Echinodermata (Starfish etc.)	6,100
13	Insecta	751,000
14	Non-insect Arthropoda (Mites, Spiders, Crustaceans etc.)	123,161
15	Pisces (Fish)	19,056
16	Amphibia (Amphibians)	4,184
17	Reptilia (Reptiles)	6,300
18	Aves (Birds)	9,040
19	Mammalia (Mammals)	4,000

Source: E.O. Wilson, Ed., 1988. *Biodiversity*. Nat. Acad. Sci. Press, Washington.





Size of individual organisms represents number of described species in major taxon. Unit Area: □ = 1,000 described species.

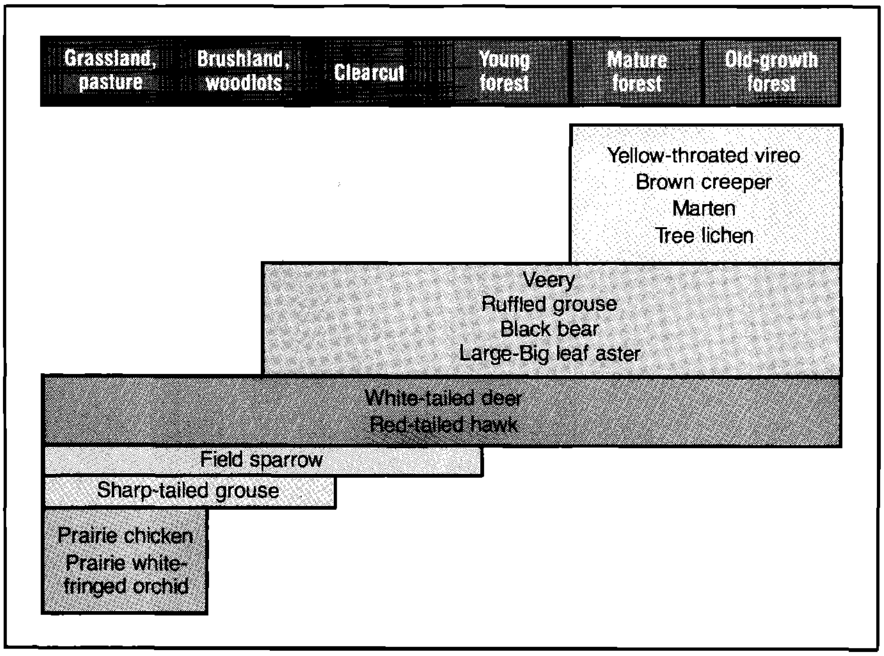


Figure 1. Generalists are found in a variety of ecosystems. In contrast, habitat specialists are limited to only a few ecosystems, such as old-growth forests and native grasslands. Maintaining regional diversity depends on maintaining ecosystems that are rare and endangered.

been recording for more than a century on oceanic islands, so habitat fragments are often called habitat islands. They may be patches of old-growth surrounded by second-growth forests, prairie fragments embedded in a matrix of agricultural lands, or once free-flowing rivers fragmented by hydroelectric and water diversion projects. In all cases, what were continuous areas are now separated by less suitable, and in some cases inhospitable, habitats for many species.

Although natural disturbance is a common occurrence, habitat fragmentation is aggravated in human-dominated landscapes. Declines in migratory bird populations in the eastern deciduous forest are related to forest fragmentation (Robbins 1979, Whitcomb et al. 1981). Extensive fragmentation due to dams and impoundments has contributed to the endangered status of fish in the Colorado River (Ono et al. 1983). Human activities not only result in the destruction of habitats, but species depending on the remaining habitat fragments often become isolated from other populations depending on when and how the habitat is fragmented. When small populations of a species are widely scattered, the chances of local extinction are greater and the chances of recolonization decrease. Habitat fragmentation can adversely affect "area-sensitive" species, such as animals requiring interior forest conditions (e.g., neotropical migratory birds) or those requiring several habitats in close proximity at different times of the year or at different stages of development (e.g., amphibians with both terrestrial and aquatic life forms)

Some area-sensitive species may also be "edge-sensitive" when biotic factors (predators, browsers, nest parasites, competitors) or abiotic factors (changes in microclimate) decrease their reproductive success. Edge-sensitive species include many birds as well as reptiles, amphibians, and plants. The significance of habitat contrast along an edge depends on the species. Ubiquitous roads and forest openings dramatically increase edge environments.

Some open-land species are edge-sensitive relative to forest edges. Prairie grouse, for example, suffer increased predation near forest edges Grassland birds such as bobolinks and several sparrow species also have lower productivity near edges (Johnson and Temple 1990).

Other area-sensitive species may be more accurately described as human-sensitive. These include many large mammals, especially carnivores (timber wolf, grizzly bear, black bear, Florida panther) that characteristically exist in low densities and are wide-ranging. The problem here has more to do with the fact that human contact is often fatal for the animals. For example, black bears prefer habitat that includes both forests and openings with a high degree of edge and a variety of plant communities; but large, relatively uninhabited tracts of such land have disappeared in many areas, bringing bears into closer contact with humans. It is not surprising that the principal source of mortality for the panther, Key deer, and manatee (all endangered) and for the threatened black bear in Florida is collisions with motor vehicles (Harris 1989). Maintaining large wide-ranging mammals in the eastern United States may require linking several undeveloped areas together with landscape corridors.

From Species to Ecosystems

A fundamental problem for biological diversity is defining long-term viability for species. It is more complex than simply the minimum population needed to survive long-term, random population fluctuations. To assess population dynamics accurately, resource managers must consider reproductive rate, population or habitat age structure, recruitment rate, survivorship, and ability to disperse. They must also take into account the amount and quality of critical habitat and how it is distributed. Many suboptimal habitats may temporarily support higher than expected populations due to emigration from more productive sources (i.e., source and sink relations), so populations do not always respond immediately to landscape alterations.

The effects of habitat loss are rarely linear; instead, populations often decline sharply once a threshold is reached. This is particularly true for species that are locally or temporarily successful and emigrate to less suitable habitats, where they reproduce below replacement levels. Adding or eliminating a few high-quality breeding habitats can cause a regional population to change substantially. For example, populations of the endangered Kirtland's warbler remained remarkably stable for the past 2 decades except for 20% declines in 1974 and 1987, when a few large breeding areas became overmature at the same time (Probst 1988), and a 20% increase in 1990 after a large block became suitable habitat (J. Probst, unpublished data).

Species that are reasonably common, or even abundant, can rapidly disappear if their reproduction or habitat is altered. Vast flocks of passenger pigeons once filled the skies, but hunting during critical nesting periods reduced their reproductive success and contributed to their extinction over a 20-year period. The Eskimo curlew, once one of the most abundant shorebirds in North America, also disappeared quickly.

Managers should focus on landscape and ecosystem features that affect population size and distribution rather than attempting the complicated task of determining what constitutes "minimum viable" populations. An estimated 2,400 to 2,600 vertebrates alone occur in the United States (Hoekstra et al. 1979). Comprehensive studies to determine minimum viable populations will be possible for only a few selected species. A practical alternative is managing for large and well-distributed populations (i.e., ecologically functional, Connor 1988) using a landscape and ecosystem approach.

Managers are devising practical monitoring systems that are biologically, statistically, and technically sound. One approach uses indicator species: by monitoring the population of a few species, managers attempt to interpret population trends of many species. However, monitoring plans are almost never comprehensive enough, and debate continues on what constitutes an indicator species and on how much indicator species can represent the ecological requirements and population trends of other species (Landres et al. 1988). Strategies are being developed to monitor species groups (Verner 1984) and specific management problems (snag densities, area-sensitive species, dispersal corridors, amphibian breeding areas, etc.). However, inventory should be completed before monitoring plans are developed, and general biodiversity assessment is a higher priority than monitoring.

Preserving single species (especially vertebrates) has dominated the attention of conservationists, but preserving ecosystems is receiving more attention (Noss 1983). Regional ecosystem approaches are needed for preserving plants, invertebrates, and less visible vertebrates. Restoring prairies and oak savannahs in the Midwest and longleaf pine communities in the South, maintaining old-growth forests in the Northwest, saving moist and dry tropical forests and wetlands throughout the world all reflect this concern. Such communities are important elements of regional and global diversity. A comprehensive approach to conserving and enhancing biological diversity requires taking into account both species and ecosystems.

Foresters should play a role in these policy discussions as well as find practical solutions to the problem

Public Benefits from Biodiversity

Many benefits of biological diversity are widely acknowledged. Some plant and animal species are vital for human utilization as food, fiber, or medicinal drugs. Hunting, fishing, and esthetic appreciation of animals and plants give pleasure to people and add billions of dollars to economies each year. Plants and animals are used in genetic research for selective breeding and as sources of new genetic material. The need to preserve genetic diversity is particularly critical given predicted geographic shifts in species distribution due to climatic warming. The number of major commercial species in agriculture and forestry are limited, so new plant varieties may have to be developed using traditional breeding methods as well as biotechnology.

Scientists are becoming increasingly aware that biotic diversity is essential to healthy and productive ecosystems. Diverse flora and fauna facilitate decomposition, nutrient cycling, and other ecological processes. Animals both large and small affect forest composition and regeneration through herbivory, seed dispersal, and population regulation of other organisms through a multiplicity of interactions. Biodiversity provides alternative food chains, biological pest controls, and increased silvicultural options. For example, genetic diversity has a very important relationship to site productivity, and some of the most valuable genetic complexes may have already been lost (Ledig 1988, Monserud and Rehfeldt 1990). Diverse life forms vary in their tolerance to environmental stress, so community composition can be a sensitive environmental monitor of climatic change or pollution. Many noncommercial species are valuable as site indicators for forestry and agriculture. Much of the diversity responsible for ecosystem health and sustainability is "invisible diversity" that is out of sight and thus out of mind.

Management Responsibilities

Public and industrial managers are important to the conservation effort because they often manage large, contiguous tracts of land. Such tracts can mitigate the effects of habitat fragmentation in surrounding landscapes. For example, large blocks of forestland may provide the interior forest conditions needed for breeding populations of area-sensitive birds; these populations may, in turn, expand to less suitable habitats on adjacent lands. However, not even the largest national forest or national park is ecologically isolated from activities and conditions in surrounding areas.

The challenge of conserving biological diversity is too comprehensive . . . to be met on public lands alone

The challenge of conserving biological diversity is too comprehensive and inclusive to be met on public lands alone. Nor is it realistic to think that conserving biological diversity is nothing more than establishing parks and preserves. Only a small fraction of Earth's surface will ever be under the protective status of a national park, a nature preserve, or a wildlife sanctuary, and the least protection is likely where it is needed the most—the tropics of Asia, South America, and Africa.

We cannot remove people and resource use from the system and create pristine forests, nor can we somehow return to presettlement conditions. Therefore, conserving and enhancing biological diversity must become an integral part of natural-resource management on the 95% of the landscape that sustains a wide variety of human activities and resource uses, including timber harvesting and food production. At regional, national, and global scales, major efforts to maintain biological diversity must occur outside parks and preserves—on lands having a variety of uses and ownerships.

It is ironic that as humans alter the ecosystems on which they depend, conserving diversity will increasingly depend on active human involvement. Active management, not just passive protectionism, is needed to coordinate different land ownership objectives Active management must create landscapes that facilitate movement and dispersal of large mammals. Active management is needed to restore species that are extirpated due to direct or indirect human impact and to reduce the threat of exotics on native species Active planning will ensure that old-growth forests, with their unique properties, are represented throughout the regional landscape, adding to regional diversity. Active management can supplement in situ conservation of genetic diversity by collecting and storing seeds and pollen of endangered plant species. Active management is vital to providing critical habitats when and where they are needed to ensure that uncommon species do not become threatened or endangered.

Recommendations

Preserving biological diversity is a complex problem that encompasses a variety of scientific, social, and economic considerations. Piecemeal approaches will likely result in oversimplification, frustration, and new, unanticipated problems. There are no "five easy steps" or simple solutions. Nevertheless, applying some general recommendations can help maintain and enhance biological diversity.

- Use a regional perspective when considering biological diversity.
- Think beyond the boundaries of specific ownerships when planning and managing.
- Plan and manage over large areas rather than using a stand-by-stand approach. Consider the cumulative impact of individual projects on regional populations and resources.
- Emphasize multispecies and ecosystem management instead of single-species and tree management. Simply stated: become an ecosystem manager
- Provide habitat sufficient to maintain species of concern (e.g., large wide-ranging mammals), not just sufficient habitat to attract immigrants from more productive sources.
- Maintain or create spatial patterns (large patches, landscape linkages, low contrast between adjacent patches) that enhance conditions for problem

species. For example, alter cutting patterns and harvest schedules to reduce forest fragmentation.

- Include the full spectrum of ecological assemblages within the landscape, from early successional to old-growth communities. Provide a variety of sites for each forest type and age as a coarse filter for genetic and ecosystem diversity.
- Conduct ecological surveys and inventories. Know what is on the land, where it is, and how much is there.
- Monitor problem species and problem ecosystems. Wherever possible, supplement monitoring of indicator species with guild (groups of species occupying similar niches) monitoring and direct ecosystem monitoring. Relate changes to local treatments. Interpret local changes relative to broader regional changes.
- Become better informed. Action follows awareness!

Maintaining and enhancing biological diversity touches all aspects of resource management. An obvious reason for protecting biological diversity is to ensure sustainable productivity of forest resources for present and future generations. It is part of being good stewards. From a broader perspective, biological diversity is an integral part of our cultural and esthetic appreciation of life. ■

Literature Cited

CONNOR, R.N. 1988. Wildlife populations: minimally viable or ecologically functional? Wildl. Soc. Bull. 16:80–84.

HARRIS, L.D. 1984. The fragmented forest. Univ. Chicago Press, Chicago, IL. 211 p.

HARRIS, L.D. 1989. The faunal significance of fragmentation of southeastern bottomland forests. P. 126–34 *in* The forested wetlands of the southern United States, D.D. Hook and R. Lea, eds. USDA For. Serv. Gen. Tech. Rep. SE-50.

HOEKSTRA, T.W., et al. 1979. Preliminary evaluation of a national wildlife and fish data base. Trans. North Am. Wildl. & Nat. Resour. Conf. 44:380–91.

JOHNSON, R.G., and S.A. TEMPLE. 1990. Nest predation and brood parasitism of tallgrass prairie birds. J. Wildl. Manage. 54:106–11.

LANDRES, P.B., J. VERNER, and J.W. THOMAS. 1988. Ecological uses of vertebrate indicator species: a critique. Conserv. Biol. 2:316–28.

LEDIG, F.T. 1988. The conservation of diversity in forest trees. BioScience 38:471–79.

MAY, R.M. 1988. How many species are there on earth? Science 241:1441–49.

MONSERUD, R.A., and G.E. REHFELDT. 1990. Genetic and environmental components of variation of site index in inland Douglas-fir. For. Sci. 36:1–9.

NOSS, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33:700–6.

OFFICE OF TECHNOLOGY ASSESSMENT. 1987. Technologies to maintain biological diversity. Summary. U.S. Gov. Print. Off., Washington, DC. Stock #052-003-01058-5.

ONO, R.D., J.D. WILLIAMS, and A. WAGNER. 1983. Vanishing fishes of North America. Stone Wall Press, Washington, DC.

PROBST, J.R. 1988. Kirtland's warbler breeding biology and habitat management. P. 28–35 *in* Integrating forest management for wildlife and fish, T.W. Hoekstra and J. Capp, comps. USDA For. Serv. Gen. Tech. Rep. NC-122.

ROBBINS, C. 1979. Effect of forest fragmentation on bird populations. P. 198–212 *in* Management of north central and northeastern forests for nongame birds, R.M. DeGraaf, ed. USDA For. Serv. Gen. Tech. Rep. NC-51.

VERNER, J. 1984. The guild concept applied to management of bird populations. Environ. Manage. 8:1–14.

WHITCOMB, R.F., et al. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. P. 125–205 *in* Forest island dynamics in man-dominated landscapes, B. Burgess and D. Sharpe, eds. Springer-Verlag New York, Inc., New York, NY.

WILCOVE, D.S. 1987. From fragmentation to extinction. Nat. Areas J. 7:23–29.

WILSON, E.O. 1985. The biological diversity crisis. BioScience 35:700–6.