11 Ecological Assessment and Planning in the Wildland–Urban Interface: A Landscape Perspective

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A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.

—Aldo Leopold

11.1 INTRODUCTION

The day starts like any other with one exception, a request to evaluate the effects of a proposed residential development in your management district. Development has occurred in adjacent districts, but not in yours. You realize that the proposal represents more than just one action, it represents the first of a series of actions that can alter the ecological integrity, the management of natural resources, and the aesthetics of the landscape. The simple action of evaluating a development plan confronts you with three questions: (1) How does the current proposal affect the structure and function of the site and adjacent areas? (2) What areas need to be conserved or protected to minimize environmental effects from future development? (3) How will these areas be protected (e.g., legally) from future development?

Of course, the land is privately owned, and a private landowner has the right to develop his or her lands in compliance with federal, state, and local environmental laws and regulations. Does this mean that managers need to resign to the fact that development will occur? Quite the contrary, as land managers, we can provide critical information and insights into the development process by identifying important sites — ecological, physical, and cultural — within the landscape and by providing guidelines to landowners to minimize environmental and cultural degradation of those sites. In addition, we can provide guidelines to local decision makers who develop policy for land-use decisions. Without this input, development will continue to degrade the environment, alter social structure, and change the aesthetic beauty of the landscape.

My intention is not to provide an exhaustive review of the extensive literature on methods to protect the environment from development (e.g., Duerksen et al. 1997; Foresman et al. 1997; Dale et al. 2000) but rather to use the literature to provide natural resource managers and land-use planners with some basic guidelines to begin to evaluate the effect of development on natural systems. This chapter is also not a cookbook with recipes to achieve specific

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outcomes, but rather it emphasizes concepts for developing specific recommendations that can be tailored for individual conditions. The chapter has three sections — "Why Ecosystems?," "Why Landscapes?," and "Tomorrow's Landscapes Today" — to address the first two questions facing a land manager. To address question three, the manager or planner can propose to (1) purchase the property, (2) purchase development rights, (3) propose tax incentives, and (4) regulate land use. These options are discussed thoroughly in Chapters 4, 5, and 6 of this book and in the Southern Wildland–Urban Interface Assessment (Macie and Hermansen 2002), and will not be discussed here. Sections "Why Ecosystems?" and "Why Landscapes?" introduce ecosystem management as a holistic approach to land-use management decisions and to evaluate the effect of development on natural systems at a landscape scale. The third section, "Tomorrow's Landscapes Today," applies ecosystem management to identify key physical, ecological, and cultural sites in the landscape, to evaluate proposed development, and to minimize negative effects from future development.

11.2 WHY ECOSYSTEMS?

In 1992, the USDA Forest Service adopted an ecosystem approach to multiple-use management (Overbay 1992). The approach was proposed and accepted by the agency as a means to shift focus from sustaining production of particular goods to sustaining the viability of physical, ecological, and social systems (Kaufmann et al. 1994). Since this policy shift, ecosystem management has been the guiding principle for management decisions in the Forest Service as well as other federal, state, and local natural resource management agencies.

Why ecosystems? An ecosystem refers to a spatially and temporally explicit place that includes all the organisms, the abiotic environment, and their interactions (Likens 1992). Unlike population and community approaches to management, which focus on the interactions of individuals and species, an ecosystem approach focuses on the interactions — flows and processes — among physical, ecological, and social components. Hence, the ecosystem is a functional unit where physical, ecological, and social components interact (Farina 2000), and an ecosystem approach to management accounts for these interactions and flows, and structure that influences them.

Ecosystems are open systems. Energy (e.g., photosynthesis, herbivory, and predation), organisms (e.g., migration, foraging and breeding, and diurnal and seasonal movements), and matter (e.g., nutrients, water, sediments, and heavy metals) flow into, within, and out of the system. Therefore, an ecosystem influences and is influenced by neighboring ecosystems (Likens 1992). For example, in the past, land managers considered individual management units as being ecologically independent of each other rather than as integrated parts of a larger ecological system. By altering a management unit, the manager not only affects the flows and processes occurring within the unit but also the flows into and out of the unit and adjacent units. Furthermore, when we consider each unit independently, we cannot assess the cumulative effects of management actions on individual units at a scale of the larger system. An ecosystem approach takes into account the effect of management activities on a site and on adjacent sites.

Ecosystems also are dynamic; that is, they change over time. These changes alter physical structure or composition and the flow of energy, organisms, and matter. An ecosystem approach acknowledges that change is a characteristic of the system and that there is not a "balance of nature" (Botkin 1990).

Initially, ecologists excluded humans from natural systems (Pickett et al.1997). Today, however, ecologists recognize that humans and their socioeconomic systems are a significant component of all ecosystems. Because physical, ecological, and social components are interdependent, a holistic or ecosystem approach to land-use decisions enables the equitable evaluation of components and their interactions (McCormick 1998). (See Christensen et al.[1996] and McCormick [1998] for excellent overviews of the components and principles of ecosystem management.) Traditionally, land-use decisions focused principally on economic factors at the expense of biophysical and other social and cultural elements. An ecosystem approach to land-use decisions acknowledges biophysical and social complexities of ecosystems and the importance of maintaining those complexities to meet the needs for goods and services used by humans for the current and future generations (Christensen et al.1996; McCormick 1998).

An ecosystem, however, is far too complex for humans to manage as a unit. So, why use an ecosystem approach to decision making? In practice, ecosystem management is more a way of thinking to acknowledge and account for the species diversity as well as physical, ecological, and social patterns and processes (Yaffee et al.1996). Grumbine (1994) offers five management goals to sustain ecological integrity under ecosystem management (Table 11.1). These goals recognize the importance of maintaining biodiversity and ecological processes and incorporating humans and their activities into the decision making process. When a land-use decision is contemplated, an ecosystem approach enables us to assess the effect of development not only on populations and biotic communities but also on biophysical and social components and on the flow of energy, species, and matter in the system. Further, an ecosystem approach enables us to evaluate the effects across ownership and management boundaries; thus, we are able to inventory and evaluate cumulative effects on the landscape. For example, watershed protection is an ecosystem approach

TABLE 11.1
Ecosystem Management Goals to Sustain Ecological Integrity

- Maintain and protect habitat for viable populations of all native species.
- Represent, within protected areas, all native ecosystem types across their natural range of variability.
- Maintain evolutionary and ecological processes (i.e., disturbance regimes, hydrological processes, nutrient cycles, species migrations).
- Manage over periods of time sufficient to maintain the evolutionary potential of species and ecosystems.
- Allow for human use and occupancy at levels that do not result in ecological degradation.

Source: Grumbine (1994).

to planning. By working within the boundaries of a watershed, which often encompass many political and managerial jurisdictions, watershed managers measure hydrologic inputs and outputs and assess, individually and collectively, how existing and proposed land uses affect water quality and quantity.

11.3 WHY LANDSCAPES?

To evaluate the effect of urbanization on physical, ecological, and social patterns and processes, a perspective that is greater than the ecosystem and encompasses the spatial interactions among ecosystems is needed (Turner et al. 2001). A landscape scale provides the opportunity to view the spatial connectedness of ecosystems and assess the cumulative effects of land-use decisions on physical, ecological, and social components (Dale et al. 2000). A landscape, however, connotes different meanings for different people. To some, a landscape may represent a pastoral scene or a planted garden. Ecologically, a landscape is a heterogeneous area composed of a cluster of interacting ecosystems that are repeated in similar form throughout (Forman and Godron 1986). For example, an agricultural landscape is composed of agricultural fields and buildings, hedgerows, and woodlots (Figure 11.1). Similarly, urban landscapes are composed of streets, buildings, and managed greenspaces. Regardless of how a landscape is defined, every landscape has three components: structure, function, and change (Forman and Godron 1986). Structure refers to the types of structural elements that you see on the landscape and their spatial arrangement. Function refers to the flow of energy, materials, and organisms within and through ecosystems. Change refers to modification of structural and flow attributes over time. Development causes change, and a landscape perspective enables managers and planners to ascertain not only the potential effects of urbanization on an ecosystem but also the effects on adjacent ecosystems (Turner 1989). A landscape perspective also accounts for the collective incremental changes by humans and provides the ability to assess their cumulative effects on the ecosystems comprising that landscape (Farina 2000).

FIGURE 11.1 Aerial photograph of an agricultural landscape depicting different patch types — remnant forest, hedgerow, field, building, and transportation.

So, how do we link ecosystem management and a landscape perspective with the issue of changing land use? Looking at an aerial photograph of an agricultural landscape, for example, we can identify different structural elements based on their morphology: agricultural fields and buildings, forests, and hedgerows (Figure 11.1). These homogeneous areas represent structural units called patches, and collectively these patches form the landscape mosaic (Forman and Godron 1986). A patch can also be defined by its functional attributes such as how it is used by a species or its role in an ecosystem process. For example, a riparian patch is characterized structurally as vegetation along streams and functionally as a zone for removing nitrogen. By viewing a landscape as a mosaic of structural and functional patches, we can define how energy, species, and materials are distributed and flow across a landscape. In addition, characterizing the landscape by structural units enables us to assess how the landscape changes spatially and temporally. Subsequently, we can ask how the proposed development plan affects spatial distribution and flow within and among patches. Further, by conducting "what if" scenarios, we can assess future losses of patches to development and the effect on the ecological integrity of the landscape (Forman and Collinge 1996; White et al. 1997). An example would be a new road: a transportation patch. A road fragments a habitat, which creates new edges and disrupts migration patterns; increases storm runoff, which alters stream biota and stability; and serves as a conduit for invasive species, which alter habitat structure. Without a landscape perspective, these cumulative effects could not be assessed.

The concept of defining a landscape by homogeneous patches is not foreign to land managers and planners. Natural resource managers have used terms such as community and forest types to describe a forest landscape. Similarly, planners use land use to designate areas with similar structural and functional attributes. Regardless of the classification system, each unit is based on structural or functional attributes that distinguish it from adjacent units. So, why use the word "patch" rather than some other common terms? First, the term "patch" simplifies terminology across different disciplines; second, the ecological concept of patch dynamics allows one to move from one spatial or temporal scale to another; and third, it is applicable to physical, ecological, and social components of the ecosystem (Farina 2000; Pickett et al. 2001).

11.3.1 Scale

Like forest-type delineation, patch delineation is scale dependent. Scale refers to the spatial and temporal dimensions of an object or process being studied or managed (Forman 1995). Scale contains two components: grain, the finest resolution of the data being collected or mapped; and extent, the areal size of the management site or the duration of the proposed action (Turner et al. 2001). An example of grain is from land cover. An area may be defined rather coarsely as forest or more finely as evergreen or deciduous or even more finely as a sugar maple forest type. Grain resolution (patch delineation) depends on the proposed objectives. For example, patch delineation of a bear habitat would be different from delineation of a butterfly habitat. Examples of extent are the forest being managed and the watershed where a proposed development might occur. Unfortunately, an array of scales is needed to define the complexities of ecosystem processes (Turner et al. 2001), and the manager/planner must pick the scale that best meets his or her objectives. To assess the effects of a proposed development plan, scale needs to have a resolution sufficient to capture population and community characteristics of the area and ecosystem processes such as species migrations, water flow, and disturbance patterns. A scale commonly used by county planners is land use/cover (grain) within a watershed (extent).

11.3.2 Patch Configuration

Patch size, shape, isolation, orientation, and spatial arrangement have significant influence on the distribution and flow of energy, species, and materials in a landscape. See Forman (1995) for an in-depth discussion of each attribute. For example, larger patches may have greater spatial heterogeneity (e.g., structural and environmental conditions) and support larger populations of species for longer periods of time than smaller patches (Arnold 1995). Similarly, smaller patches have greater edge to area ratios and subsequently greater edge effect than larger patches. Edge effect, which can be detrimental to interior dependent species, is the biophysical environment created at the interface between two patches. This edge effect creates edge habitat. In a forest patch, edge habitat is drier because of increased solar radiation and wind, has higher predation and parasitism rates, and may have greater biodiversity than interior habitat (Saunders et al. 1991). The width of edge habitat is species dependent. For example, for forest trees, edge habitat is about 30 m (Levenson 1981), but for some birds it may exceed 500 m (Wilcove et al. 1986), although 100 m seems to be an appropriate width (Temple 1986). Edge effect may be tempered by including a buffer between the core habitat needing protection and the actual edge. One concept used to minimize edge effect is a multiple-use module (MUM) (Harris 1984; Noss and Harris 1986) (Figure 11.2). The MUM contains a core of protected area, a zone of low utilization (e.g., recreation), and a zone of intense utilization (e.g., agriculture and development). These zones can be established through existing zoning regulations and ordinances at the town, county, and state level. In fact, zoning regulations and ordinances can be developed to minimize fragmentation and biodiversity degradation.

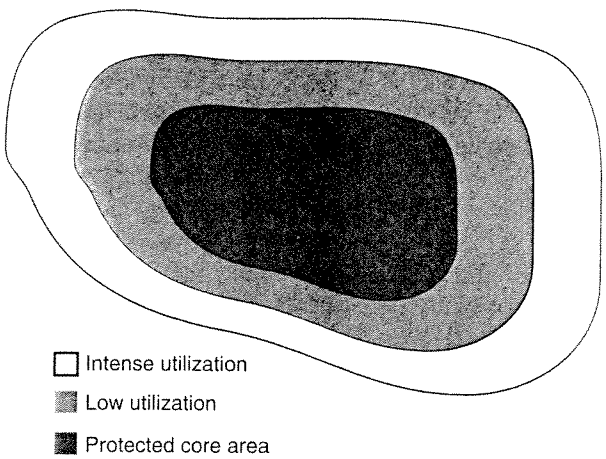

FIGURE 11.2 Graphic illustration of the core conservation area being protected by zones of low and intense utilization. (Adapted from Noss and Harris 1986.)

Forest interior habitat tends to be shadier, cooler, and moister, and possesses a greater density of mesic plant species than an edge habitat (Ranney et al. 1981). The amount of interior habitat depends on patch shape and size. A long, elongated patch may have no interior habitat or an insufficient amount of interior habitat to support interior species. By comparison, a patch of similar size but having a regular or circular shape may have an interior habitat if it is larger than 5 ha (Figure 11.3) (Levenson 1981). This does not mean that all protected patches need to be circles or squares. Elongated patches can connect patches aiding in the dispersal of species, and lobes and extensions from patches add to shape complexity and may influence the movement of organisms (Forman 1995).

Patch isolation significantly affects the movement and dispersal of organisms. Considerable discussion has focused on the functionality of corridors (e.g., Simberloff and Cox 1987; Beier and Noss 1998). Corridors need to be thought of as an element of connectivity rather than just linear habitats and designed to meet the needs of species being managed (Farina 2000). In general, habitat patches that are closer, linked, or occur in a hospitable landscape matrix allow species to disperse more freely among patches and support species for longer periods of time than patches that are distant from one another or occur in inhospitable landscapes (Arnold 1995). Likewise, large patches may be preferred habitats to conserve and protect, but smaller patches, distributed across the landscape, may serve as steppingstones across a hostile environment and improve connectivity among patches (Forman and Collinge 1996). For example, in urban landscapes, green spaces and belts often link patches of natural habitat. Forman and Collinge (1996) call these smaller patches outliers and support their uses in conservation plans (Figure 11.4).

11.3.3 Disturbance

Geomorphology and other abiotic conditions (e.g., climate, topography, soils, moisture availability), biotic interactions (e.g., competition, herbivory, predator–prey, exotic species), and natural and human disturbances create patches and alter their spatial arrangement on a landscape (Farina 2000; Turner et al. 2001). This section focuses only on attributes of natural and human disturbances. Natural disturbances include windstorms (e.g., hurricanes, tornadoes, thunderstorms), fire, floods, and insect and pathogen outbreaks. Examples of disturbance attributes include severity (intensity), magnitude (spatial — size and shape), frequency (number of events), and return interval (temporal) (Pickett and White 1985; Turner et al. 2001). Collectively, all disturbance types and their attributes describe the disturbance regime for a landscape (Pickett 1998). It is important to note that it is unknown at what time a particular spot will undergo a natural disturbance; however, what is known is that such events will occur at some point in time (Bormann and Likens 1979; Denslow

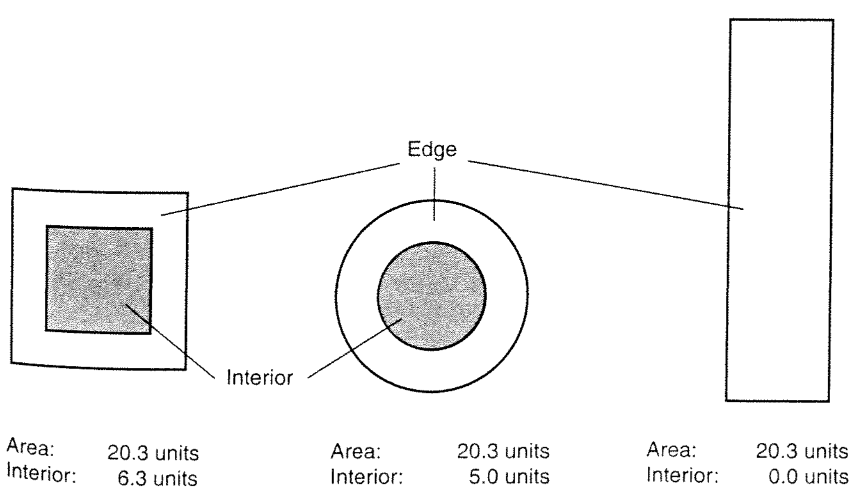

FIGURE 11.3 Illustration of the effect of different patch shape on interior habitat.

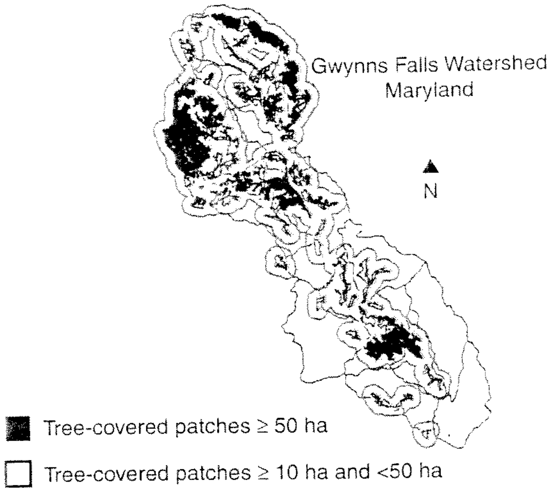

FIGURE 11.4 Distribution of tree-covered patches in an urbanizing watershed, illustrating the importance of including stepping-stones in landscape planning.

1980). Because disturbances will occur, managers and planners need to consider how development will affect the disturbance regime and how disturbances affect the development. For example, the coastal plain landscape contains fire-dependent ecosystems and is also a zone of rapid development. With development, fire suppression occurs to protect properties, but fuels still accumulate. Consequently, when a fire does occur, it is often a conflagration rather than a low-intensity surface fire characteristic of those ecosystems (see Chapter 13). Managers and planners need to account for fire by establishing prescribed burning regimes and proposing firewise landscaping and construction (Monroe 2002).

Natural disturbances create spatial heterogeneity, the landscape mosaic of patches, and changing the disturbance regime will alter this mosaic (Clark 1986; Pickett 1998). Humans alter disturbance regimes through their activities. Fires are suppressed, rivers are dammed, and streams are channelized. These actions directly and indirectly cause shifts in species composition of communities and alter the movement of energy, species, and matter through the system. With fire suppression, short-lived fire-dependent species are being replaced by long-lived mesic species. In addition, nutrient cycling is drastically altered (Stuart 1998). No longer is there a flush of nutrients after a fire. With fire suppression, nutrients reside in live vegetation and dead biomass over a longer period of time. When a fire does occur, its intensity may be so great that textural and chemical composition of soils can be altered. Organic matter burns to a greater depth, reducing the nutrient holding capacity of the soil; soils become hydrophobic (unable to absorb water); and nutrients are volatilized (Stuart 1998).

Because of their effect on ecosystems and humans and their property, large, infrequent disturbances are of particular concern to natural resource managers and land planners (Dale et al. 1998). Dale et al. (1998) identify three management options to plan for this type of disturbance: (1) manage the system prior to the disturbance; (2) manage the disturbance; and (3) manage the system after the disturbance. By managing the system prior to a disturbance, managers can minimize the effects of the disturbance on management goals. For example, reducing fuel load rather than suppressing fires diminishes the severity of the fire when it does occur. Managing a disturbance is often motivated by human desire to lessen effects on life and property (Dale et al. 1998). Such actions are often costly and may result in greater damage than if no management took place. Again, fire provides an excellent example. The disturbance is controlled with suppression, but control is only temporary. A conflagration can still occur, destroying personal property and altering ecosystem structure and function. Efforts to manage a site after a large, infrequent disturbance can also be problematic by creating undesirable plant communities, altering community development, and introducing nonnative species (Dale et al. 1998). An ecosystem and landscape approach to land-use planning enables managers and planners to identify, protect, and maintain viable populations of native species and native ecosystem types and their processes across their natural range of variability. So, when a disturbance occurs in a region, natural populations and processes are represented, thus available to begin a recovery cycle.

Urbanization is a disturbance. Urbanization, however, is different from natural disturbances. With urbanization, land features (e.g., streams and forests) become linear because of roads, ownership, and management practices. Urbanization creates patches that have more regular shapes, smaller sizes, and more diverse types. In addition, landscape changes are more permanent and natural processes (succession and nutrient cycling) are suppressed or altered. These differences alter landscape structure and function and subsequently change the distribution and flow of energy, species, and materials across a landscape.

11.4 TOMORROW'S LANDSCAPES TODAY

The wildland–urban interface is a zone of rapid transformation of natural habitat to urban land use. Urbanization directly and indirectly affects natural ecosystems (McDonnell et al. 1997). The most obvious direct effects are deforestation and fragmentation. Deforestation creates new forest edge, simplifies edges, decreases forest interior habitat, and increases patch isolation (Saunders et al. 1991; Zipperer 1993). Examples of indirect effects include urban heat island effect, soil hydrophobicity (White and McDonnell 1988), introductions of exotic species (Reichard and White 2001), air pollution (Lovett et al. 2000), and altered disturbance regime (Pickett 1998).

As managers, we must try to minimize urban effects on the natural ecosystems to sustain the goods and services provided by them (Christensen et al. 1996). In his book, *The Seven Habits of Highly Effective People*, Stephen Covey (1989) suggests that we "begin with the end in mind." As managers, we need not only think about how a landscape will be structurally and functionally changed after an area has been developed but also how to plan for future events. What should the future landscape look like with continual development? What features are important? What features can be lost? Although final decisions about the future landscape depend on land-use regulations and the goals and objectives of landowners, land managers can provide critical information to decision makers on how the landscape functions. By identifying critical elements of the landscape that contain significant structural and functional attributes before development occurs, the elements might be protected and environmental degradation minimized (Forman and Collinge 1997).

Some managers may state: "just tell me what to save." Unfortunately, there are no pat answers or solutions to conserving critical landscape elements. Each situation is unique. A number of concepts can be applied to each development scenario, but the final decision needs be made within the context of the landscape being developed and planning objectives. Harris (1984) proposes four critical landscape questions of patch importance that we can use to define tomorrow's landscapes:

1. What patches are strategically located with respect to the function and integrity of the overall landscape?
2. What patches make a specific contribution to biodiversity in terms of genetics, endemic species, greater species richness, or ecotypes?
3. What patches are more susceptible to development?
4. Does a patch and its linkages fit into the landscape pattern and processes?

An ecosystem approach to decision making enables a manager or a planner to answer these questions.

Hunter (1990) proposes a two-filter approach — a macro- or coarse-scale filter and a micro- or fine-scale filter — to answer the landscape questions and to begin defining tomorrow's landscape. At the broad-scale filter, the land manager assesses the patch configuration and ecological processes, and the context in which they occur. Fine-scale filters identify site differences from a physical, ecological, and cultural perspective (LaGro 2001).

11.4.1 Landscape Filters

At the coarse-scale level, we map out landscape structure and function. Current geographical information software (GIS) and other specialty software such as FRAGSTATS (McGarigal and Marks 1995) can aid in quantifying patches by their size, edge-to-area ratio, shape, interior habitat, and nearest neighbor of similar size or habitat. The coarse-scale filter also needs to include a temporal component to account for the seral stages of ecosystems and the effects of disturbances. Ephemeral patches need to be identified and mapped because they may provide critical habitat for some species (Smallidge and Leopold 1997). Although the application of a GIS would aid in the analyses, its use is not a prerequisite for the assessment. Assessments can be conducted, for example, on 7.5-min U.S. Geological Survey topographic maps or aerial photographs. What is important is to map patches composing the landscape mosaic (see Diaz and Apostol 1992) and the ecological processes — the movement of energy (e.g., food webs, water flowing downhill), organisms (e.g., seasonal and breeding migrations), and materials (e.g., hydrology, nutrient cycling, sediments). By doing so, we can begin to assess how development may remove significant patches and disrupt ecosystem processes. For example, within a watershed, important hydrologic sources (e.g., headwaters, seeps, springs, streams, aquifers), riparian habitats, and wetlands can be identified and mapped to evaluate how urbanization may alter the flow of water across and within the watershed.

Although patch importance is determined by management or planning objectives, importance links landscape structure, function, and change to achieve the goals of ecosystem management (Table 11.1). For example, variable source areas in water movement include significant locations such as riparian areas, headwaters, and seeps. Similarly, migration corridors for mammals, reptiles, and amphibians reflect landscape connectivity. The intersection of contrasting habitats indicates a unique habitat feature used by a variety of species. Each of these structural and functional attributes represents a set of structural and functional elements that need to be identified before landscape alterations occur.

Duerksen et al. (1997) identifies strategies for patch selection (Table 11.2). These strategies generally follow concepts for refuge design (Figure 11.5) (Simberloff 1997):

- Large patches will hold more species than a smaller patch.
- Assuming the patches are of the same habitat type, a large patch is preferable to several small patches.
- If only small patches are available, they should be clustered and preferably linked rather than linear or disconnected.
- Reduce the edge to interior ratio to minimize edge effect.

TABLE 11.2
Criteria and Principles to Select Significant Patches within a Landscape

1. Select and maintain large, intact patches of native vegetation, prevent fragmentation by development, and establish MUM to negate development along edges.
2. Establish priorities for protecting biodiversity and maintaining ecological processes in protected areas.
3. Protect not only threatened and endangered species but also rare landscape elements. Divert development toward "common" patches and landscape attributes.
4. Reduce patch isolation by maintaining connectivity through creating a hospitable landscape matrix, stepping-stones of habitat, and corridors.
5. Select patches to create riparian buffers around headwater streams, streams, and variable source areas.
6. Establish patch redundancy to protect from disturbances.
7. Maintain or reestablish disturbance regime.

Source: Adapted from Duerksen et al. (1997).

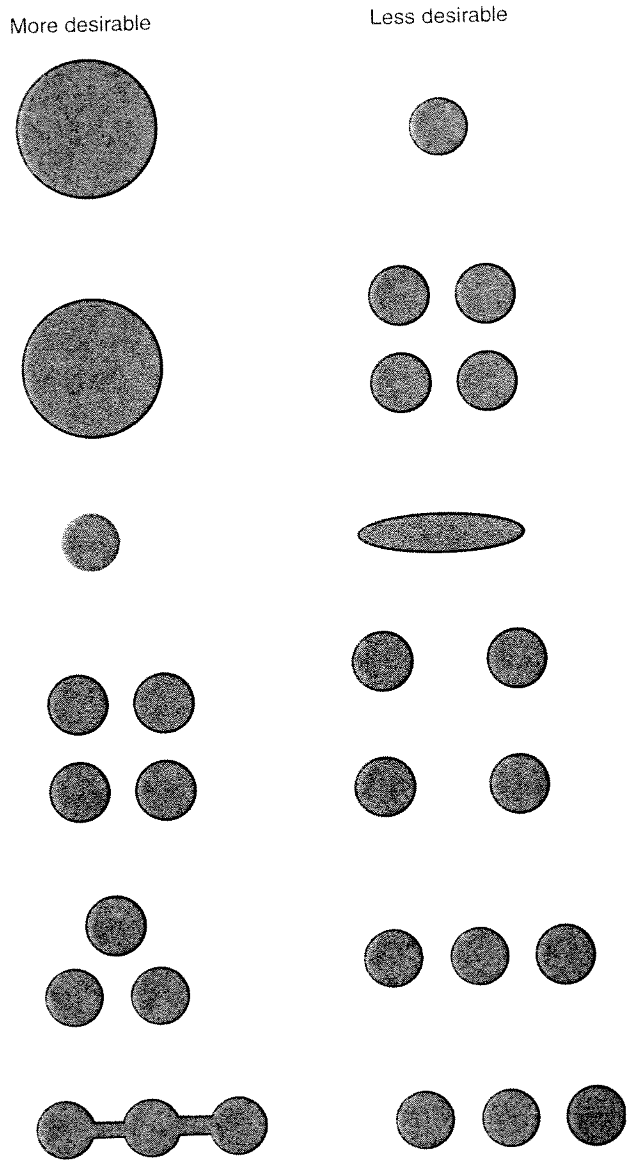

FIGURE 11.5 Desirable and less desirable patch configuration for refuge design. (From Simberloff (1997). With permission.)

These strategies have been successfully applied to land-use decisions in the Colorado Front Range to protect large, unfragmented patches of natural habitat, maintain native biodiversity and ecosystem structure and functions, and maintain connectivity (Duerksen et al. 1997).

How large is large when selecting patches? It depends on the objectives of the selection process, disturbance regime, and landscape context. For example, if an objective is to maintain or restore a viable population of a large predator, then significantly larger patches are needed than if the objective is to maintain forested habitat for carrion beetles. In general, larger animals need larger spaces to breed and survive than smaller animals (Holling 1992). Nevertheless, even if large mammals are absent from the regional fauna, the largest possible patches should be selected for conservation to minimize the loss of a species or community type to large, infrequent disturbances (Pickett and Thompson 1978). Selection should include not only the desirable patch type but also its seral stages (Harris 1984).

Context plays an important role in evaluating which patch to keep and which to develop. Context refers to where the patch occurs within the landscape and what surrounds the patch. In general, land managers will encounter some variation of three context types: forest, agricultural, and urban (Zipperer et al. 1990). Each context type differs in opportunities for conservation and protection of biodiversity and ecosystem processes. Forest context offers the greatest flexibility to identify significant patches. By comparison, options in agricultural and urban contexts may be limited and depend on the extent of previous patterns of deforestation and fragmentation. For example, large patches necessary to maintain large mammal species may not be available in urban and agricultural contexts. Context also influences patch importance. What may have been an unimportant patch in a forest context could be a significant patch in an urban or agricultural context because of the absence of other patch types. Within these deforested landscapes, patch occurrence can significantly affect its importance with respect to species presence and dispersal across a landscape (Andrén 1994).

Although larger patches are often favored over smaller patches with similar habitat value, both Forman and Collinge (1996) and Hunter (1990) argue for including smaller patches of natural habitats in the landscape design. In agricultural and urban contexts especially, smaller patches provide ecological benefits by protecting rare habitats and species outside the large patches; enhancing connectivity between large patches by providing "stepping-stones" for species movement; and enhancing heterogeneous conditions throughout the landscape (Forman and Collinge 1996).

Once the coarse-level assessment has been completed, patches can be prioritized by their attributes. For example, in a forest context, a score of 1 may be given to patches <50 ha, whereas a score of 5 may be given to patches >1000 ha. By comparison, a score of 1 may be given to patches <1 ha, and a score of 5 for patches >100 ha in an urban landscape. A similar scoring range can be developed for each of the other measured attributes, such as riparian habitat, headwater area, corridors, and unique spatial arrangements. Using a spreadsheet, we can sum, average, weight, or use the maximum value to identify and rank patches based on their structural and functional significance (see Duever and Noss 1990; White et al. 1997).

Once scoring has been completed for attributes deemed important at the coarse-scale level, a fine-scale-level assessment needs to be conducted to identify intrinsic differences among patches. LaGro (2001) identified important physical, ecological, and cultural attributes of site content (Table 11.3). Each of these categories can be expanded to meet objective needs. Duever and Noss (1990) provide an expanded list of ecological elements that can be used to answer the following questions: what patches make a specific contribution to biodiversity in terms of genetic, endemic species, greater species richness, or ecotypes, and what patches are more susceptible to development (Table 11.4)? From their list, Duever and Noss (1990) developed a scoring protocol to rank patches by their ecological importance. For example, for vulnerability to future development, they scored a patch as 1 if protection was guaranteed by deed restriction, easement, or established regulatory authority and as 5 if the patch was slated for development or had no significant regulatory protection. Using the scoring approach, Duever and Noss (1990) conducted "what if" scenarios to determine whether rankings would change under different land management decisions. The final resolution of the assessment depends on objectives and data availability.

11.4.2 Examples

The conservation of significant habitats is not new, but linking conservation strategies with land development decisions has only recently been acknowledged as an important step toward creating sustainable landscapes (Cohan and Lerner 2003). To illustrate the evaluation process, I will use two terrestrial examples — the Highlands Region of New York and New Jersey and Alachua County, FL.

TABLE 11.3
Examples of Physical, Ecological, and Cultural Attributes that May Be Included when Inventorying Site Content

Physical		
	Topography	
		Elevation
		Slope
		Aspect
	Geology	
		Serpentine
		Caves, ledges, escarpments
	Hydrology	
		Surface water
		Ground water
		Aquifer recharge
		Thermal springs
		Wetlands
	Hazards	
		Earthquakes
		Volcanos
		Landslides
	Soils	
		Permeability
		Erosion potential
		Textural/chemical composition
		Depth to water table
		Depth to bedrock
Ecological		
	Threatened and endangered species	
		Federal and state listings
	Unique community types	
	Significant wildlife habitat	
		Breeding/nesting, foraging
Cultural		
	Historic	
		Buildings, meeting locations, burial grounds, gardens
	Circulation/use and transportation	
		Roads, trails, paths
	Perceptual amenities	
		Viewsheds
	Human populations	
		Native
		Ethnic

Source: LaGro (2001).

The Highlands of New York–New Jersey (1.5 million acres) is part of a geomorphic province called the Reading Pong that stretches from northwest Connecticut to east-central Pennsylvania (Figure 11.6) (van Diver 1992). The Highlands, although only an hour from Manhattan, N Y, is renowned for its biological diversity, unique ecological communities, and significant cultural sites. In addition, over 11 million people use the water resources of the Highlands and more than 14 million individuals visit the region annually.

Human population growth threatens this region. Just in the past decade, human population levels increased by 11.5

TABLE 11.4
Possible Criteria Used to Rank the Importance of Patches within a Landscape

Vulnerability: How vulnerable is the patch to being developed? Is the patch protected through deeds and conservation easements; is it owned by individuals willing to develop; or does it occur on a good developable site? Is the patch vulnerable to the initiation of disturbances?

Rarity: Does the patch contain rare plants and animals? Is the patch a rare community type? Is the patch community listed by the state's Heritage Program?

Connectedness: Is the patch connected to other elements of the landscape? Is it isolated from large parcels of land; is it part of a natural corridor; or does it serve as a stepping-stone between two significant habitats?

Completeness: Does the patch represent ecological communities with a full complement of species? If species are missing, can neighboring sites be used as a source for colonizing individuals? How disturbed or degraded is the site? Is the patch large enough to contain different seral stages and representations from different types of disturbances?

Manageability: Manageability can be viewed from two perspectives: management for products and management to maintain the ecological integrity of the site. If the patch is degraded, can it be restored? Are sites too small to restore a complement of species and natural processes?

Nature-oriented human use potential: Is the patch suitable for passive recreation? Is it accessible for recreational use, or is it aesthetically pleasing?

Source: Duever and Noss (1990).

percent to 1.4 million individuals. In October 2000, Congress authorized a study of urbanization effects on the region. One of four goals of the regional study was to identify significant areas to conserve and protect (Phelps and Hoppe 2002). To accomplish this objective, criteria were selected and importance weighted for each of the five critical resources (Table 11.5). One criterion for water resources was the presence of an aquifer (coarse filter) and weights were given based on the type of aquifer (fine filter) (Hatfield et al. 2003). Data were mapped to a 30 m grid and each grid cell was assigned a value from 1 to 5 for each criterion of a resource. To create the final resource map that depicted critical areas, the authors assigned a cell's value based on the maximum value of a criterion used to evaluate that resource. For example, to evaluate biological conservation, individual criteria could be scored as 2 for critical animal habitat, 3 for critical plant habitat, and 2 for significant vegetation community. The cell's final value for biological

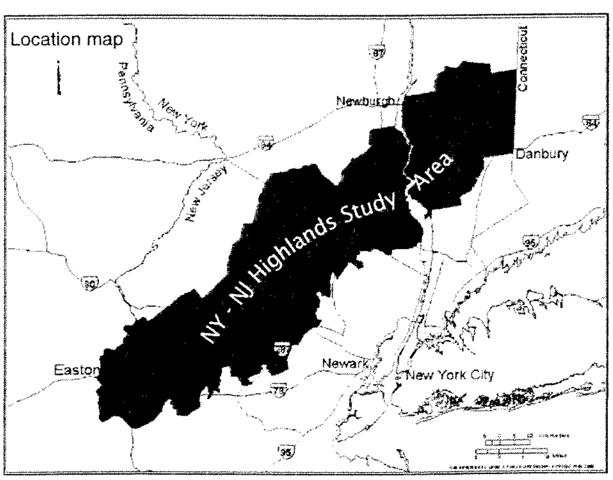

FIGURE 11.6 Location of the Highlands Regional Study in New York and New Jersey.

conservation would be 3. This approach enabled the authors to evaluate resources individually and collectively as well as regional and local patterns.

Like the Highlands Region, Alachua County, FL, has rapidly increased in population. During the past decade, Alachua County's human population grew by 20 percent to more than 218,000 individuals. Also, like the Highlands Region, Alachua County has a number of unique geological and ecological sites. Recognizing the ecological and social importance of conserving or protecting these sites, county planners, commissioners, and environmentalists created a program in 2000 called Alachua County Forever. With voter-approved funds, the program purchases unique properties or their development rights. Each recommended parcel of land is evaluated, scored, and prioritized based on six categories (coarse filters) and 26 criteria (fine filters) (Table 11.6). Each criterion is scored from 1 to 5, with 1 being the least beneficial and 5 being the most beneficial. For the environmental and human categories, scores are averaged and multiplied by a weight of 1.3333. The acquisition and management categories are also averaged and weighted by a factor of 0.6667. By June 2003, 158,669 acres had been identified as significant and over 65,000 acres of land had been purchased.

Landscape assessments often focus on ecological and physical components of an ecosystem to maintain ecological integrity. In working landscapes, social and cultural components also play an important role in defining integrity (LaGro 2001). In both examples, social and cultural attributes were assessed. In the Highlands study, the assessment evaluated two cultural resources: farmland and recreation. The recreation critical element included viewsheds and cultural and historical sites. In the Alachua County Forever assessment, economic and management factors were evaluated.

Obviously, a significant amount of information is needed to assess current and future development propos-

TABLE 11.5
Resources, Criteria, and Rationale Used to Identify Areas for Conservation and Protection in the New York–New Jersey Highlands Region

Resource/Criteria	Rationale
Water	
Aquifer	Provides groundwater for drinking water supply wells
Wellhead protection zone	Immediate source of groundwater for public water supply
Riparian zones including streams with 150-ft buffer	Buffers surface water systems from nonpoint pollution, overland runoff, and soil erosion
Headwater streams	Sources for surface waters, sensitive to pollution
Steep slopes: > 15%	Soil erosion source
Wetlands	Surface waters important to flood and pollution control
Biological Conservation	
Critical animal habitat	Habitat important for wildlife populations, including threatened and endangered species
Critical plant habitat	Habitat important for plant populations, including threatened and endangered species
Significant natural vegetation communities	Intact and rare communities of native vegetation
Recreation and Open Space	
Trails with buffers	Access for humans to experience nature
Scenic viewsheds	Accessible viewpoints to enjoy scenic beauty
Visible ridgetops	Accessible viewpoints to enjoy scenic beauty from valley roadways
Existing parks	Public investment
Historical, cultural, and recreational resource areas with 150-ft buffer	Significant historical or cultural resource
Recreational waters and shoreline	Major recreational areas
Farmland	
Cultivated lands	Active agriculture
Preserved farmlands	Public investment
Forest Resources	
Forest stewardship lands	Active forest management
Contiguous forest tracts	Forest management efficiency

Source: Hatfield et al. (2003).

als within a landscape. Information technology provides access to a variety of databases containing information on flora and fauna distribution, movement of species, and disturbance regimes in a region (see Cooperrider et al. 1999 for data sources). Further information can be gathered from discussions with local residents and other land managers. The assessment cannot be done overnight. It requires time to conduct appropriate assessment, interpret the information, and build political support for the evaluation. However, once the time has been invested, maps can be periodically updated to reflect current landscape structure, evaluate any proposed human activities on the landscape, and reassess patch importance. Without the assessment, evaluations are only guesses with anecdotal information.

11.5 CONCLUSION

Ecological assessment provides the manager with information on characteristics that are needed to maintain the physical, ecological, and social processes required for healthy ecosystems and for delivering ecosystem goods and services (Kaufmann et al. 1994). Landscapes are composed of a mosaic of patch types and ownership types. Land-use decisions are based on ownership. Ecological decisions are based on patch types and the movement of energy, organisms, and materials in the landscapes. Ecosystem management provides the avenue to link ecological and land-use decisions and assesses how development will alter the landscape. Returning to Harris's four questions, the proposed assessment provides a means to identify strategically important patches with respect to the landscape function, patches significantly contributing to biodiversity, patches susceptible to development, and a patch's importance to the overall landscape. So, when a request for site development needs to be evaluated, the manager can provide scientific-based information on potential benefits and costs of the proposed action, and use the information to propose alternatives.

TABLE 11.6
Categories and Criteria Used by the Alachua County (FL) Forever Program to Evaluate Unique Ecological and Geological Sites

Category	Criterion
Protection of water resource	Whether the property has geologic/hydrologic conditions that would easily enable contamination of vulnerable aquifers that have value as drinking water sources Whether the property serves an important groundwater recharge function Whether the property contains or has direct connections to lakes, creeks, rivers, springs, sinkholes, or wetlands for which conservation of the property will protect or improve surface water quality Whether the property serves an important flood management function
Protection of natural communities and landscapes	Whether the property contains a diversity of natural communities Whether the natural communities present on the property are rare Whether there is ecological quality in the communities present on the property Whether the property is functionally connected to other natural communities Whether the property is adjacent to properties that are in public ownership or have other environmental protections such as conservation easements Whether the property is large enough to contribute substantially to conservation efforts Whether the property contains important, Florida-specific geologic features such as caves or springs Whether the property is relatively free from internal fragmentation from roads, power lines, and other features that create barriers and edge effects
Protection of plant and animal species	Whether the property serves as documented or potential habitat for rare, threatened, or endangered species or species of special concern Whether the property serves as documented or potential habitat for species with a large home range Whether the property contains plants or animals that are endemic or near-endemic to Florida or Alachua County Whether the property serves as a special wildlife migration or aggregation site for activities such as breeding, roosting, colonial nesting, or over-wintering Whether the property offers high vegetation quality and species diversity Whether the property has a low incidence of nonnative invasive species
Social and human values	Whether the property offers opportunities for compatible resource-based recreation, if appropriate Whether the property contributes to urban green space, provides a municipal defining greenbelt, provides scenic vistas, or has other value from an urban and regional planning perspective Average for environmental and human values
Management issues	Whether it will be practical to manage the property to protect its environmental, social, and other values (examples include controlled burning, exotic removal, maintaining hydroperiod, etc.) Whether this management can be completed in a cost-effective manner
Economic and acquisition issues	Whether there is potential for purchasing the property with matching funds from municipal, state, federal, or private contributions Whether the overall resource value justifies the potential cost of acquisition Whether there is imminent threat of losing the environmental, social, or other values of the property through development and/or lack of sufficient legislative protections (this requires analysis of current land use, zoning, owner intent, location) Whether there is an opportunity to protect the environmental, social, or other values of the property through an economically attractive less-than-fee mechanism, such as a conservation easement Average for acquisition and management values

Source: Alachua County Environmental Protection Department (2003).

REFERENCES

Alachua County Environmental Protection Department, 2003. Land conservation, http://environment.Alachua-county.org/Land_Conservation/. [Date accessed: December 2003.]

Andrén, H., 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review, *Oikos* 71: 355–366.

Arnold, G.W., 1995. Incorporating landscape pattern into conservation programs, in *Mosaic Landscapes and Ecological Processes,* L. Hansson, L. Fahrig, and G. Merriam, Eds., Chapman & Hall, London, pp. 309–337.

Beier, P. and R.F. Noss, 1998. Do habitat corridors provide connectivity? *Conservation Biology* 12: 1242–1252.

Bormann, F.H. and G.E. Likens, 1979. Catastrophic disturbance and the steady-state in northern hardwood forests, *American Scientist* 67: 660–669.

Botkin, D.B., 1990. *Discordant Harmonies: A New Ecology for the Twenty-First Century,* Oxford University Press, New York.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C.D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parson, C.H. Peterson, M.G. Turner, and R.G. Woodmansee, 1996. The report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management, *Ecological Applications* 6: 665–691.

Clark, J.S., 1986. Coastal forest tree populations in a changing environment, southeastern Long Island, New York, *Ecological Monographs* 56: 259–277.

Cohan, J.P. and J.A. Lerner, 2003. *Integrating Land Use Planning and Biodiversity,* Defenders of Wildlife, Washington, DC.

Cooperrider, A.Y., L. Fox, III, L.R. Garrett, and N.T. Hobbs, 1999. Data collection, management, and inventory, in *Ecological Stewardship: A Common Reference for Ecosystem Management,* Vol. III, W.T. Sexton, A.J. Malk, R.C. Szaro, and N. C. Johnson, Eds., Elsevier Science, Oxford, U.K., pp. 603–627.

Covey, S.R., 1989. *The 7 Habits of Highly Effective People: Restoring the Character Ethic,* Simon and Schuster, New York.

Dale, V.H., S. Brown, A. Haeuber, N.T. Hobbs, N. Huntly, R.J. Naiman, W.E. Riebsame, M.G. Turner, and T.J. Valone, 2000. Ecological principles and guidelines for managing the use of land, *Ecological Applications* 10: 639–670.

Dale, V.H., A.E. Lugo, J.A. MacMahon, and S.T.A. Pickett, 1998. Ecosystem management in context of large, infrequent disturbances, *Ecosystems* 1: 546–557.

Denslow, J.S., 1980. Patterns of plant species diversity during succession under different disturbance regimes, *Oecologia* 46: 18–21.

Diaz, N. and D. Apostol, 1992. Forest Landscape Analysis and Design, R6-ECO-TP-043-92, U.S. Department of Agriculture, Forest Service, Seattle.

Duerksen, C.J., D.L. Elliott, N.T. Hobbs, E. Johnson, and J.R. Miller, 1997. Habitat Planning: Where the Wild Things Are, PAS 470/471, American Planning Association, Chicago.

Duever, L.C. and R.F. Noss, 1990. A computerized method of priority ranking for natural areas, in *Ecosystem Management: Rare Species and Significant Habitats,* R. S. Mitchell, C. J. Sheviak, and D. J. Leopold, Eds., New York State Museum, Albany, pp. 22–33.

Farina, A., 2000. *Landscape Ecology in Action,* Kluwer Academic Publishers, Dordrecht, Netherlands.

Foresman, T.W., S.T.A. Pickett, and W.C. Zipperer, 1997. Methods for spatial and temporal land use and land cover assessment for urban ecosystems in the greater Baltimore-Chesapeake Region, *Urban Ecosystems* 1: 201–216.

Forman, R.T.T., 1995. *Land Mosaics,* Cambridge University Press, New York.

Forman, R.T.T. and S.K. Collinge, 1996. The 'spatial solution' to conserving biodiversity in landscapes and regions, in *Conservation of Faunal Diversity in Forested Landscapes,* R.M. DeGraaf and R.I. Miller, Eds., Chapman & Hall, New York, pp. 537–568.

Forman, R.T.T. and S.K. Collinge, 1997. Nature conserved in changing landscapes with and without spatial planning, *Landscape and Urban Planning* 37: 129–135.

Forman, R.T.T. and M. Godron, 1986. *Landscape Ecology,* John Wiley, New York.

Grumbine, R.E., 1994. What is ecosystem management, *Conservation Biology* 8: 27–38.

Harris, L.D., 1984. *The Fragmented Forest,* University of Chicago Press, Chicago.

Hatfield, C.,R. Lathrop, and D. Tulloch, 2003. Land Resources, in New York–New Jersey Highlands Regional Technical Report, M.C. Hoppe, Ed., U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA, pp. 45–219.

Holling, C.S., 1992. Cross-scale morphology, geometry and dynamics of ecosystems, *Ecological Monographs* 62: 447–502.

Hunter, M.L., Jr., 1990. *Wildlife, Forests, and Forestry,* Prentice-Hall, Englewood Cliffs, NJ.

Kaufmann, M.R., R.T. Graham, D.A. Boyce, Jr., W.H. Moir, L. Perry, R.T. Reynolds, R.L. Bassett, P. Mehlhop, C. B. Edminster, W.M. Block, and P.S. Corn, 1994. An Ecological Basis for Ecosystem Management, General Technical Report RM-246, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

LaGro, J.A., Jr., 2001. *Site Analyses: Linking Program and Concept in Land Planning and Design,* John Wiley and Sons, New York.

Levenson, J.B., 1981. Woodlots as biogeographic islands in Southeastern Wisconsin, in *Forest Island Dynamics in Man-Dominated Landscapes,* R.L. Burgess and D.M. Sharpe, Eds., Springer-Verlag, New York, pp. 1340.

Likens, G.E., 1992. *The Ecosystem Approach: Its Use and Abuse,* Ecology Institute, Olendor/Luhe, Germany.

Lovett, G.M., M.M. Traynor, R.V. Pouyat, W. Zhu, and J.W. Baxter, 2000. Atmospheric deposition to oak forests along an urban-rural gradient, *Environmental Science and Technology* 34: 4294–4300.

Macie, E.A. and L.A. Hermansen, Eds., 2002. Human Influences on Forest Ecosystems: The Southern Wildland–Urban Interface Assessment, General Technical Report SRS-55, U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC.

McCormick, F.J., 1998. Principles of ecosystem management and sustainable development, in *Ecosystem Management for Sustainability*, J. D. Peine, Ed., Lewis Publishers, New York, pp. 3–22.

McDonnell, M.J., S.T.A. Pickett, P. Groffman, P. Bohlen, R.V. Pouyat, W.C. Zipperer, R.W. Parmelee, and K. Medley, 1997. Ecosystem processes along an urban-to-rural gradient, *Urban Ecosystems* 1: 21–36.

McGarigal, K. and B.J. Marks, 1995. FRAGSTATS. Spatial Analysis Program for Quantifying Landscape Structure, General Technical Report PNW-GTR-351, U.S. Department of Agriculture, Forest Service, Portland, OR.

Monroe, M.C., 2002. Fire, in Human Influences on Forest Ecosystems: The Southern Wildland–Urban Interface Assessment, E. A. Macie and L.A. Hermansen, Eds., General Technical Report SRS-55, U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC, pp. 133–150.

Noss, R.F. and L.D. Harris, 1986. Nodes, networks, and MUM's: preserving diversity at all scales, *Environmental Management* 10: 299–309.

Overbay, J.C., Ed., 1992. Ecosystem management, Speech delivered at the National Workshop on Taking an Ecological Approach to Management, Salt Lake City, UT, U.S. Department of Agriculture, Forest Service, Washington, DC.

Phelps, M.G. and M.C. Hoppe, 2002. New York–New Jersey Highlands Regional Study, NA-TP-02-03, U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA.

Pickett, S.T.A., 1998. Natural processes, in *Status and Trends of the Nation's Biological Resources*, Vol. 1, M.J. Mac, P.A. Opler, C.E.P. Haecker, and P.D. Doran, Eds., U.S. Geological Survey, Washington, DC., pp. 11–35.

Pickett, S.T.A., M.L. Cadenasso, J.M. Grove, C.H. Nilon, P.V. Pouyat, W.C. Zipperer, and R. Costanza, 2001. Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas, *Annual Review of Ecology and Systematics* 32: 127–157.

Pickett, S.T.A., W.R. Burch, Jr., S.E. Dalton, T.W. Foresman, J.M. Grove, and R.A. Rowntree, 1997. A conceptual framework for the study of human ecosystems in urban areas, *Urban Ecosystems* 1: 185–201.

Pickett, S.T.A. and J.N. Thompson, 1978. Patch dynamics and the design of nature reserves, *Biological Conservation* 13: 27–37.

Pickett, S.T.A. and P.S. White, Eds., 1985. *The Ecology of Natural Disturbance and Patch Dynamics*, Academic Press, New York.

Ranney, J.W., M.C. Bruner, and J.B. Levenson, 1981. The importance of edge in the structure and dynamics of forest islands, in *Forest Island Dynamics in Man-dominated Landscapes*, R.L. Burgess and D.M. Sharpe, Eds., Springer-Verlag, New York, pp. 67–96.

Reichard, S.H. and P.S. White, 2001. Horticulture as a pathway of invasive plant introductions in the U.S., *Bioscience* 51: 103–113.

Saunders, D.A., R.J. Hobbs, and C.R. Margules, 1991. Biological consequences of ecosystem fragmentation: a review, *Conservation Biology* 5: 18–32.

Simberloff, D., 1997. Biogeographic approaches and the new conservation biology, in *The Ecological Basis of Conservation*, S.T. A. Pickett, R.S. Ostfeld, M. Shachak, and G.E. Likens, Eds., Chapman & Hall, New York, pp. 274–284.

Simberloff, D. and J. Cox, 1987. Consequences and costs of conservation corridors, *Conservation Biology* 1: 63–71.

Smallidge, P. J. and D.J. Leopold, 1997. Vegetation management for the maintenance and conservation of butterfly habitats in temperate human-dominated landscapes, *Landscape and Urban Planning* 38: 259–280.

Stuart, J.D., 1998. Effect of fire suppression on ecosystems and diversity, in *Status and Trends of the Nation's Biological Resources*, Vol. 1, J.M. Mac, P.A. Opler, C.E.P. Haecker, and P.D. Doran, Eds., U.S. Geological Survey, Washington, pp. 45–47.

Temple, S.A., 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models, in *Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates*, J. Verner, M.L. Morrison, and C.J. Ralph, Eds., University of Wisconsin Press, Madison, pp. 301–304.

Turner, M.G., 1989. Landscape ecology: the effect of pattern on process, *Annual Review of Ecology and Systematics* 20: 171–197.

Turner, M.G., R.H. Gardner, and R.V. O'Neill, 2001. *Landscape Ecology in Theory and Practice*, Springer-Verlag, New York.

van Diver, B.B., 1992. *Roadside Geology of New York*, Mountain Press Publishing Company, Missoula, MT.

White, C.S. and M.J. McDonnell, 1988. Nitrogen cycling processes and soil characteristics in an urban versus rural forest, *Biogeochemistry* 5: 243–262.

White, D., P.G. Minotti, M.J. Barczak, J.C. Sifneos, K.E. Freemark, C.F. Satelmann, A.R. Kiester, and E.M. Preston, 1997. Assessing the risks to biodiversity from future landscape change, *Conservation Biology* 11: 349–360.

Wilcove, D.S., C.H. McLellan, and A.P. Dobson, 1986. Habitat fragmentation in the temperate zone, in *Conservation Biology: The Science of Scarcity and Diversity*, M.E. Soulé, Ed., Sinauer Association, Sunderland, MA., pp. 237–256.

Yaffee, S.L., A.F. Phillips, I.C. Frentz, P.W. Hardy, S.M. Maleki, and B.E. Thorpe, 1996. *Ecosystem Management in the U.S.: Assessment of Current Experience*, Island Press, Washington, DC.

Zipperer, W.C., 1993. Deforestation patterns and their effects on forest patches, *Landscape Ecology* 8: 177–184.

Zipperer, W.C., R.L. Burgess, and R.D. Nyland, 1990. Patterns of deforestation and reforestation in different landscape types in central New York, *Forest Ecology and Management* 36: 103–117.