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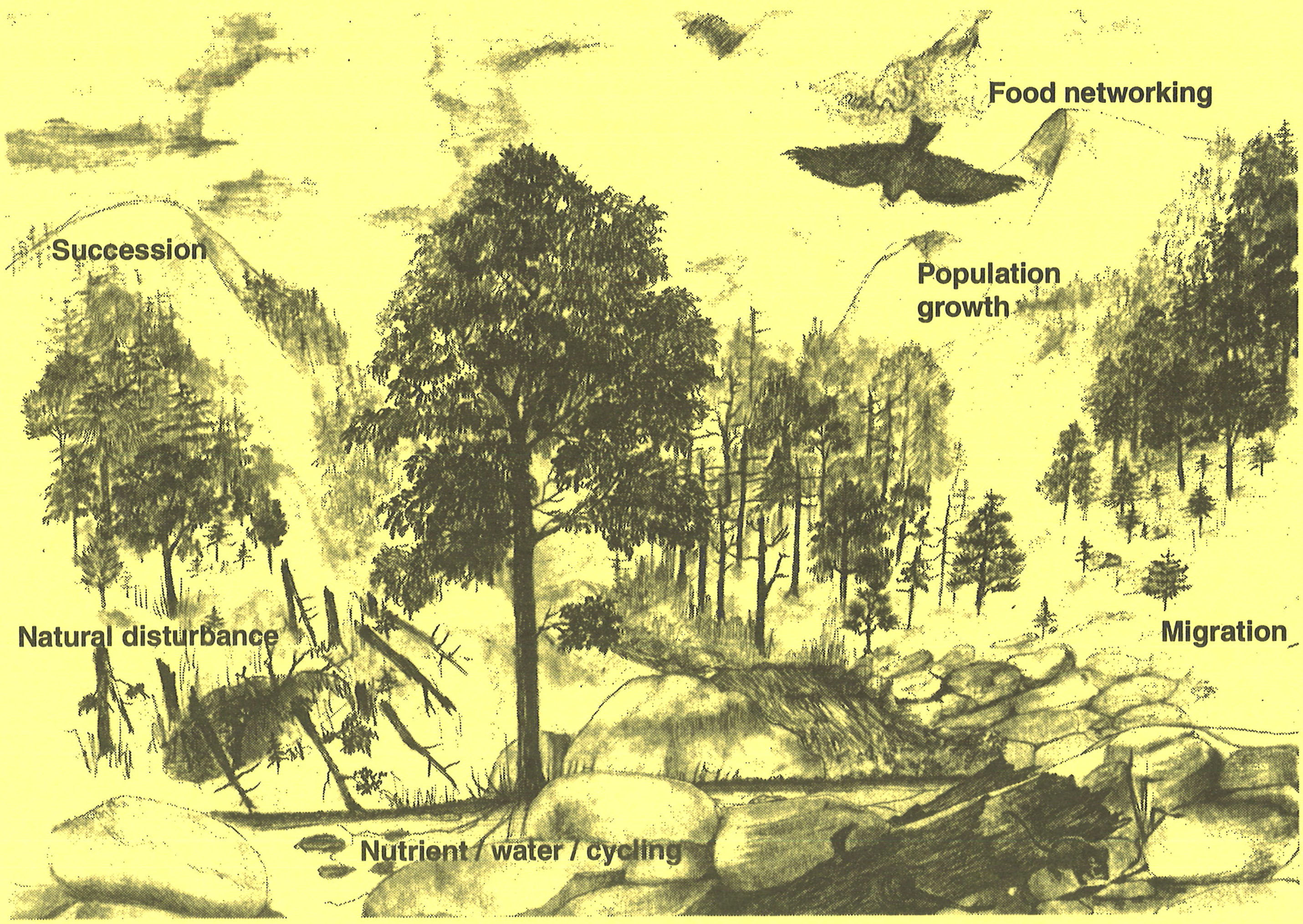
Applied Ecosystem Management on Nonindustrial Forest Land

William B. Leak
Mariko Yamasaki
David B. Kittredge, Jr.
Neil I. Lamson
Marie-Louise Smith



Abstract

Defines ecosystem management, discusses the terminology and attributes related to this broad approach to forest management and protection, and lists specific steps for applying ecosystem management on a typical nonindustrial private ownership in the Northeast.

The Authors

WILLIAM B. LEAK (silviculture), MARIKO YAMASAKI (wildlife biology), AND MARIE-LOUISE SMITH (ecology) are with the Northeastern Forest Experiment Station's Forestry Sciences Laboratory at Durham, New Hampshire.

DAVID B. KITTREDGE, JR. (forest management) is an extension forester with the Department of Forestry and Wildlife Management, University of Massachusetts, Amherst.

NEIL I. LAMSON (silviculture and management) is with the Northeastern Area, State and Private Forestry at Durham, New Hampshire.

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Introduction

The term "ecosystem management" causes a certain amount of concern, puzzlement, and even resentment among both public and private forest managers and owners. Some view ecosystem management as a term for practices that are hardly new, others believe it represents a preservationist view of forest management, and still others readily admit they do not know how ecosystem management should be defined.

In this report we define ecosystem management, discuss the terminology and attributes related to this broad approach to forest management, and list specific steps for applying ecosystem management on a typical nonindustrial private ownership in the Northeast.

What is Ecosystem Management?

We define ecosystem management as a broad approach to forest management and protection that provides for and considers an array of resource values, plant and animal species, and natural processes at both the landscape and property or landowner level. It is difficult to manage an ecosystem, particularly when it comprises many individual ownerships. As a result, it probably is appropriate to consider an ecosystem-based approach to management, that is, a sensitivity to the interactions among adjacent properties and the maintenance of important values, species populations, and processes over time.

Because ecosystems are not restricted to property boundaries, ecosystem management must consider the relationships between one property and another. It provides additional information that enables forest-land owners to meet specific objectives for their property while ensuring that the many benefits available from their ownership are available to future generations.

Is this necessary cooperation among neighboring landowners possible? In the past, foresters and owners attempted to initiate landowner cooperatives to harvest and market wood products. Yet few of these cooperatives have been successful, probably because the wood had little value or its quality was so uneven that it was difficult to determine how to distribute the returns from management. An ecosystem-based approach to woodlot management adds other forest benefits to the list of reasons why landowners should consider cooperation. Coincidentally, these additional benefits, for example, wildlife habitat and recreation, are the ones in which landowners express great interest.

In the past, we have asked landowners or forest managers to look inside their property boundaries when defining goals and making decisions. Ecosystem management asks people to stand on their property line and look out into surrounding stands because ecosystem functions and processes (e.g., nutrient cycling, wildlife habitat, water flow) are not limited by boundary markers. Such an approach allows one to view his or her property within the context of the broader landscape. Landowners who become aware of ecosystem features beyond their own property will be able to make more informed management decisions.

Another way to understand the concept of an ecosystem-based approach to management is to compare it with the traditional practice of managing for multiple uses. Although the latter approach is followed by most practicing foresters, much has changed during the last several decades. For example, the fields of conservation biology and landscape ecology are only 15 to 20 years old, and computer mapping, satellite imagery, and global positioning systems are relatively recent tools that enable today's foresters and scientists to think on an ecosystem and/or landscape level.

In recent years we also have learned a great deal about the response of ecosystems to disturbances as well as ecosystem functions such as nutrient cycling and the requirements of wildlife, including those of rare species, at the landscape level. And new administrative tools are available to maintain forest land. Examples include use-value taxation and the purchase and/or donation of development rights.

The principles of ecosystem management and the traditional multiple-use approach to forest management are contrasted in the following table (derived from SAF 1993):

Multiple-use	Ecosystem management
Goal/objective	
Sustained flow of specific products or ***outputs*** to meet human needs	Maintains ecological ***conditions*** within a forest, while meeting human needs
Implementation	
Follows agricultural model of organization	Reflects patterns of natural disturbance
Emphasis	
Production efficiency within environmental constraints	Retains complexity and processes
Unit of management	
Stands and ***aggregations of stands within an ownership***	***Ecosystems*** and landscapes ***across ownerships***
Time unit	
Multi-rotations with rotation length determined by landowner objectives	Multi-rotations with length reflecting natural disturbance, intensive management will cause some to be shorter

But is the ecosystem-based approach really new? In fact, this concept incorporates many of the principles proposed by Aldo Leopold during the 1940's. The following excerpt from an essay he wrote in 1947 reflects a decidedly ecosystem-based approach to forest management:

> I have a farm in one of the sand-counties of central Wisconsin. I bought it because I wanted a place to plant pines. One reason for selecting my particular

farm was that it adjoined the only remaining stand of mature pines in the County.

This pine grove is an historical landmark. It is the spot [or very near the spot] where, in 1828, a young Lieutenant named Jefferson Davis cut the pine logs to build Fort Winnebago. He floated them down the Wisconsin River to the fort. In the ensuing century a thousand other rafts of pine logs floated past this grove to build that empire of red barns now called the Middle West.

This grove is also an ecological landmark. It is the nearest spot where a city-worn refugee from the south can hear the wind sing in tall timber. It harbors one of the best remnants of deer, ruffed grouse, and pileated woodpeckers in southern Wisconsin.

My neighbor, who owns the grove, has treated it rather decently through the years. When his son got married, the grove furnished lumber for the new house, and it could spare such light cuttings. But when war prices of lumber soared skyward, the temptation to slash became too strong. Today the grove lies prostrate, and its long logs are feeding a hungry saw.

By all the accepted rules of forestry, my neighbor was justified in slashing the grove. The stand was even-aged; mature, and invaded by heart-rot. Yet any schoolboy would know, in his heart, that there is something wrong about erasing the last remnant of pine timber from a county. When a farmer owns a rarity he should feel some obligation as its custodian, and a community should feel some obligation to help him carry the economic cost of custodianship. Yet our present land-use conscience is silent on such questions.

With regard to woodlots across New England, there probably are two major differences in the way forestry has been practiced on woodlots for decades and the way it would be applied using an ecosystem-based approach. First, rather than dwelling on the forest within the stone walls of a particular ownership, we would be more sensitive to the ecosystem in which the property resides, that is, we would be concerned about the effect of our management activities on the ecosystem beyond the woodlot's boundaries [e.g., is this the last stand of pine in the county?]. Foresters routinely look beyond property boundaries when considering water quality. For example, if it is determined that harvesting activities would adversely affect water quality downstream (and off the property), they implement Best Management Practices to minimize erosion and sedimentation. An ecosystem-based approach simply asks the forest manager to also consider functions and conditions in addition to water resources.

Second, we also would be more sensitive to the "cogs and wheels" of the ecosystem that Aldo Leopold advised us not to discard in our "intelligent tinkering." For example, do rare species of wildlife use the property? Does it contain rare plant communities or associations? Can we modify management to protect these resources?

It should be emphasized that the recent emergence of ecosystem management does not negate the previous work of forest managers. Indeed, operating with the best available information through the years, the forestry profession can point to numerous successes in meeting societal needs as well as landowner goals. For example, at one time, foresters in New England girdled yellow birch to favor spruce pulpwood, and oak to favor pine. They made the right decisions at the time, but advances in forest research have placed those decisions in a different light. An ecosystem-based approach to management simply integrates the latest information into the practice of forestry.

Why Practice Ecosystem Management?

We believe that following some of the principles outlined in this publication will enhance forest productivity with respect to timber harvests, fish and wildlife habitat, botanical/zoological variety, and recreational/aesthetic benefits while minimizing impacts from forest insects and diseases, wind and fire, and market changes. These values gradually will accrue to the managed property and adjacent ownerships and will be maintained over time. In addition, we have an obligation to ensure that America's forests are improved and protected for future generations. Those who use and enjoy forest land need to respect the forest and the rights of those who own it. Forest-land owners have the right to make decisions about management activities that best meet their goals. However, we believe that with ownership comes an obligation to care for one's land for future generations.

What is an Ecosystem?

The term "ecosystem" refers to a somewhat self-enclosed or independent system. Such systems can range from an aquarium to the Earth itself. A small forest property does not function well as an ecosystem because it interacts closely with surrounding properties relative to wildlife, water, aesthetics, seed/pollen exchange, human use, etc. To effectively manage a small property from an ecosystem standpoint, we need to consider relationships with adjacent holdings that might comprise hundreds of acres. A watershed or subwatershed that encompasses a property provides logical boundaries, particularly since watersheds maintain some degree of independence from each other. One rule of thumb (DeGraaf et al. 1992) is that a defined ecosystem can be up to about 10 times larger than the managed property for ownerships as large as 250 acres. Although ecosystems sometimes are equated with vegetative communities, a broader definition seems appropriate for the many small and often interdependent communities typical of New England and many other regions of the country.

In addition to its boundaries, an ecosystem is described and analyzed with respect to physical attributes, biological attributes, natural processes, and conceptual attributes.

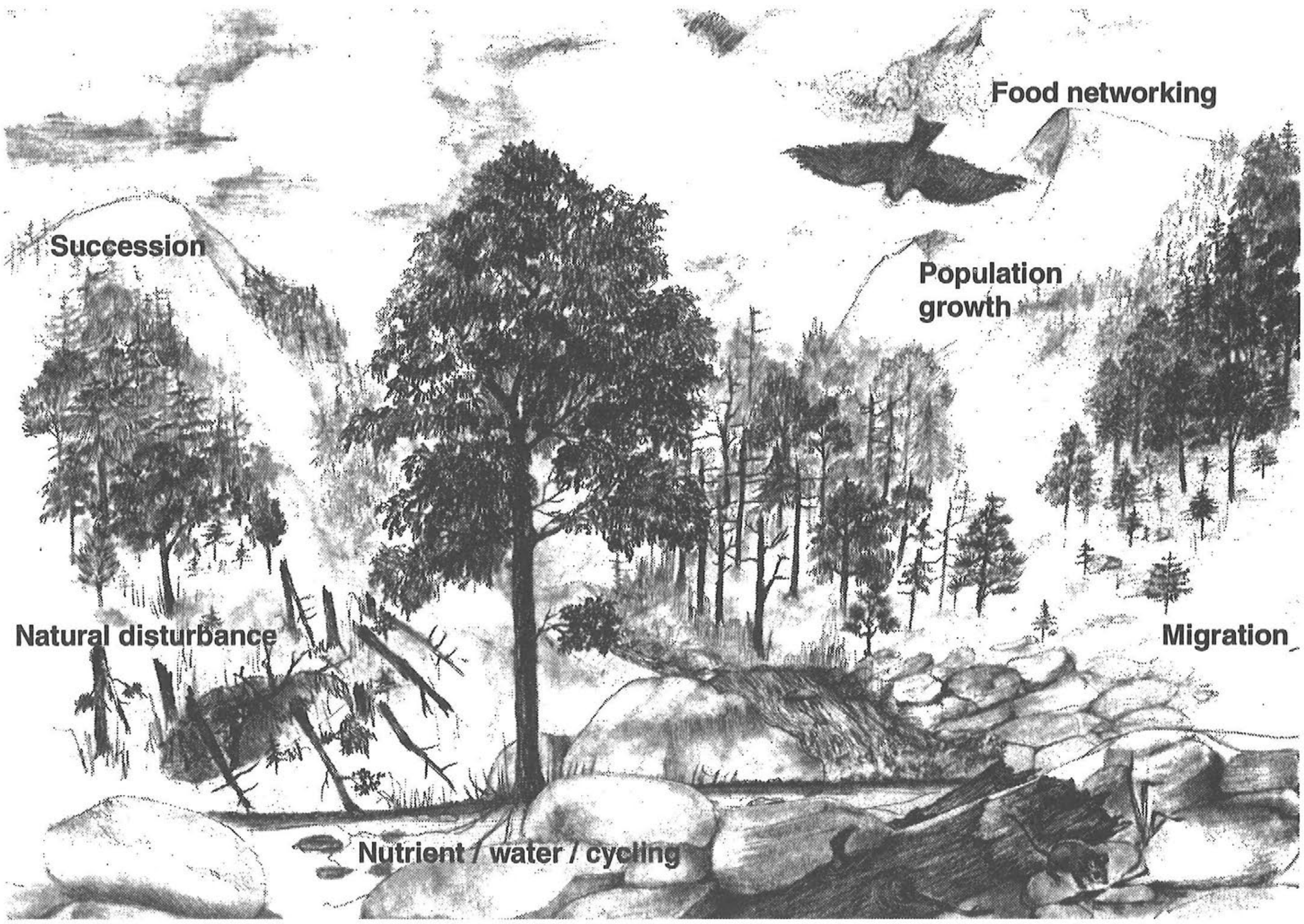

Figure 1.—Ecosystem processes.

Physical Attributes

The primary physical attributes (with some embedded biological features) are the land and water. These tend to be somewhat permanent features of the ecosystem while the biological features discussed in the next section are changeable. Physical attributes can be defined in terms of landtype (ecological landtype, soil series, important forest soil, or habitat type, etc.) and aquatic type (cold/warm-water pond or stream). These classifications provide the basis for determining an ecosystem's ability to produce certain resource values—types of timber, wildlife habitat, fish, bog plants, etc.

Biological Attributes

Ecosystems contain spatially arranged biological attributes such as forest cover types and age classes, upland nonforest types (e.g., fields), and wetland nonforest types (e.g., alder swamps). Some of these coincide with the landtypes mentioned in the previous section. These features relate closely to resource values and, as discussed later, need to be described for both the ecosystem as a whole and for individual ownerships. Within these forest/nonforest types there are plant/animal populations as well as biological features that relate to wildlife habitat or botanical diversity. Examples include standing and fallen dead wood, shrub layers, midstories, and herbaceous ground cover, seeps, unusual botanical communities, and dens and raptor nests.

Natural Processes

Certain natural processes take place within an ecosystem. One of the objectives of ecosystem management is to encourage, control, or limit these processes to enhance and maintain various resource values. The primary processes are succession, natural disturbance, population growth (birth, death, migration), food networking (who eats who), and water/nutrient/material cycling (Fig. 1).

Succession. Early or mid-successional stands, such as birch and pine, will convert gradually to late successional types, such as hemlock, spruce-fir, or northern hardwoods depending on the landtype and region. Part of the manager's job is to control succession by cutting (or no cutting) to meet the overall objectives for the property and ecosystem. We can also apply the term succession to changes that occur in the understory and herbaceous communities as well as to the conversion of abandoned fields to forest. Even nonforested wetlands experience changes over time due to natural processes. These changes can be hastened or reversed by certain types of management.

Natural disturbance. Windthrow is the major natural physical disturbance on many nonindustrial properties, though fire and flooding are important in certain regions and on certain types of soil. Historically, windthrow was one of the primary factors responsible for initiating the regeneration of early successional communities, and the maintenance of an intolerant species component. On some sites, and with certain species such as balsam fir, windthrow can be a major obstacle in managing and maintaining ecosystems. Managers can control windthrow to some extent by choosing species and cutting regimes carefully and by developing stands that are large enough to withstand at least partial wind damage. Insect infestations are another form of natural disturbance that can act selectively on tree species, affecting growth, mortality, and seed and litter production. Infestations also can be managed to a certain extent by controlling the composition of susceptible species as well as the age, size, condition, and spatial arrangement of stands.

Population growth. Birth (regeneration) and death (mortality) are the primary factors affecting plant and animal populations and the resulting age distribution (numbers of individuals per age class). Populations that are maintaining themselves exhibit a well-distributed range of age classes. Foresters are familiar with this concept through their understanding of the need for a balanced distribution of age or size classes in species they wish to maintain over time. Migration (immigration and emigration) is another feature of population growth that can be important among certain animal populations. And, since age is a poor indicator of size in many plant and animal species, growth rate per individual also is an important population characteristic. Some of the offshoots of these population growth factors include volume, biomass, carbon storage, deadwood production, and annual deer harvest. Due to the subtle effects of natural selection, population changes also may be occurring with respect to genetic makeup.

Food networking. One of the most complex processes within an ecosystem is related to food supplies.This process applies to deer eating browse, hawks eating mice, insects eating our favorite trees, and birds eating those insects. When food sources are out of balance with food seekers, populations may collapse or migrate, or the food source may be diminished. Simple systems tend to be much more vulnerable than complex ones. For example, stands of pure oak are in jeopardy during outbreaks of gypsy moth whereas mixed stands may suffer less damage and continue to function.

Water/nutrient/materials cycling. Vegetation is the primary means for recycling water, nutrients, and other materials within a forested ecosystem. Any disturbance of the vegetation tends to disrupt this cycle such that the release is greater than the uptake. That is why removing all vegetation from a wetland tends to raise the water table, or why clearcutting an entire watershed results in a flush of nutrients from the system. One of the concerns about "acid rain" is that it may result in more nutrients being released than are returned to the system. Following extreme disturbance, organic and mineral particules may be lost from the system (erosion).

Conceptual Attributes

Ecosystems also are analyzed and compared with respect to their conceptual attributes. The primary ones are sustainability or integrity, productivity, and biodiversity.

Sustainability. This term generally means that ecosystem attributes are being maintained over time. The term "nonsustainability" means that an attribute is disappearing due to natural processes or human impact, e.g., oak is not regenerating, fish are not reproducing, or acres of successional stands are declining. In short, some process within the ecosystem is not functioning like we thought it would, and certain features of the ecosystem—for better or worse—are running down. Used in this context, the term "integrity" (whole, complete, unimpaired) means about the same thing. The notion of sustainability or integrity also involves time. Is what we are doing sustainable, i.e., will the benefits we derive also be enjoyed by future generations?

Productivity. The overall productivity of an ecosystem is nearly impossible to determine or compare with any standard. We can estimate the productivity of an individual component of the ecosystem, such as timber volume growth, but such measures do not take into account the purposes of management or the capability of the land. Perhaps productivity should relate to how well the realizable goals of management are being achieved. In an ecosystem in which both timber production and fishing are management goals, productivity might mean the percentage of prime oak habitat that is producing and regenerating oaks as well as the percentage of cold-water stream that is providing good feeding/breeding/hiding trout habitat.

Biodiversity. Biodiversity usually is defined at three levels: landscape, species, and genetic. At the landscape level, we mean the range in broad cover types (forest, nonforest, wetland, water, softwoods, hardwoods), stand age classes, opening sizes, and topographic features. These gross features, in turn, are related to aesthetics, wildlife habitat, and perhaps water characteristics. Although there are several methods for measuring species diversity, we are concerned primarily with the number of plant/animal species occurring in viable, sustaining populations. Genetic diversity can be measured only by intensive study, though certain genetic characteristics can be observed. One example is the variation in fall coloration among red or sugar maple trees.

Applying Ecosystem Management

The task of carrying out ecosystem management involves four primary steps: inventory, analysis and evaluation, planning, and follow-up. These are similar to the steps followed in traditional management planning but are expanded to allow for the broader areal extent and range of disciplines inherent in the ecosystem approach.

Inventory

Once the boundaries of the ecosystem have been defined (e.g., a watershed with one or more client properties and adjacent nonclient properties), an inventory of physical/ biological attributes is needed at both the ecosystem and property (landowner) level.

At the ecosystem level, use aerial photographs to sketch in to the extent possible the broad forest cover types (softwood and hardwood at least), nonforest, wetlands, and open water. We should identify the age/size class of the forest cover, especially whether the stands are seedlings/saplings or poletimber/sawtimber. Using available soil maps, it is useful to know what landtypes or soils underlie the cover types, e.g., whether a stand of pine is on outwash sands or fine-textured till. A knowledge of land ownership also facilitates planning, particularly knowing whether nonclient properties are protected from development or have management restrictions. Local land trusts provide such information, and some states maintain a GIS (geographic information system) data layer of protected lands and wetlands. Other sources of information include state maps of deer wintering areas, data bases on rare or endangered species, and available information on water and fishing resources. Also useful are the locations of farms, housing developments, roads and recreational trails, and other areas of concentrated human activity.

A finer resolution inventory is required on client properties that includes a stand map and notes or data on timber volumes, species, soils/landtypes, regeneration, insect/ disease conditions, wildlife/botanical features, and areas of erosion/sedimentation.

Analysis and Evaluation

The primary purpose of the analysis and evaluation phase is to examine the ecosystem and property inventories and determine needs or opportunities at these two levels. This will lead (next section) to the development of ecosystem-level and landowner-level objectives that will be as consistent as possible with one another.

Ecosystem level. Guidelines on composition and structure goals to maximize wildlife diversity are available at the landscape level. Table 7 of the Appendix provides suggested goals on amounts of forest vs. nonforest, stand size classes, cover types, and hard mast (DeGraaf et al. 1992). This publication is a guide to the management of forests in New England, based on a detailed literature review as well as field experience, to provide habitat required by the native amphibians, reptiles, birds, and mammals—more than 300 terrestrial species. Comparison of the ecosystem-level inventory with these guidelines provides an initial estimate of some of the major ecosystem needs.

The presence of unique wildlife, water, and scenic resources within the ecosystem needs to be noted and analyzed. In particular, we need to be aware of unique features that are related to the management of client properties. For example, a deer wintering area (thermal cover) anywhere within the ecosystem also implies the need for adjacent areas of browse, travel corridors, hard mast, and herbaceous growth in early spring. An alder wetland that is frequented by woodcock implies the need for adjacent areas of abandoned fields or forest openings for roosting/singing. A trout stream that bisects or borders several ownerships implies the need for adjacent sources of dead and down material, small openings, and cold-water seeps coupled with control of all sources of siltation.

Areas of concentrated human activity—houses and housing developments, roads, trails, etc.—generate both social and biological concerns. In this publication we do not provide information on how to solve human-related problems. We only make the point that concentrated human activity imposes certain potential impacts that must be considered when adopting an ecosystem-based approach to management. Forest operations near popular areas may result in negative responses from the public unless the timing and conduct of the operation is planned and controlled carefully. Increased public use of previously isolated tracts of forest land frequently limits the ability of hunters to harvest game. Such restrictions could lead to numerous complaints about damage from animals as well serious impacts on desired vegetation. In addition, year-round feeding of birds in residential areas could encourage unwanted visits from foraging bears.

The biological impacts from increased human activity can include an added component of nest parasites such as brown-headed cowbirds, predators such as domestic cats and dogs, increased populations of animals that are comfortable around human surroundings (e.g., raccoon, opossum, skunk, chipmunk, squirrel, blue jay), and increases in nonnative wildlife (e.g., house mouse, Norway rat, house sparrow, and starling) as well as exotic plants (e.g., purple loosestrife and certain honeysuckles). Also, the frequency and duration of startling noises and other human disturbance could affect the occurrence and reproductive success of a variety of waterfowl, wading birds, raptors, certain large carnivores, and ungulates.

Property (landowner) level. Examining the property inventory will reveal landowner opportunities with respect to timber and wildlife values but also opportunities to meet some ecosystem-level objectives. For example, many landscapes in New England are deficient in seedling-sapling stands. If the landowner's property contains overmature northern hardwoods (which regenerate well following clearcutting), there is an opportunity to achieve some timber returns for the landowner through small clearcuts while meeting an ecosystem-level objective. If the landowner's property abuts a trout stream, there may be opportunities to influence the overall productivity of the stream by maintaining overmature timber along stream edges to provide organic debris, by providing small openings for terrestrial insects, and by protecting cold-water seeps that maintain water temperatures during summer.

Planning

The planning phase begins with the establishment of specific goals at both the ecosystem and landowner level to meet the opportunities detected in the analysis and evaluation of the inventories.

In addition to setting specific ecosystem-level goals in terms of composition, stand size-class distribution, and fruit/mast availability (Table 7, Appendix), some general guidelines should be defined for maintaining the value of special ecosystem features such as water courses, unique communities, and wildlife habitats (e.g., deer yards and alder thickets). We reiterate that this approach does not imply any sacrifice of landowner goals. Rather, certain landowner goals cannot be realized without considering the influence of conditions throughout the broader landscape. For example, viable populations of turkeys are welcomed by many landowners throughout New England who may be hunters or who simply enjoy seeing these large, historically important birds. The optimum habitat for turkey consists of mature stands of oak and beech with relatively open understories, interspersed small clearings, some cultivated land, some large hardwood and conifer roost trees, spring seeps, groups of conifers, a variety of soft mast (apple, grape, ash, hophornbeam, cherry, etc.), "brushed out" roads and trails, and some south-facing slope positions (Vermont Fish and Wildlife Dept. 1986). Few individual landowners can singly provide all these habitat conditions, yet many could provide one or two critical features to supplement the array of features over the 500 to 1,000 or more acres that comprise average turkey home range.

Most landowner goals are framed in terms of general or specific resource benefits: timber, fish/wildlife, aesthetics, and recreation. The relationship of these interests to overall ecosystem goals needs careful consideration. A landowner's interest in producing high-value timber is closely related to ecosystem-level needs for regenerating acres, sawtimber and large sawtimber stands, mast (oak) production, and coniferous acres (e.g., white pine or spruce). Landowner interests in certain wildlife species, e.g., grouse, closely complement the ecosystem-level needs for acreage in early successional stands. Landowner (or nonclient) interests in maintaining natural areas will complement ecosystem-level goals for providing sawtimber or large sawtimber coniferous/deciduous stands with a high proportion of dead/down material and cavity trees.

The next step is to translate landowner goals into a stand-by-stand schedule of operations that will produce the benefits desired by the client, and begin to eliminate some of the deficiencies in ecosystem conditions. On the basis of risk, value, condition, and stocking, stands can be scheduled for regeneration or intermediate cuttings, deferment, or no vegetation management. The schedule should account for changes that will take place naturally due to succession, maturation, and natural disturbance. For example, a lack of coniferous acreage at the ecosystem level might best be met through natural succession on soils/landtypes conducive to the regeneration of softwoods.

During this scheduling phase, attention turns from stand-level needs to desired within-stand conditions, which include certain wildlife features (e.g., exposed perches, canopy closure, wildlife trees, midstory/shrub/ground vegetation, dead/down material (DeGraaf et al. 1992)), and protection of small-scale unique features (e.g., unusual plants/ communities, bogs and seeps, archeological sites). These features can be provided/protected through carefully designed silvicultural/harvesting prescriptions.

At this stage of planning, the consultant or manager may see the need to go beyond anticipating what might happen on neighboring properties and look for opportunities to initiate interaction with other landowners to help attain ecosystem goals.

Followup

The primary goal during followup is to implement the next series of operations outlined in the planning schedule, to assess the success of past operations, and to reassess ecosystem and property conditions. One of the primary sources of change is revised landowner objectives or revised directions on nonclient properties.

Ecosystem Management: An Example

We applied the principles of ecosystem management to a hypothetical but typical forest property in New England, though these principles also are applicable to landscapes in many regions of the country. Our ecosystem is a subwatershed of about 745 acres that surrounds a client property of about 135 acres (Fig. 2). The available wildlife guidelines suggest that surrounding landscapes can be up to about 10 times the size of a client's property (DeGraaf et al. 1992), so the defined ecosystem could be about twice as large.

Ecosystem Inventory

The ecosystem includes the following characteristics coded by number/letter on a sketch map (Fig. 2) prepared from an aerial photo supplemented with a general knowledge of the area.

Unit 1. About 65 acres of upper elevation (1,200 to 1,600 feet) shallow bedrock supporting hemlock, a few spruce and pine, an occasional large oak, and some open areas of blueberry resulting from past fires. Although in private ownership, this area is a well-known blueberry/hiking area. Snowshoe hares are abundant, probably with coexisting predators such as bobcat, red fox, and perhaps an occasional goshawk.

Unit 2. About 440 acres of mixed northern hardwood sawtimber (beech, sugar maple, yellow birch, red maple, and some ash) with a scattering of oak and pine growing on moderately to well-drained till. A history of rough pasturage and light cultivation has contributed to the mixed species composition.

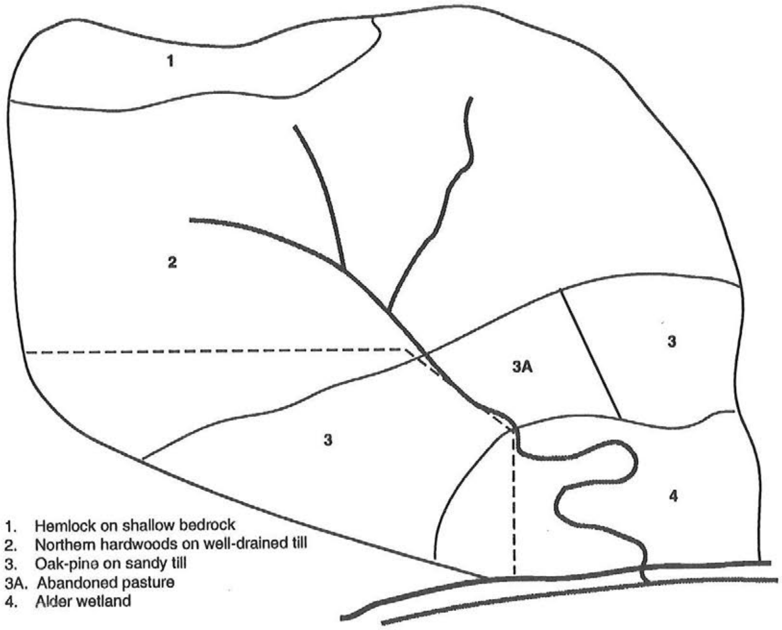

Figure 2.—This ecosystem in New England includes several forest cover types, pasture, stream, and a client private ownership.

Unit 3 (including 3A). About 165 acres of sandy, washed till which characteristically supports good oak and some pine but includes an understory of beech and red maple. Within this area, Unit 3A is defined as 30 acres of abandoned pasture that is being invaded by milkweed and sumac.

Unit 4. About 75 acres of wetland in alder with some encroaching red maple. This area is a well-known nesting/feeding area for woodcock.

Other. A small trout stream that becomes a meandering wetland stream at the base of the subwatershed. There are no known rare or endangered plant/animal species according to Natural Heritage and State Fish and Wildlife agencies.

Property Inventory

The primary stands on the client property are:

No. 2. About 40 acres at the base of ecosystem Unit 2. This is a large-sawtimber stand of northern hardwoods with a good component of white ash, yellow birch, and sugar maple concentrated around some seepy areas where compact till is near the surface. The understory and midstory are well developed with a strong component of beech. There are numerous large- and small-diameter cavity trees.

No. 3. About 80 acres within ecosystem Unit 3. This is sandy till supporting a stand of good-quality oak (30 percent) and white pine of moderate quality (20 percent). The remainder is in red maple, beech, and white/gray birch. The understory has a high proportion of red maple and beech along with some clumps of oak and pine. Cavity trees are abundant; near the stream are drainages and seeps with hemlock and wet ground vegetation.

No. 4. About 15 acres within ecosystem Unit 4. This portion of the wetland contains alder with a high proportion of invading red maple that is reducing the value of the area as cover for woodcock.

Analysis and Evaluation

In this section we look at the overall condition of the ecosystem as well as the outlook for improvement or deterioration of these conditions through natural change and landowner management activities. First, we compare existing conditions with landscape objectives from DeGraaf et al. (1992). We emphasize that existing conditions at the ecosystem level can be based on quick estimates from aerial photographs and a general knowledge of the area; no detailed inventory efforts are required:

	Percent of total acreage	
Land class	Goal	Existing
Regeneration	5-15	0
Sapling/pole	30-40	0
Large/small sawtimber	50-60	100
Early successional hardwood	5-15	0
Late successional		
Hardwood	20-35	69
Hard mast	5	5+
Conifer	35-50	12
Nonforest upland	3-5	4
Nonforest wetland	1-3	<10

The percentages under the "existing" column are based on estimates from the aerial photo interpretation and data from the landowner inventory. For example, the existing percentage for conifer reflects the 65 acres in ecosystem Unit 1 plus 20 percent (white pine) of the acreage in Unit 3. To maintain wildlife diversity at the ecosystem level, the requirements are obvious: increases are needed in regenerating acres (and, subsequently, sapling/pole acres), early successional hardwoods, and conifers. The following are opportunities within each ecosystem unit:

Unit 1. Hemlock, spruce, and fir on shallow bedrock. This unit is essentially in climax condition and will tend to remain in softwoods (with some openings) barring heavy disturbance from fire or windthrow. There is no client ownership within this unit.

Unit 2. Northern hardwoods on well- to moderately well-drained till. This stand will tend to remain in northern hardwoods, with some decline in the scattered oak and pine. This is the best opportunity to create some regenerating and/or early successional areas on the 40 acres that are client owned. There is no indication that nonclient properties will be managed.

Unit 3. Oak, pine, and mixed hardwoods on sandy till. Without management, this stand will experience increases in beech and red maple, probably with some hemlock, though oak and pine will remain as components. The timber values in this unit are high. The opportunities on the 80 acres of client-owned property are to increase the proportions of pine and oak through small-group release of existing advanced regeneration coupled with small groups and scarification during pine seed years to increase the composition of pine.

The nonforest acreage (3A) is an important part of the landscape and will revert to forest if left alone. The owner of this pasture could be approached concerning the possibilities of a mowing operation, or leasing the property for grazing. This nonforest acreage adds significantly to the ecosystem's values with respect to hunting or observing wildlife. Thus, the interests of the client-landowner would be served by developing arrangements for maintaining nonforest conditions.

Unit 4. Alder wetland. To keep this area in alder, the invading red maple on the 15 acres of client-owned property could be removed for fuelwood with the remaining alder maintained by mowing.

Planning

The ecosystem objective is to move closer to the composition and stand-size conditions outlined earlier (DeGraaf et al. 1992). This means:

1. Increasing the acres in regeneration and early successional stands.
2. Increasing the acres in softwoods.
3. Maintaining the existing nonforest area.
4. Maintaining some large sawtimber, especially cavity trees, along the stream and protect the seeps in and around the stream banks.
5. Looking for opportunities to maintain within-stand conditions important for wildlife including shrub and midstory layers, dead and down material, softwood inclusions, high perches such as super-dominant white pines, large-diameter cavity trees, and mast trees (in stands with a minimal oak component).

In this example we assume that the landowner wants timber income on a fairly regular basis and also has some interest in wildlife and hunting. The following approaches should meet these needs and help improve ecosystem conditions:

1. Even-age management (clearcutting) in Unit 2 (about 6 acres every 15 years) along with an improvement cut (especially high-risk valuable trees). Leave vigorous mast trees (oak and beech) as well as large-diameter cavity trees. Approach other landowners in the ecosystem on the possibilities of supplementary regeneration cutting.

2. Group/small patch cutting in the stand in Unit 3, releasing advanced growth of oak and pine. Remove about one-quarter of the volume every 15 years. In good pine seed years, consider scarification within small patches (without pine or oak advanced growth) to regenerate new pine seedlings. Leave most of the large-diameter cavity trees along the stream bank, and avoid logging activity through the seeps.

3. Light (home use) fuelwood cutting of the red maple in Unit 4. Consider a periodic mowing operation in the remaining alder, which would be repeated every 15 to 20 years. Check the area for beaver activity since flooding from beaver could eliminate the need for (or negate the effect of) treatment.

4. Ask the owner of the abandoned pasture (Unit 3A) to consider a mowing operation or leasing the grazing land.

Followup

The following are major concerns with respect to monitoring activities:

1. Changes in cutting activity or land use on the nonclient properties. This could result in changes in ecosystem objectives and subsequent revision in the approaches followed on the client property. For example, if there was an significant increase in clearcutting on nonclient properties, less early successional habitat would be required on the client property. It might then be more appropriate to use group selection (rather than even-age management) on the client's stand in Unit 2.

2. Success in regenerating oak and pine in the stand in Unit 3.

3. Condition of the alder wetland (Unit 4), particularly the reinvasion of red maple and the condition of the alder.

4. General awareness of new and unusual plant or animal communities, or the presence of tree diseases, insects, or declines.

5. Major changes in land use such as new roads, housing developments, and recreational developments such as snowmobile/mountain bike trails.

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Appendix

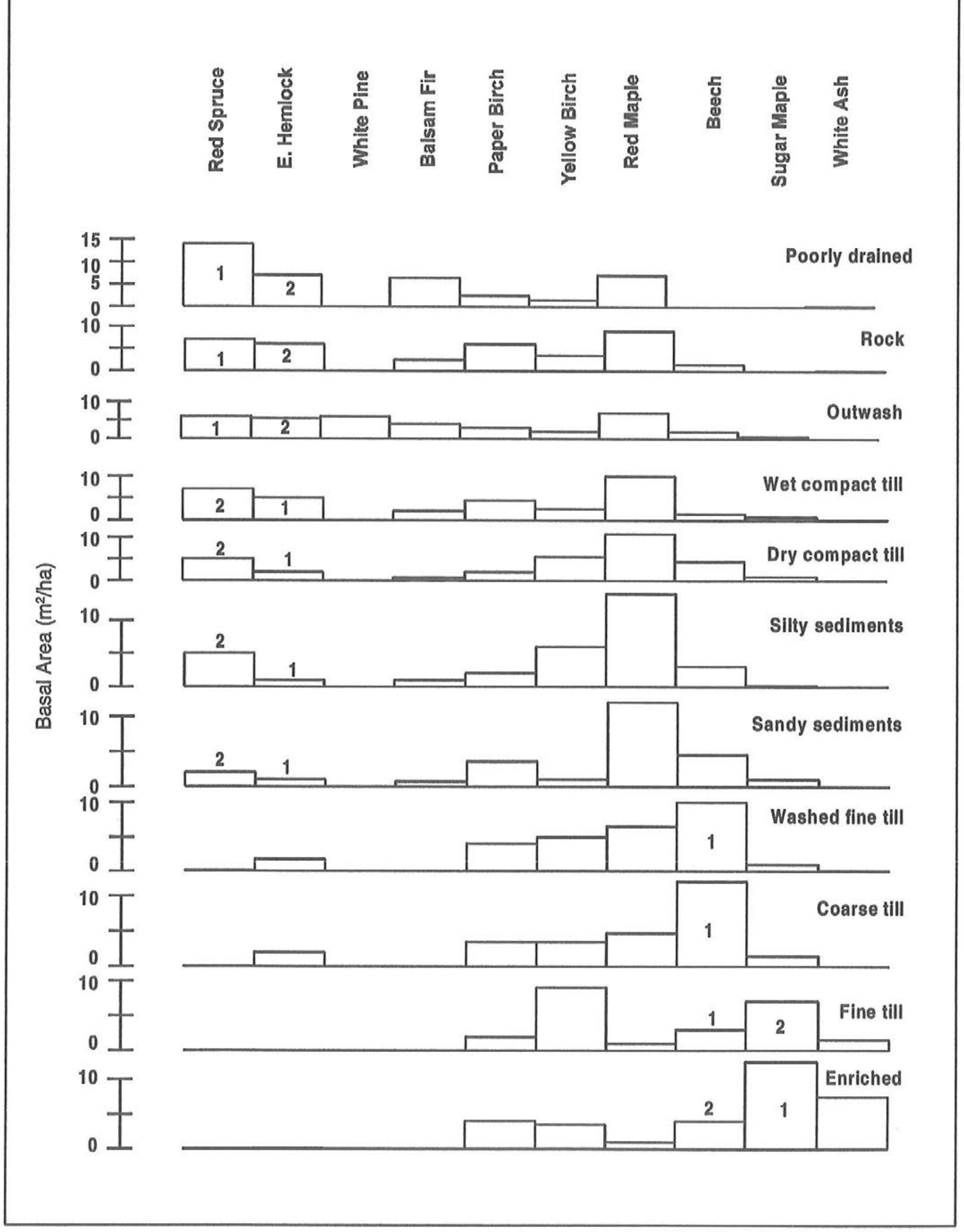

Figure 3.— Basal area (m^2/ha) by species and habitat for successional stands on granitic drift in the southern White Mountains of New Hampshire: 1 = most abundant species, 2 = second most abundant species found in old climax stands.

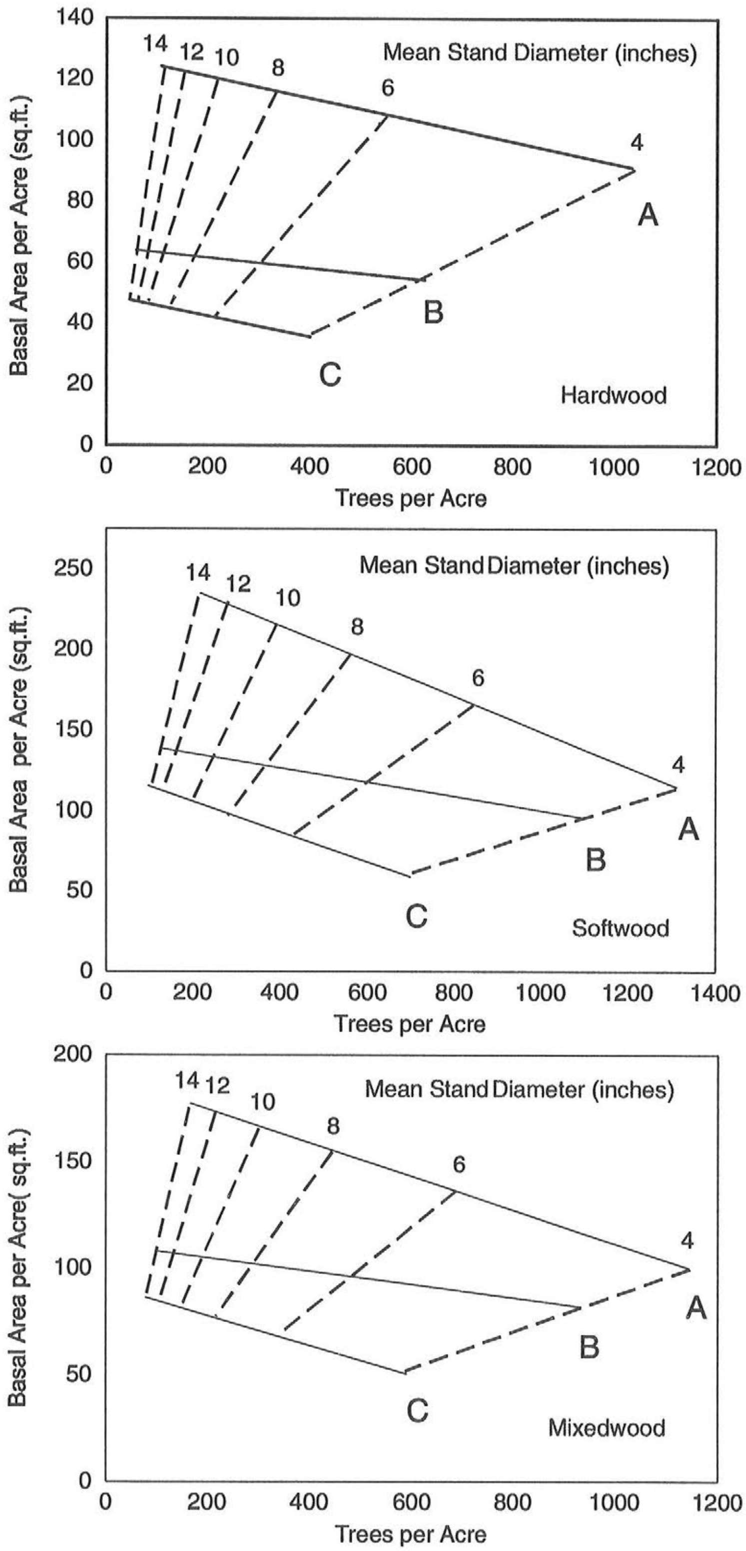

Figure 4.— Generalized stocking chart for hardwood (particularly northern hardwood), mixed hardwood/conifer, and softwood (particularly spruce-fir/hemlock) forest cover types (from Solomon et al. 1995). The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response/ acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.

Index to Tables

Table 1.—State fish and wildlife agencies that provide habitat management recommendations in the 20-state Northeastern Area

State	Responsible Agency	Address	Phone
Connecticut	Dep. of Environ. Protection, Wildlife Div.	79 Elm St., Hartford, CT 06106	(203) 424-3011
Delaware	Dep. of Nat. Resources and Environ. Control, Div. of Fish and Wildlife	89 Kings Highway, PO Box 1401, Dover, DE 19903	(302) 739-5297
Illinois	Dep. of Conservation, Wildlife Div.	Lincoln Tower Plaza, 524 S. Second St., Springfield, IL 62701-1787	(217) 782-6384
Indiana	Dep. of Nat. Resources, Div. of Fish and Wildlife	402 W. Washington St., #W273, Indianapolis, IN 46204-2212	(317) 232-4080
Iowa	Dep. of Nat. Resources, Fish and Wildlife Div.	E. Ninth and Grand Ave., Wallace Bldg., Des Moines, IA 50319-0034	(515) 281-5145
Maine	Dep. of Inland Fisheries and Wildlife, Wildlife Resources Assessment	650 State St., Bangor, ME 04401-5654	(207) 941-4467
Maryland	Dep. of Nat. Resources, Res. Conservation Service — Wildlife	Tawes State Office Bldg., Annapolis, MD 21401	(301) 974-3195
Massachusetts	Dep. of Fisheries, Wildlife, and Environ. Law Enforcement	Field Headquarters, Westborough, MA 01581	(508) 792-7270
Michigan	Dep. of Nat. Resources., Wildlife Div.	Steven T. Mason Building, Box 30444, Lansing, MI 48909-7944	(517) 373-1263
Minnesota	Dep. of Nat. Resources, Div. of Fish and Wildlife	500 Lafayette Rd., St. Paul, MN 55155-4001	(612) 296-3344
Missouri	Dep. of Conservation, Wildlife Div.	PO Box 180, 2901 Truman Blvd., Jefferson City, MO 65102	(314) 751-4115
New Hampshire	Fish and Game Dep, Wildlife Div.	2 Hazen Dr., Concord, NH 03301	(603) 271-2462
New Jersey	Dep. of Environ. Protect. and Energy, Div. of Fish, Game, and Wildlife	CN 400, Trenton, NJ 08625-0400	(609) 292-6685
New York	Dep. of Environ. Conservation, Div. of Fish and Wildlife	50 Wolf Road, Albany NY 12233	(518) 457-0696
Ohio	Dep. of Nat. Resources, Div. of Wildlife	1840 Belcher Dr., Columbus, OH 43224-1329	(614) 265-6300
Pennsylvania	Game Commission, Bureau of Wildlife Management	2001 Elmerton Ave., Harrisburg, PA 17110-9797	(717) 787-9825
Rhode Island	Dep. of Environ. Manage. Div. of Fish and Wildlife	Stedman Government Center, 4808 Towerhill Rd., Wakefield, RI 02879	(401) 789-3094
Vermont	Dep. of Fish and Wildlife	103 South Main St., Waterbury, VT 05677	(802) 244-7331
West Virginia	Dep. of Nat. Resources	1900 Kanawha Blvd., East, Charleston, WV 25305	(304) 558-2771
Wisconsin	Dep. of Nat. Resources, Bureau of Wildlife Management	Box 7921, Madison, WI 53707	(608) 267-2948

Table 2.—State Natural Heritage Programs that provide information on ecosystems and rare species in the 20-state Northeastern Area

State	Agency	Address	Phone
Connecticut	Natural Diversity Database, Dep. of Environ. Protection	Natural Resources Center, Store Level, 79 Elm St., P.O. Box 5066, Hartford, CT 06106	(203) 424-3540
Delaware	Natural Heritage Program, Div. of Parks and Recreation	89 Kings Highway, Dover, DE 19903	(302) 739-5285
Illinois	Natural Heritage Division, Dep. of Conservation	Lincoln Tower Plaza, 524 S. Second St., Springfield, IL 62701-1787	(217) 785-8774
Indiana	Natural Heritage Data Center, Div. of Nature Preserves, Dep. of Nat. Res.	402 W. Washington St., #W267, Indianapolis, IN 46204-2212	(317) 232-4052
Iowa	Natural Areas Inventory, Preserves and Ecol. Serv., Dep. of Nat. Resources	E. Ninth and Grand Ave., Wallace Bldg., Des Moines, IA 50319-0034	(515) 281-8524
Maine	Natural Areas Program, Office of Community Development	State House Station 130, 219 Capitol Ave., Augusta, ME 04333	(207) 624-6800
Maryland	Natural Heritage Program, Dep. of Natural Resources	Tawes State Office Bldg., E-1, Annapolis, MD 21401	(410) 974-2870
Massachusetts	Natural Heritage and Endangered Species Program, Div. of Fish and Wildlife	Field Headquarters, Westborough, MA 01581	(508) 792-7270
Michigan	Natural Features Inventory, Dep. of Natural Resources	Steven T. Mason Building, 5th floor, Box 30444, Lansing, MI 48909-7944	(517) 373-1552
Minnesota	Natural Heritage Program, Nongame Inventory and Research, Dep. of Natural Resources	500 Lafayette Rd., Box 7 St. Paul, MN 55155-4001	(612) 296-3344
Missouri	Natural Heritage Database, Dep. of Conservation	PO Box 180, 2901 W. Truman Blvd., Jefferson City, MO 65102	(314) 751-4115
New Hampshire	Natural Heritage Inventory, Dep. of Res. and Econ. Development, Div. of Forest and Lands	PO Box 856, 172 Pembroke Rd., Concord, NH 03302-0856	(603) 271-3623
New Jersey	Natural Heritage Program, Office of Natural Lands Management	501 E. State St., CN 404, Trenton, NJ 08625-0400	(609) 984-1339
New York	Natural Heritage Program, Dep. of Environ. Conservation	700 Troy-Schenectady Road, Latham, NY 12110-2400	(518) 783-3932
Ohio	Natural Heritage Program, Div. of Natural Areas and Preserves, Dep. of Nat. Resour.	Fountain Square, Building F, Columbus, OH 43224	(614) 265-6453
Pennsylvania	Natural Diversity Inventory PNDI-East	The Nature Conservancy, 34 Airport Dr., Middletown, PA 17057	(717) 948-3962
Pennsylvania	Natural Diversity Inventory PNDI-West	Western PA Conservancy, Natural Areas Program, 316 Fourth Ave., Pittsburgh, PA 15222	(412) 288-2777
Pennsylvania	Natural Diversity Inventory PNDI-Central	Bureau of Forestry, P.O. Box 8552, Harrisburg, PA 17105-8552	(717) 783-0388
Rhode Island	Heritage Program, Div. of Planning and Development, Dep. of Environ. Manage.	83 Park Street, Providence, RI 02903	(401) 277-2776
Vermont	Nongame and Natural Heritage Program, Dep. of Fish and Wildlife	103 S. Main Street, Waterbury, VT 05671-0501	(802) 241-3700
West Virginia	Natural Heritage Program, Dep. of Nat. Resources	Operations Center, Ward Road, P.O. Box 67, Elkins, WV 26241	(304) 637-0245
Wisconsin	Natural Heritage Program, Endangered Resources, Dep. of Natural Resources	101 S. Webster St., Box 7921, Madison, WI 53707	(608) 266-7012

Table 3.—State extension wildlife specialists in the 20-state Northeastern Area

State	Agency	Address	Phone
Connecticut	Wildlife Extension Specialist	Box U-87, Univ. of Connecticut, Storrs, CT 06269-4087	(203) 486-2840
Delaware	Director of Extension Service	Univ. of Delaware, Townsend Hall, Newark, DE 19716	(302) 451-8062
Illinois	Director of Extension Service	122 Mumford Hall, 1301 West Gregory Dr., Univ. of Illinois, Urbana, IL 61801	(217) 333-2660
Indiana	Extension Wildlife Specialist	Dep. of Forestry and Nat. Resources, Purdue Univ., West Lafayette, IN 47907	(317) 494-3586
Iowa	Extension Wildlife Conservationist	103 Science II, Iowa State Univ., Ames, IA 50011	(515) 294-7429
Maine	Extension Wildlife Specialist	234 Nutting Hall, Univ. of Maine, Orono, ME 04469	(207) 581-2902
Maryland	Cooperative Extension Service	Symons Hall, College Park, MD 20742	(301) 405-2906
Massachusetts	Director of Cooperative Extension	Univ. of Massachusetts, Stockbridge Hall, Amherst, MA 01003	(413) 545-4800
Michigan	Prog. Dir., Agriculture and Natural Resource	11 Agric. Hall, Michigan State Univ., East Lansing, MI 48824-1039	(517) 355-0117
Minnesota	Extension Wildlife Specialist	216 Hodson Hall, Univ. of Minnesota, St. Paul, MN 55108	(612) 624-3298
Missouri	Director of Extension Service	309 Univ. Hall, Univ. of Missouri, Columbia, MO 65211	(314) 882-7754
New Hampshire	Wildlife Extension Specialist	110 Pettee Hall, Univ. of New Hampshire, Durham, NH 03824	(603) 862-3594
New Jersey	Director of Extension Service	Rutgers, The State Univ., Cook College, PO Box 231, New Brunswick, NJ 08903	(908) 932-9306
New York	Nat. Resource Extension Specialist	Dep. of Nat. Resources, 112 Fernow Hall, Cornell Univ., Ithaca, NY 14853-3001	(607) 255-2114
Ohio	Nat. Resource Extension Specialist	Ohio State Univ., 2021 Coffey Rd., Columbus, OH 43210	(614) 292-9884
Pennsylvania	Wildlife Resource Specialist	320 Forest Resources Lab, Pennsylvania State Univ., University Park, PA 16802	(814) 863-8442
Rhode Island	Director of Extension Service	Univ. of Rhode Island, Kingston, RI 02881	(401) 792-2474
Vermont	Forest Management Specialist	Aiken Center, Univ. of Vermont, Burlington, VT 05405-0088	(802) 656-3258
West Virginia	Wildlife Extension Specialist	307-B Percival Hall, West Virginia Univ., Morgantown, WV 26506	(304) 293-4947
Wisconsin	Extension Wildlife Specialist	Russell Laboratories, Univ. of Wisconsin, Madison, WI 53706	(608) 263-2071

Table 4.—Sources of spatial information for the 20-state Northeastern Area

State	Responsible Agency	Address	Phone
Connecticut	Geographic Information Services, Natural Resources Center, Dep. of Environmental Protection	79 Elm Street, Store Floor, Hartford, CT 06106	(806) 424-3540
Delaware	Division of Resource Management, State Forestry Office, Dep. of Agriculture	2320 S. duPont Highway, P.O. Drawer D, Dover, DE 19901	(302) 739-4811
Illinois	State Geological Survey, Dep. of Natural Resources	615 East Peabody Drive, Champaign, IL 61820	(217) 333-4085
Indiana	Dep. of Natural Resources, Division of Forestry	402 West Washington Street, Room W296, Indianapolis, IN 46204	(317) 232-4108
Iowa	Dep. of Natural Resources	900 Grand Avenue, Des Moines, IA 50319	(515) 281-5815
Maine	Office of GIS	State House Station 125, Augusta, ME 04333-0125	(207) 287-6144
Maryland	Office of State Planning	Room 1101 State Office Building, 301 West Preston Street, Baltimore, MD 21201	(410) 225-4500
Massachusetts	Geographic Information Systems, Executive Offices of Environmental Affairs	20 Somerset Street, 3rd. Floor, Boston, MA 02108	(617) 727-5227 ext. 322
Michigan	Dep. of Natural Resources	P.O. Box 30028, Lansing, MI 48909	(517) 335-3347
Minnesota	Land Management Information Center, Office of Planning	658 Cedar Street, St. Paul, MN 55155	(617) 296-1211
Missouri	Dep. of Natural Resources, Div. of Administrative Support	P.O. Box 176, Jefferson City MO 65102	(573) 751-2963
New Hampshire	Complex Systems Research Center, NH GRANIT	Univ. of New Hampshire, Durham, NH 03824	(603) 862-1792
New Jersey	Division of Parks and Forestry, Forestry Services	CN 404, Trenton, NJ 08625	(609) 984-0813
New York	State Dep. of Environmental Conservation, Div. of Lands and Forests	50 Wolf Road, Room 438, Albany, NY 12233-4255	(518) 457-7433
Ohio	USDA Forest Service	359 Main Road, Delaware, OH 43015	(614) 368-0097
Pennsylvania	Geological Survey	P.O. Box 8453, Harrisburg, PA 17105-8453	(717) 787-2169
Rhode Island	Geographic Information Systems, Dep. of Administration-Planning	One Capitol Hill, Providence, RI 02908-5872	(401) 277-6483
Vermont	Center for Geographic Information, Inc.	206 Morrill Hall, University of Vermont, Burlington VT 05405-0106	(802) 656-4277
West Virginia	Geological and Economic Survey	P.O. Box 879, Morgantown, WV 26507-0879	(304) 594-2331
Wisconsin	Dep. of Natural Resources, Geological Services Unit	101 South Webster Street, IM\8, PO Box 7921, Madison, WI 53707-7921	(608) 266-3054

Table 5.—Number of species by taxonomic class and average home-range area (acres) in New England (DeGraaf et al. 1992)

Taxonomic class	Unknown / N/A	1 - 10	11 - 50	> 50	Total
Amphibian	0	25	1	0	26
Reptile	0	21	7	2	30
Bird	17	141	30	32	220
Mammal	9	31	5	17	62
Total	26	218	43	51	338

Table 6.—Number of species that use various habitat-breadth combinations for 338 wildlife species in New England (DeGraaf et al. 1992): forest (F), nonforest (NF), water (W), krummholz (K)

Habitat breadth	Amphibian	Reptile	Bird	Mammal	Total
One combination					
F	0	1	15	2	18
NF	0	0	33	2	35
W	0	1	4	0	5
K	0	0	0	0	0
Two combinations					
F-K	0	0	7	3	10
F-N	7	7	111	21	146
F-W	1	0	1	0	2
NF-W	1	8	21	1	31
K-W	0	0	0	0	0
NF-K	0	0	0	0	0
Three combinations					
F-K-N	0	1	10	17	28
F-NF-W	16	9	17	15	57
NF-K-W	0	1	0	0	1
F-K-W	0	0	0	0	0
Four combinations					
F-K-NF-W	1	2	1	1	5

Table 7.—Habitat opportunity classes (i.e., general nature of landscape conditions) and composition goals to achieve wildlife diversity on New England forested landscapes (DeGraaf et al. 1992), in percent of acreage

Composition	Habitat opportunity class			
	I	II	III	IV
Breadth				
Forest	> 90	> 90	70-90	70-90
Nonforest	0-10	< 5	5-30	5-30
Water	< 5	> 5	< 5	> 5
Size class				
Regeneration	5-15	5-15	5-10	5-15
Sapling/pole	30-40	30-40	25-35	30-40
Sawtimber	40-50	40-50	55-65	40-50
Large sawtimber	< 10	< 10	< 10	< 10
Cover type				
Deciduous				
Short rotation	5-15	10-25	5-10	5-20
Long rotatio	20-35	15-30	20-40	10-20
Hard mast	1-5	1-5	5-25	1-15
Coniferous	35-50	35-60	10-35	25-50
Nonforest				
Upland	3-5	3-5	15-30	5-10
Wetland	1-3	1-3	1-3	3-5

Table 8.—Number of wildlife species by taxonomic class that use various stand size-class combinations in New England: regeneration (R), sapling/pole (SP), sawtimber (S), large sawtimber (LS) (DeGraaf et al. 1992)

Size-class combination	Amphibian	Reptile	Bird	Mammal	Total
None	1	10	58	3	72
One					
R only	0	0	22	4	26
SP only	0	0	0	0	0
S only	0	0	0	0	0
LS only	0	0	4	0	4
Two:					
R-SP	0	0	11	3	14
R-S	0	0	0	0	0
R-LS	0	0	3	1	4
SP-S	0	0	0	0	0
SP-LS	0	0	0	0	0
S-LS	0	0	12	3	15
Three					
R-SP-S	0	0	4	0	4
R-SP-LS	0	0	0	0	0
R-S-LS	0	0	8	9	17
SP-S-LS	4	4	18	4	30
Four:					
R-SP-S-LS	21	16	80	35	152

Table 9.—Estimated use by 80 nongame bird species in Michigan of large forest openings (> approx. 10 acres), small openings, forest edge, and closed forest (Taylor and Taylor 1979)

Habitat used	Number of species
Only large openings	16
Only small openings	0
Only edge	0
Only closed forest	0
Large and small openings	5
Large/small openings plus edge	19
Small openings and edge	15
Small openings, edge, forest	11
Edge and closed forest	1
All categories	13
Total species	80

Table 10.—Distribution of 107 bird species by forest-type combinations in Wisconsin (Temple et al. 1979)

Forest composition	Number of species
Deciduous forest primarily	1
Mixed forest primarily	0
Boreal forest primarily	6
Deciduous and mixed	15
Mixed and boreal	30
Deciduous, mixed, and boreal	55
Total species	107

Table 11.—Occurrence and density of 48 species of breeding birds in seral stages of white, red, and jack pine forests. Density is number of territorial males per 10 ha: xxxx ≥ 10, xxx = 5 to 10, xx = 1 to < 5, x = < 1 (Capen 1979)

	Seral stage			
Species	Seedling/sapling	Pole	Mature	Pine/hardwood
Common flicker	-	-	-	xx
Pileated woodpecker	-	-	-	x
Yellow-bellied sapsucker	-		xx	xx
Hairy woodpecker	-	-	-	x
Downy woodpecker	-	-	-	x
Great crested flycatcher	xx	-	xx	-
Eastern wood pewee	xx	-	xx	xx
Olive-sided flycatcher	-	-	-	x
Blue jay	x	xx	x	-
Black-capped chickadee	xx	xx	xx	x
White-breasted nuthatch	-	-	x	x
Red-breasted nuthatch	-	-	xx	-
Brown thrasher	xx	-	-	-
American robin	xx	xxxx	xx	xx
Hermit thrush	-	xx	x	xx
Wood thrush	-	-	xx	-
Veery	-	-	xx	xxx
Golden-crowned kinglet	-	-	xx	-
Ruby-crowned kinglet	-	-	x	-
Cedar waxwing	xx	xx	-	xx
Solitary vireo	-	-	x	x
Red-eyed vireo	x	-	xx	xx
Black-and-white warbler	-	xx	xx	x
Nashville warbler	xx	xx	-	-
Yellow warbler	x	xxxx	-	-
Magnolia warbler	xx	-	-	xx
Yellow-rumped warbler	xx	xx	xx	xx
Black-throated-green warbler	-	-	xxx	xx
Blackburnian warbler	-	-	xxx	x
Chestnut-sided warbler	-	-	-	x
Pine warbler	-	-	xxx	-
Kirtland's warbler	x	-	-	-
Ovenbird	-	xx	xxx	x
Mourning warbler	-	xx	-	xx
Common yellowthroat	xx	xxx	-	xx
Canada warbler	-	-	xx	xx
American redstart	-	-	-	x
Scarlet tanager	-	-	xx	x
Rose-breasted grosbeak	x	-	x	x
Purple finch	xx	-	xx	x
American goldfinch	xxx	xxx	xx	x
Rufous-sided towhee	xx	xxx	xx	x
Vesper sparrow	xx	-	-	-
Dark-eyed junco	xxx	-	xx	x
Chipping sparrow	xxx	xxxx	xx	xx
Field sparrow	xxx	xx	-	-
White-throated sparrow	x	-	x	xxx
Song sparrow	xxxx	xx	-	xxx

Table 12.—Density of bird populations in northeastern spruce-fir by species and forest type, in pairs per 40 ha: 0 = absent, + = < 5, * = 5 to10, ** = 11 to 25, * = > 25 (Crawford and Titterington 1979)**

Species	Balsam fir	Mature spruce	Mixed growth	Budworm spruce-fir	Nonbudworm spruce-fir	Young spruce
Yellow-bellied sapsucker	0	0	*	+	+	0
Black-capped chickadee	0	+	*	+	+	*
Boreal chickadee	+	+	0	*	+	+
Red-breasted nuthatch	+	*	+	*	+	*
Brown creeper	0	+	0	+	0	0
Winter wren	*	+	+	+	+	**
American robin	0	+	+	+	+	**
Wood thrush	0	+	+	0	0	0
Hermit thrush	0	*	+	+	+	+
Swainson's thrush	**	*	+	**	+	**
Veery	0	+	*	+	0	+
Golden-crowned kinglet	0	***	+	*	**	*
Solitary vireo	+	**	0	*	0	0
Red-eyed vireo	+	+	***	*	+	0
Black-and-white warbler	0	0	**	0	*	0
Tennessee warbler	*	0	0	***	0	0
Nashville warbler	0	0	**	*	*	0
Magnolia warbler	**	***	**	***	***	***
Black-throated blue warbler	0	**	+	+	0	0
Cape May warbler	0	0	0	***	0	0
Yellow-rumped warbler	*	*	+	**	**	0
Black-throated green warbler	**	**	*	+	0	+
Blackburnian warbler	+	***	**	**	+	+
Chestnut-sided warbler	0	0	*	0	**	+
Bay-breasted warbler	**	0	0	***	0	0
Ovenbird	+	+	***	*	*	0
Canada warbler	*	*	**	+	0	0
Purple finch	0	*	+	+	+	*
Dark-eyed junco	0	***	0	*	+	***
White-throated sparrow	*	*	*	**	***	0
Ave. pairs/40 ha	128	264	231	334	190	249
Ave. no. species	20	23	24	34	26	17

Table 13.—Snag-using characteristics of cavity-nesting birds of the Northeastern United States (modified from Evans and Conner 1979)

Species	Feeding	Perching	Nesting	Roosting	Optimum d.b.h.			
					4	8	12	20 +
					--------- *inches* ---------			
Wood duck			x					x
Common goldeneye			x					x
Hooded merganser			x					x
Common merganser			x					x
Turkey vulture		x	x					x
Peregrine falcon		x	x					x
Merlin		x	x					x
American kestrel		x	x				x	
Common barn owl		x	x	x				x
Screech owl		x	x	x			x	
Barred owl		x	x	x				x
Boreal owl		x	x	x			x	
Saw-whet owl		x	x	x			x	
Chimney swift			x	x				x
Common flicker	x	x	x	x			x	
Pileated woodpecker	x	x	x	x				x
Red-bellied woodpecker	x	x	x	x			x	
Red-headed woodpecker	x	x	x	x				x
Yellow-bellied sapsucker	x	x	x	x			x	
Hairy woodpecker	x	x	x	x			x	
Downy woodpecker	x	x	x	x		x		
Black-backed woodpecker	x	x	x	x			x	
Three-toed woodpecker	x	x	x	x			x	
Great-crested flycatcher		x	x				x	
Tree swallow			x				x	
Purple martin			x	x			x	
Black-capped chickadee			x		x			
Boreal chickadee			x		x			
Tufted titmouse			x	x			x	
White-breasted nuthatch	x		x	x			x	
Red-breasted nuthatch	x		x	x			x	
Brown creeper	x		x	x			x	
House wren			x	x			x	
Winter wren			x			x		
Eastern bluebird		x	x	x		x		
Prothonotary warbler			x			x		

Table 14.—Generalized relationships between land factors and site-index class for red oak in West Virginia (Weitzman and Trimble 1957)[a]

Aspect	Soil depth	Slope	Slope position			
			Bottom	1/3	2/3	Upper
	Feet	*Percent*				
N,NE,E	1-2	0-20	90	80	70	70
		21-40	80	70	70	60
		41+	70	60	60	50
	2-3	0-20	100	90	80	80
		21-40	90	80	80	70
		41+	80	70	70	60
	3+	0-20	100	90	80	80
		21-40	90	90	80	70
		41+	80	80	70	60
NW,SE	1-2	0-20	80	70	70	60
		21-40	70	60	60	60
		41+	60	60	50	50
	2-3	0-20	90	80	70	70
		21-40	80	70	70	60
		41+	70	60	60	50
	3+	0-20	90	80	80	70
		21-40	80	80	70	60
		41+	70	70	60	60
S,SW,W	1-2	0-20	70	70	60	50
		21-40	60	60	50	50
		41+	50	50	50	40
	2-3	0-20	80	70	70	60
		21-40	70	60	60	60
		41+	60	60	50	50
	3+	0-20	80	80	70	60
		21-40	70	70	60	60
		41+	60	60	60	50

[a]Areas with less than 1 foot of soil generally have site-index values of 30 to 50; oak stands seldom found in areas with site-index values of 90 to 100.

Table 15.—Landtype association (LTA) characteristics of the Ottawa National Forest, Western Upper Peninsula, Michigan (J. Jordan, Ottawa National Forest, pers. commun.)

LTA	Percent forest[a]	Major glacial landform	Dominant soils[b]	Dominant potential vegetation[c]
1	3	Successional moraine	Deep, somewhat excessively drained, coarse textured	*Tsuga* series
2	18	Terminal moraine	Deep, well drained, coarse textured; and moderately well drained, moderately coarse textured	*Acer-Tsuga* series
3	2	Ground moraine, bedrock controlled	Stony, moderately well drained, medium-textured cap over moderately coarse textures	*Acer-Tsuga* series
4	2	Ground moraine, stony	Stony, moderately well drained, moderately coarse textured	*Acer-Tsuga* series
5	6	High, bedrock-controlled moraines and outcrops	Moderately deep, moderately well drained, moderately fine textured	*Acer-Tsuga* series
6	6	Terminal moraine	Moderately well drained, moderately medium-textured cap over moderately fine textures	*Acer-Tsuga* and *Acer* series
7	10	Drumloid ground moraine	Moderately well drained, medium textured and moderately coarse textured	*Acer-Tsuga* and *Acer* series
8		Lake Gogebic		
9	5	Ground moraine	Moderately well drained, somewhat poorly drained and poorly drained, moderately coarse textured	*Acer-Tsuga* and *Tsuga* series
10	1	Ground moraine, wet	Moderately well drained, moderately coarse-textured and very poorly-drained organics	*Acer-Tsuga* and *Tsuga-Thuja* series
11	5	Bedrock controlled, ground moraine	Moderately well drained, moderately coarse textured	*Acer* series
12	3	Ground moraine	Moderately well drained, somewhat poorly drained, fine textured	*Tsuga-Acer* series
13	4	Dissected ground moraine	Moderately well drained, moderately fine textured	*Tsuga-Thuja* series
14	7	Outwash plains	Deep, somewhat excessively drained, coarse textured	*Acer-Quercus* series
14a	3	Valley terraces	Deep, well drained, moderately coarse textured underlain by coarse textured	*Tsuga* series
15	< 1	Outwash lake plain	Deep, excessively drained, coarse textured	*Pinus* series
16	2	Dissected lake plains	Moderately well drained, fine textured	*Tsuga-Thuja* series
17	3	Lake plain, sandy	Deep, somewhat excessively drained, coarse textured; and moderately well drained, medium textured	*Acer-Quercus* and *Tsuga* series
18	6	Dissected lake plain margin	Deep, somewhat excessively, coarse textured; and well drained, medium and coarse textured	*Tsuga* series *Acer-Tsuga* series
19	7	Lake plain, clayey	Deep moderately well drained and somewhat poorly drained, fine textured	*Tsuga-Thuja* and *Fraxinus* series
20	6	River valleys	Somewhat excessively to moderately well drained, coarse to fine textured	Variable

[a]Percentage of total National Forest System ownership (928,221) acres within the Ottawa National Forest boundary.
[b]Soils that make up at least 75% of the LTA.
[c]Series class that is a grouping of plant associations (habitat types) with a common climax, dominant species.

Table 16.—Nutrient removals, leaching losses, and soil capitals for three harvested sites in New Hampshire (Hornbeck and Leak 1992), in pounds per acre

	Calcium			Potassium			Magnesium			Nitrogen			Phosphorus		
Item	SC[a]	BC[b]	WTH[c]	SC	BC	WTH	SC	BC	WTH	SC	BC	WTH	SC	BC	WTH
Removal by harvest	120	156	386	45	58	145	12	16	43	83	109	271	7	8	21
Dissolved ion losses in streamflow due to harvest	30	54	34	34	54	7	3	8	13	25	65	7	0	0	0
Total losses due to harvest	150	210	420	79	112	152	15	24	56	108	174	278	7	8	21
Total soil capital (K)	11.72	11.72	9.56	5.70	5.70	6.02	8.68	8.68	8.79	5.86	5.86	7.82	2.96	2.96	1.42

[a]Strip-cut, bole-only harvest at Hubbard Brook Experimental Forest (Hornbeck et al. 1987).
[b]Block clearcut, bole-only harvest at Hubbard Brook Experimental Forest (Hornbeck et al. 1987).
[c]Block clearcut, whole-tree harvest at Success, New Hampshire (Hornbeck and Kropelin 1982).

Table 17.—Relation of characteristic species to soils and topographic position in north-central Massachusetts (Whitney 1991)

Soils and topographic position	Tree	Shrub	Fern
Moderately to very poorly drained sands and peats	*Picea rubens* *Betula alleghaniensis*	*Ilex sp.* *Kalmia angustifolia* *Kalmia latifolia* *Nemopanthus mucronata* *Vaccinium corymbosum* *Viburnum cassinoides* *Viburnum dentatum*	*Osmunda cinnamomea* *Thelypteris simulata*
Sand plains	*Quercus illicifolia* *Amelanchier sp.* *Pinus rigida*		
Sands-lower slopes		*V. cassinoides*	
Outcrops-midslopes		*Vaccinium vacillans*	*Pteridium aquilinum*
Outcrops-ridge crests	*Betula lenta* *Quercus alba* *Pinus strobus*	*Vaccinium angustifolium*	*Dryopteris marginalis* *Polypodium vulgare*
Till-midslopes	*Quercus rubra* *Castanea dentata* sprouts		
Till-lower slopes	*Tilia americana*	*Viburnum acerifolium*	
Moderately to very poorly drained till; coves	*Acer saccharum* *Tsuga canadensis* *Ostrya virginiana* *Fraxinus americana*	*Corylus sp.* *Hamamelis virginiana* *Viburnum alnifolium* *Viburrnum dentatum*	*Athyrium felix-femina* *Dennstaedtia punctilobula* *Dryopteris spinulosa* *Onoclea sensibilis* *Osmunda cinnamomea* *Polystichum acrostichoides* *Thelypteris noveboracensis*

Table 18.—Soils, habitat types, and characteristic climax species for northern Lake States (Coffman et al. 1983)

Soil	Habitat type	Climax species
Sands	*Pinus-Vaccinium-Deschampsia*	*Pinus banksiana, P. resinosa*
	Pinus-Vaccinium-Carex	*Pinus resinosa, Picea mariana, Pinus banksiana*
	Quercus-Acer-Epigaea	*Quercus rubra, Acer rubrum, Pinus strobus*
	Tsuga-Maianthemum-Vaccinium	*Tsuga canadensis, Acer rubrum*
Loams	*Tsuga-Maianthemum*	*Tsuga canadensis, Acer saccharum, Acer rubrum*
	Acer-Quercus-Viburnum	*Acer rubrum, Quercus rubra*
	Acer-Tsuga-Dryopteris	*Acer saccharum, Tsuga canadensis*
	Acer-Viola-Osmorhiza	*Acer saccharum*
	Osmorhiza-Caulophyllum	*Acer saccharum, Tsuga canadensis, Tilia americana*
Silt/Clay	*Tsuga-Acer-Mitchella*	*Acer saccharum, Tsuga canadensis*
	Tsuga-Thuja-Lonicera	*Tsuga canadensis, Thuja occidentalis, Abies balsamea, Acer saccharum*
	Tsuga-Thuja-Petasites	*Tsuga canadensis, Thuja occidentalis, Abies balsamea, Acer rubrum*
Impeded drainage	*Tsuga-Maianthemum-Coptis*	*Tsuga canadensis, Acer rubrum, Acer saccharum*
	Fraxinus-Impatiens	*Fraxinus americana, Acer rubrum, Acer saccharum, Fraxinus nigra*
	Fraxinus-Mentha-Carex	*Fraxinus nigra, Ulmus americana, Acer rubrum, Carex sp.*
	Fraxinus-Eupatorium	*Fraxinus nigra, Ulmus americana*
	Tsuga-Thuja-Mitella	*Thuja occidentalis, Tsuga canadensis*
	Tsuga-Thuja-Sphagnum	*Tsuga canadensis, Thuja occidentalis, Abies balsames, Picea mariana*
	Picea-Osmunda	*Picea mariana, Thuja occidentalis, Tsuga canadensis*
	Picea-Chaemedaphne-Sphagnum	*Picea mariana, Larix laricina*

Table 19.—Ecological land type phases in the Highland Rim Section (222E) and Shawnee Hills Section (222D) on Hoosier National Forest, Indiana (Van Kley et al. 1995)

Slope position	Aspect/site moisture	Dominant soil characteristics	Vegetation group
		Highland Rim Section (222E)	
Ridgetop—narrow	Dry	Shallow mean A horizon < 3.3 cm	*Quercus prinus / Vaccinium*
Ridgetop	Dry-mesic	Shallow mean A horizon > 3.3 cm	*Quercus alba-Acer saccharum / Parthenocissus*
Upper and mid slopes	Southwest/dry	Shallow mean A horizon < 3.3 cm	*Quercus prinus/Carex picta - Vaccinium*
Upper and mid slopes	South/dry-mesic	Moderate mean A horizon > 3.3 < 6 cm	*Quercus alba-Acer saccharum / Parthenocissus*
Flat ridgetop	Mesic	Deep loess, lacking limestone bedrock	*Fagus-Acer saccharum / Arisaema*
Flat ridgetop	Mesic	Limestone bedrock	*Acer saccharum / Arisaema- Jeffersonia*
Mid and lower slopes	North/mesic	Deeper mean A horizon > 6 cm, lacking limestone bedrock	*Fagus-Acer saccharum / Arisaema*
Mid and lower slopes	Variable/mesic	Limestone bedrock	*Acer saccharum / Jeffersonia*
Bottomland - perennial/ intermittent stream	Headwaters/mesic		*Fagus-Acer saccharum / Arisaema*
Bottomland - minor stream valley	Midreach / wet - mesic		*Platanus / Asarum*
Bottomland major stream valley	Floodplain/ toeslope	Deep alluvial soils, seasonal flooding	*Fagus-Acer saccharum / Boehmeria-Asarum*
Bottomland - major stream floodplain	Bottomlands	Deep alluvial soils, severe seasonal flooding	*Acer saccharinum / Boehmeria*
		Shawnee Hills Section (222D)	
Ridgetop—ridge ends and knobs	Dry	B horizon soil texture, clay loam or coarser	*Quercus prinus / Vaccinium*
Ridgetop—saddles	Dry	B horizon soil texture, clay loam or coarser	*Quercus alba-Acer saccharum / Parthenocissus*
Ridgetop	Dry	B horizon soil texture, fine clay loam or finer	*Quercus stellata / Vaccinium*
Upper and midslopes	Southwest/dry	Moderate mean A horizon > 3.3 < 6 cm; B horizon soil texture, clay loam or coarser	*Quercus prinus /Smilax - Vaccinium*
Upper and midslopes	Exposed south/ dry - mesic	Moderate mean A horizon > 3.3 < 6 cm; B horizon soil texture, clay loam or coarser	*Quercus alba-Acer saccharum / Parthenocissus*
Upper and midslopes	Southwest/dry	Moderate mean A horizon > 3.3 < 6 cm; B horizon soil texture, fine clay loam or finer	*Quercus stellata / Vaccinium*
Upper and midslopes	Southwest/dry	Moderate mean A horizon > 3.3 < 6 cm; B horizon soil texture, fine clay loam or finer	*Quercus stellata / Eryngium*
Cliffs		Limestone/sandstone	*Acer rubrum-Quercus sp.-Fagus / Hydrangea*
Flat ridgetop	Mesic	Fragipans usually present	*Fagus-Acer saccharum / Arisaema*
Midslopes	Northeast/mesic	Weathered sandstone with loess	*Fagus-Acer saccharum / Arisaema*
Mid to lower slopes and benches	Northeast/wet- mesic	Small limestone outcrops, elevated soil pH	*Acer saccharum / Asarum*
Midslopes	Variable/mesic	Small limestone outcrops, elevated soil pH	*Acer saccharum / Arisaema- Jeffersonia*
Bottomland- perennial/ intermittent stream	Headwaters/wet - mesic		*Fagus-Acer saccharum / Arisaema*
Bottomland-minor stream valley	Midreach/wet- mesic		*Platanus / Asarum*
Bottomland-major stream floodplain	Bottomlands	Fresh alluvium visible, seasonal flooding	*Acer saccharinum / Boehmeria*

Leak, William B.; Yamasaki, Mariko; Kittredge, David, B. , Jr.; Lamson, Neil I.; Smith, Marie-Louise. 1997. **Applied ecosystem management on nonindustrial forest land.** Gen. Tech. Rep. NE-239. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 30 p.

Defines ecosystem management, discusses the terminology and attributes related to this broad approach to forest management and protection, and lists specific steps for applying ecosystem management on a typical nonindustrial private ownership in New England.

Keywords: Ecosystem management, nonindustrial ownership, sustainability, landscape ecology.

Headquarters of the Northeastern Forest Experiment Station is in Radnor, Pennsylvania. Field laboratories are maintained at:

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