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Biodiversity in the Forests of Maine:

Guidelines for Land Management

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Acknowledgements

There are two groups of people whose contributions to this manual were vital and invaluable. The members of the Working Forest Committee, listed on the next page, persevered through many long, difficult discussions to come to agreement about the subject matter for the manual, and the initial definition, goal, and importance to biodiversity statements. The authors took on the daunting task of filling in the details, including recommended practices. Meeting with a committee to hear comment on and criticism of one's writing is never easy, but the authors took it all in good humor. The Working Forest Committee continued their work through two more drafts, working towards agreement whenever possible, agreeing to disagree when necessary, and taking on the ultimate responsibility for the content of the manual. The result, this manual, is a testament to the dedication, expertise, and tenacity of the committee and the authors. It was a privilege to work with them.

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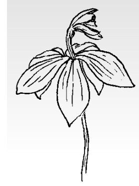
Overview:

Introduction

By Catherine A. Elliott, Gro Flatebo,
Carol R. Foss, and Philip Gerard



THE EFFECTS OF FOREST MANAGEMENT practices on both site-specific and landscape-level characteristics influence biological diversity in Maine's managed forest. This manual provides descriptions of those characteristics and recommends voluntary forestry practices that can help maintain forest biodiversity in Maine. The recommendations apply to private and public forestlands that are actively managed to produce timber and other forest products. The suggested practices are intended to maintain current biodiversity, but they can also be used to enhance components of biodiversity that have become locally or regionally uncommon. These recommendations contribute to the growing body of knowledge about managing forest resources but are not intended to be considered a comprehensive guide to forest management. Best Management Practices (BMPs) for erosion control and protection of water quality, silvicultural guidelines, species-specific habitat management practices, and techniques for addressing aesthetics, recreational, and non-timber income-producing activities are addressed in other publications.

By focusing on the potential influences of forest management on biological diversity this publication complements and expands on "A Forester's Guide to Managing Wildlife Habitats in Maine" (Elliott 1988), while adding a set of broad, landscape-level considerations and recommendations that have been absent from most previously published guidelines. The manual is primarily intended for use by foresters, biologists, loggers, forestland owners, and forestland managers; educators, land-use planners, and others interested in forest biodiversity will also find it useful. A list of agencies and organizations in Maine that offer landowner advice or assistance related to forest biodiversity is included in Appendix A.

Each chapter is organized using these headings:

- Definition: A concise description of the characteristic being addressed.
- Importance to Biodiversity: A statement of how the characteristic supports biodiversity.
- Goal: The desired outcome of the recommended practices.
- Background and Rationale: A summary of available information about the characteristic, outlining reasons for concern, relevance of the topic to forest management and biodiversity conservation, and justification for the recommended actions.
- Considerations: Factors that may influence implementation of the recommended practices.
- Recommended Practices: Specific actions that landowners can implement to maintain biodiversity while conducting forest management. Look for the R symbol to find pages where Recommended Practices are listed.
- Cross References: A list of other chapters containing related information.
- References and Literature Cited: The scientific literature from which the information in the text was drawn, and additional reference material.

It is important to note that it is not necessary, desirable, or even possible, to implement every suggested practice on every acre of land. Certain recommendations, such as those relating to buffer zones or protected areas, may involve economic tradeoffs unacceptable to some landowners. Other suggested practices, such as those relating to soil productivity, are generally applicable regardless of landowner objectives or forest type. Some recommendations, such as those related to special habitats, will not apply to all ownerships. In some instances, recommendations that address different characteristics of biodiversity are contradictory. Recommendations for managing forested landscapes focus on characteristics of biodiversity that occur at scales larger than a single stand. They can be considered when managing ownerships of all sizes, but the larger the parcel, the more recommendations can be applied. Another important point to keep in mind is that a practice implemented to address one aspect of biodiversity may address several other aspects as well. Finally, although some landowners may have the resources to implement many of the recommendations immediately, others may need to approach implementation over a longer period of time.

Although this manual is a compendium of the best scientific data and theory currently available, it should be viewed as a work in progress. It is fairly certain that lengthening rotations and growing larger trees in multi-aged stands can be used to improve the status of biodiversity. The effectiveness of silvicultural manipulation (e.g., retaining mature structural components in younger even-aged stands) in maintaining or enhancing biodiversity is still the subject of research and debate. Monitoring, as well as current and future manipulative studies, will be necessary to evaluate the success or failure of the practices suggested here. Through adoption of adaptive management, where new knowledge is acquired and quickly transformed into forest management practices, techniques for maintaining and enhancing biodiversity will continue to evolve.

Readers' interests and needs will direct their approach to exploring this manual. The Overview and the introductions to the sections on Site-Specific and Landscape-Level Considerations are recommended for all readers. For some, specific sections or chapters may be of particular interest; other readers may undertake to read the entire manual. Whatever your purpose or approach, it is hoped that you will find the information presented to be useful, understandable, and thought provoking.

Your comments and suggestions are welcome and should be addressed to the editor.

Overview:

The Maine Forest Biodiversity Project

By Gro Flatebo and Carol R. Foss

IN MAY OF 1994, NEARLY 100 PEOPLE CAME together to discuss the issue of biodiversity in Maine's forests. Representing forestland owners and managers (large and small, public and private, non-profit and commercial), advocates (environmental, sporting, property-rights, land-conservation, and others), the scientific community, state and federal agencies, and educators, the group learned from outside experts and from each other. At the end of this two-day meeting, the group agreed to constitute itself as the Maine Forest Biodiversity Project (MFBP), to meet again for further mutual education about biodiversity, and to begin work on three tasks:

1. assessing the status and trends of biodiversity in Maine;
2. recommending forest practices that help to maintain biodiversity; and
3. completing an effort begun by the Maine State Planning Office to define and assess the potential for an ecological reserve system on Maine's public and private conservation lands.

During the next four years, the group met regularly to discuss the conservation of biodiversity, to stay apprised of various protection and research efforts currently underway, and to keep up with the developing science of this emerging field. Along the way several projects were undertaken[1] to further explore the status of Maine's biodiversity and steps that could be taken to help maintain it. The mission of the MFBP has been to explore and develop strategies that help maintain viable populations of existing native species and viable representatives of existing native ecosystems in Maine. MFBP participants believe that the maintenance of biodiversity can be achieved through a combination of reserve lands and managed forests.

Meeting monthly for over a year, the Working Forest Committee of the MFBP came to agreement on a list of forest characteristics relevant to biodiversity that are affected by forest management. A definition, explanation of importance, and management goal were

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[1] MFBP initiates include:

- Publications:
  - Gawler, S.C., J.J. Albright, P.D. Vickery, and F.C. Smith. 1996. Biological Diversity in Maine: an assessment of status and trends in the terrestrial and freshwater landscape. Report prepared for the Maine Forest Biodiversity Project. Natural Areas Program, Maine Dept. Cons., Augusta, ME. 80 pp. + app.
  - McMahon, J. 1998. An Inventory of Potential Ecological Reserves on Maine's Public Lands and Private Conservation Lands. Report prepared for the Maine Forest Biodiversity Project. State Planning Office, Maine Dept. Cons., August, ME. 121 pp.
  - Elliott, C.A. (Ed.). 1999. Biodiversity in the Forests of Maine: guidelines for land management. Manual prepared for the Maine Forest Biodiversity Project. Univ. Maine Coop. Ext., Univ. Maine, Orono, ME. Bull. 7147. 134 pp. + app.
  - Allen, T.G. and A.J. Plantinga. 1999. Investigations into the Potential of Measuring Biodiversity in Maine's Forests with Forest Inventory and Analysis (FIA) Data. Maine Agric. For. Exp. Sta., Univ. Maine, Orono, ME. Tech. Bull. 171. 89 pp.
- Public conference titled "Biodiversity in Maine: Issues and Opportunities" was held 20 November 1998 at the University of Maine.

developed for each of these forest characteristics. Realizing the value of this information to forestland owners, managers, foresters, loggers, and others around the state, the MFBP hired a team of authors to write a manual useful both as a reference and as a field guide to maintaining biodiversity in the managed forest. In addition to the authors who completed the manual, Charles Niebling, formerly of Innovative Natural Resource Solutions, contributed to early versions. Three full manuscript drafts received both individual review and over 50 hours of panel review by the 22 members of the committee. This manual represents several years of collaborative effort among committee members, the authors, and the editor.

Members of the Working Forest Committee included many of Maine's senior foresters, biologists, and ecologists. These professionals brought their expertise to this project from their work as research scientists, professional foresters and wildlife biologists, state and federal agency personnel, and scientific specialists for environmental organizations. Because of the diversity of experience represented by this group, the inherent difficulties of a group writing process, and the rapidly growing pool of information on the subject of biodiversity, not all committee members are in complete agreement with every aspect of this manual. Although the original list of forest characteristics was developed by consensus, presentation of specific management practices does not imply unanimous endorsement by all members of the committee. However, it is hoped that the diversity of committee member backgrounds that sometimes precluded agreement has, by nature of that same diversity, increased the value of this manual as an effective and practical guide.

Overview:

Managed Forests and Biodiversity

By Gro Flatebo, Carol R. Foss, and Philip Gerard

BROADLY DEFINED, BIOLOGICAL DIVERSITY, OR "biodiversity," includes all forms of life — trees and other plants, invertebrate and vertebrate animals, fungi, and microorganism—as well as the different levels at which life operates, from genetic differences among individuals to complex interactions within ecosystems (Gawler et al. 1996, Hunter 1997). The term biodiversity encompasses biological "structures" (genes, organisms, populations, or communities) as well as biological "processes" (energy transfer, nutrient cycling, and succession).

A primary goal for biodiversity in Maine's managed forest is to ensure that adequate habitat is present over time across the landscape to maintain viable populations of all native plant and animal species currently occurring in Maine. The information presented in this manual can help managers accomplish this goal by implementing recommended stand- and landscape-level practices.

At the stand level, management techniques related to canopy structure, tree species diversity, dead wood, mast, and soils are presented. In addition, management recommendations for special habitats and ecosystems are included. At the landscape level, planning for the presence of all forest-community types and successional stages, while avoiding fragmentation and ensuring connectivity, is addressed.

Management for forest products can be a relatively biodiversity-friendly use of the land. The myriad of organisms that persist and thrive in many managed forests bear testimony to the compatibility of maintaining biodiversity and managing for timber and other forest products. Of course, other human-related factors also affect forest biodiversity including air and water pollution, exotic diseases and pests, conversion to other land uses, and activities such as hunting, trapping, fishing, and recreation. These factors are also addressed in this manual.

Biodiversity is of interest to foresters and forestland owners for a number of reasons well beyond protection of rare or endangered species. Biodiversity provides an important natural stabilizing mechanism within ecosystems and supports a number of essential forest-ecosystem functions. Pollination, seed dispersal, the breakdown of nutrients and organic matter, pest control, and other vital processes all depend on the variety of organisms and interactions represented by biodiversity.

Forestland managers who strive to understand the effects of forest management on biodiversity will gain practical information on supporting long-term forest health and integrity. In addition, biodiversity can provide a forestland manager with an effective, efficient, and robust context for long-term forest management and conservation (Waller 1996):

1. Biodiversity represents a broad and important set of ecological values, including ecological processes as well as species and habitats.
2. Concern for biodiversity is inclusive and allows managers to integrate multiple concerns, managing the overall system

instead of favoring particular species or habitats over others.

3. By emphasizing ecosystems and processes, maintaining biodiversity protects many species, including those that are obscure, unknown, or inadequately studied, before they become threatened or endangered.
4. Effectively maintaining biodiversity protects environmental values such as air and water quality.
5. Protecting individual threatened or endangered species is an important but insufficient conservation strategy; managing for biodiversity allows more flexible options and solutions.
6. Maintaining ecological processes requires attention to larger areas and more informed management.
7. Maintaining biodiversity often entails a landscape approach to ensure adequate representation and connectivity of habitat types.

In the past, foresters have included management for particular wildlife species or small groups of species and for water quality in their management planning process. Many practitioners are now incorporating additional considerations important to the broadest array of species and ecological processes. These include attention to the physical structure of the forest, stand size and shape, and the importance of biological legacies (structural elements that provide continuity of ecological process, species, and habitats between mature and regenerating stands, such as live overstory trees, patches of older forest, multiple canopy layers, and forest-floor characteristics). Maintaining biodiversity also involves looking at and managing forests at multiple scales, including stands, watersheds, and regions, because ecosystems and ecosystem processes occur at these overlapping scales. Because no single stand provides all habitat values or maintains all ecological processes, landscape-level analysis can help to determine whether an appropriate balance of habitats is available on the landscape, and whether there is adequate connectivity among habitats to maintain all components of biodiversity.

Knowledge of the relationship between forest practices and the needs of individual wildlife species is important, particularly when a species requires specific habitat elements (e.g., large nest trees for some raptors) or natural communities within the forest (e.g., mature softwood stands for over-wintering deer) to complete their life cycles. However, our knowledge of the habitat relationships of most of Maine’s forest species is inadequate for management on a species-by-species basis. Thus, an effective approach for conserving native wildlife species in Maine’s managed forests is to focus on characteristics of site-specific and landscape-level structure and composition likely to maintain habitat quality for most of the state’s forest species.

In the past decade many states and provinces in North America have begun to plan for systems of protected areas, commonly referred to as ecological reserves, specifically to achieve the goal of maintaining biodiversity. Ecological reserves, which are usually off-limits to timber harvesting, may be created to provide habitat for rare or very sensitive species or to serve as benchmark areas for study of undisturbed forest systems. Private forestlands assume an important role in attaining this goal because public-reserve lands are usually next to or embedded in private lands. Additionally, most reserves, on their own, are unlikely to be large enough to maintain a region’s biodiversity (McMahon 1993). The management recommendations presented in this manual are intended to strengthen the contributions of private and public forestlands to maintain biodiversity on local and regional scales.

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Gawler, S.C., J.J. Albright, P.D. Vickery, and F.C. Smith. 1996. Biological Diversity in Maine: an assessment of status and trends in the terrestrial and freshwater landscape. Report prepared for the Maine Forest Biodiversity Project. Natural Areas Program, Maine Dept. Cons., Augusta, ME. 80 pp. + app.

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Key Concepts

By Gro Flatebo

MAINTAINING BIODIVERSITY IN MAINE'S managed forest is an important challenge as we move into the next millenium. The chapters in this manual detail goals, background information, and management recommendations for 22 characteristics critical to maintaining forest biodiversity. For those faced with the task of incorporating the recommendations into on-the-ground management plans, it is important to keep in mind two factors:

1. a single recommended practice may serve multiple purposes; and
2. not all practices can, or should, be implemented on every acre.

To further assist readers with synthesizing this material, six key concepts have been drawn from the chapters to provide a starting point:

- Think of individual stands as part of the landscape in which they are embedded. Forest managers can consider the interconnectedness of ecosystems, the proportions of stand types and successional stages, and the spatial pattern of stand types, sizes, and successional stages on the landscape. Planning at the landscape level provides continuity of ecosystem types over time, enabling species to disperse and colonize. Landowners with small holdings can manage their lands with an eye to the characteristics of the surrounding forests.
- Within the mosaic of stand types, sizes, and age classes on the landscape, maintain a component of mature and overmature forest. Maintaining complexity across the landscape enhances biodiversity and dampens the effects of natural disturbances. Late-successional stands that are functional in terms of size and structure host an array of species that are less abundant in younger forests, as well as some species that depend on late-successional conditions.

- Consider what natural disturbance processes have taught us about tools and mechanisms to maintain biodiversity. Natural disturbances, including fire, wind, ice, insects, and pathogens, produced the landscape patterns in which native plants and animals evolved and continue to contribute to the heterogeneity of our forests. Most natural disturbances leave complex patterns of stand shapes, sizes, and ages, as well as complex structures including woody debris and remnant live patches.
- Maintain biological legacies within stands. Biological legacies are the threads of continuity passing from old to new stands. Examples of biological legacies are large, dead wood left on site after a harvest; large, live overstory trees; patches of older forest; multiple canopy layers; and soil structural characteristics of the forest floor. Biological legacies maintain processes, habitats, and linkages within the stand.
- Consider what is left behind during a harvest, as well as what is removed. Maintaining biodiversity and forest sustainability requires attention to the structure and processes that persist after the harvest has been completed.

- Understand the importance of special habitats and features on your land and adapt your management to maintain them. Many special habitats and features are critical for certain species at some point in their life cycle. They are often rare or especially vulnerable to alteration or disturbance and require special consideration during forest management activities.

Site-Specific Considerations:

Introduction

By Carol R. Foss

MAINE HAS A DIVERSE PATTERN OF FOREST-land ownership, from small holdings of a few acres to large ownerships of millions of acres. Practices are described that all landowners, regardless of size or type of ownership, can incorporate into their forest management activities, but not all site-specific practices are applicable to every acre of every ownership, and some may be contradictory. In general, a combination of site-specific and landscape-level practices is most practical and is likely to have a positive effect on biodiversity.

Site-specific considerations include five stand characteristics and 10 special habitats and ecosystems. Stand characteristics addressed are:

1. vertical structure and crown closure,
2. native species composition,
3. downed woody material, snags, and cavity trees,
4. mast, and
5. forest soils, forest floor, and site productivity.

Special habitats and ecosystems are discrete, localized areas that may be rare across the landscape, such as old growth and primary forests, or somewhat common, such as vernal pools. They often provide habitat for species or species groups that are found nowhere else. Special habitats and ecosystems may be entirely within a small ownership. Although streams, rivers, lakes, and wetlands may cross multiple ownerships or vast landscapes, a chapter on riparian and stream ecosystems is included here because negative effects on biodiversity in these habitats are often the result of cumulative site-specific actions by individual landowners.

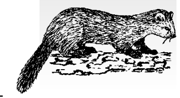
Of the many unique forest habitats or ecosystems that one may encounter in Maine, 10 were considered to be most directly affected by forestland management and most important to biodiversity in Maine's managed forest. They are:

1. riparian and stream ecosystems,
2. vernal pools,
3. beaver-influenced ecosystems,
4. woodland seeps and springs,
5. nesting areas for colonial wading birds,
6. deer wintering areas,
7. nest sites for woodland raptors,
8. old-growth and primary forests,
9. rare plant or animal sites, and
10. rare natural communities.

Stand Characteristics:

Vertical Structure and Crown Closure

By Gro Flatebo



DEFINITION

Vertical structure is the extent to which plants are layered within a stand. The degree of layering varies with forest type and is determined by the arrangement of growth forms (trees, vines, shrubs, herbs, mosses, lichens, and liverworts), by the distribution of different tree species having different heights, diameters, and crown characteristics, and by trees of the same species but of different ages and sizes. The extent to which vertical structure varies within the stand determines the degree of vertical diversity. Crown closure is the degree to which the overstory foliage fills the growing space. Stand density as well as growth form, leaf type, and other crown characteristics affect crown closure.

IMPORTANCE TO BIODIVERSITY

In many forest types, vertical structure provides a range of habitats used by different organisms. Forests that are well stratified will generally support a greater array of plant and animal species as compared to forests in which most of the vegetation is concentrated in one layer. Lack of vertical structure can have negative effects on species that rely on specific layers of vegetation for food and cover. Crown closure is a major determinant of the amount of light, precipitation, wind, heat, and other factors that penetrate the canopy and reach the forest floor. The resulting macro- and microclimatic conditions affect the diversity of organisms that occur.

GOAL

Maintain an adequate representation of diverse vertical structures and degrees of crown closure in forest types that are naturally characterized by a variety of foliage layers and crown closures.

BACKGROUND AND RATIONALE

The degree of development of vertical structure is a result of a stand's stage of development, stand disturbance history, age structure, site productivity, and species composition. Maine's forests usually develop several layers of foliage — an overstory, understory, shrub layer, and ground or herb layer (Figure 1).

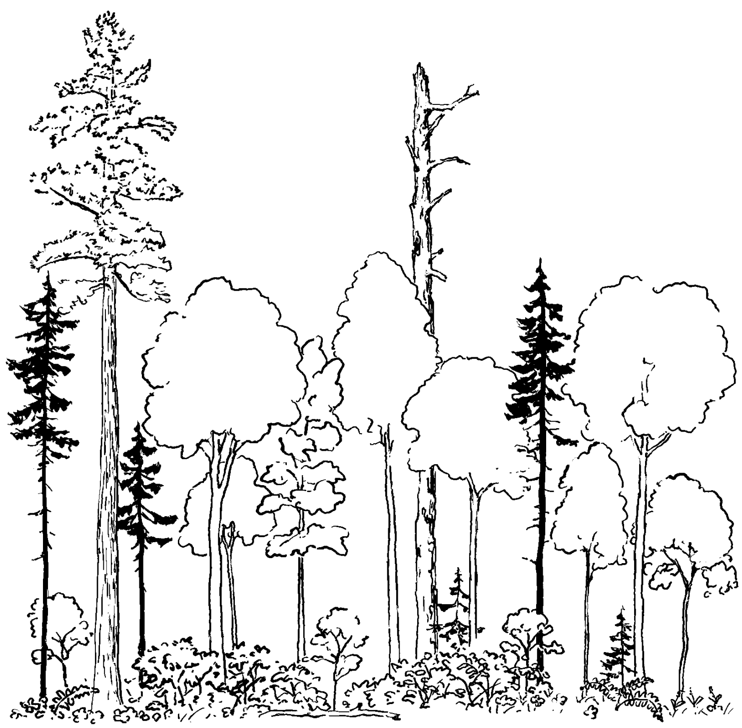


Figure 1

Vertical structure in a forest is determined by the presence or absence of foliage layers from the ground to the upper canopy. The degree of crown closure influences the development of understory, shrub, and ground vegetation layers.

In an even-aged stand, a forest canopy forms about 10 to 20 years following disturbance. As the canopy closes, vegetation on the forest floor begins to thin and die out and species composition changes. During the initial stages of crown closure, the canopy is dense and little light reaches the forest floor. After several decades, as subdominant trees in the crown die, more light reaches the forest floor and plants can survive in the understory. As the base of the living canopy rises, more light reaches the forest floor and plants can invade and survive. The implications of these stages on biodiversity are outlined in Table 1.

Vertical structure is limited in early- and mid-successional stands. However, some common wildlife species thrive in these stands where a dense layer of ground vegetation provides protection from weather and predators, easily accessible food, and seasonally important food. Ungulates, such as white-tailed deer, as well as many other mammals, birds, and invertebrates use these stands (DeGraaf et al. 1992).

Later successional stages feature an older, more-developed canopy that is taller and has more vertical structure. This translates into greater foliage-height diversity, more canopy gaps, greater foliar biomass, and greater leaf-surface area that provide a variety of habitats that are used extensively by birds, small mammals, epiphytes, and invertebrates. As canopy heights increase, vertical profiling and selective use of the canopy by birds increases. For example, raptors use trees above the canopy as nesting or roosting sites; hawking and sallying species favor open sites in the upper canopy where there is greater maneuverability; foliage gleaners focus their foraging on leaves recently exposed to sunlight; and trunk-gleaning species favor lower, older portions of the canopy where furrowed bark is more abundant (Sharpe 1996). The live and dead branches and generally rougher bark of large trees host a myriad of invertebrates, epiphytes (mosses, lichens, and liverworts), and microbial organisms.

Table 1

Features of biodiversity at four stages of stand development. (Adapted from Oliver and Larson 1996).

Stand Development Stage	Stage Age (depends on site quality)	Coarse Woody Debris (Spies 1997)	Vertical Structure	Plant Species Diversity	Animal Species Diversity
Stand Initiation site conditions	10 to 30 years depending on depending on disturbance type	Variable to plentiful	Simple	High	High[1]
Stem Exclusion	20 to 80 years	Variable, plentiful if decay-resistant trees in initial stand	Simple	Low	Low
Understory Reinitiation	60 to 150 years	Little, few inputs	Becoming more complex	Medium	Medium
Shifting Mosaic or Old Growth	150 years +	Plentiful	Complex	High	High[2]

[1] Vertebrate and invertebrate species adapted to open habitats.

[2] Fewer common species than in the stand initiation phase. Typically, species use large dead trees, deep multi-layered canopies, deep forest soils, or organic matter.

Site productivity relates to vertical diversity in that it can affect the rate of succession. Better-quality sites compact seral stages into fewer years, and vertical diversity will develop sooner on better sites than on poorer sites (Crawford and Frank 1987).

Coniferous overstory inclusions of hemlock, spruce, fir, or pine can provide feeding, nesting, and winter shelter opportunities that are otherwise not available in hardwood stands. Likewise oak, beech, and other hardwoods in conifer stands can provide foraging and nesting sites as well as mast. Wildlife use of overstory inclusions increases as the trees increase in size (DeGraaf et al. 1992).

A range of tree sizes will foster a greater diversity of wildlife species. For example, some bird species, such as the redstart and brown creeper, prefer small trees, while others, such as great blue heron, osprey, and owls, require larger trees.

The plant species within a stand influence vertical structure through their growth forms, crown characteristics, and leaf type (i.e., broad-leaved deciduous versus needles). These characteristics, together with stand density, determine how much light penetrates the forest canopy to reach the understory and forest floor to support other vegetation layers.

As a general rule, even-aged forests have little vertical structure and uneven-aged forests have more vertical structure (Hunter 1990). Forest stands under even-aged management cycle between the stand-initiation stage, stem-exclusion stage, and the understory-reinitiation stage. More recently, some stands are being harvested midway through the stem-exclusion stage (Seymour 1992). Even-aged forest management can simplify forest structure by fostering a younger forest with less vertical structure.

Uneven-aged stands have several age classes of trees and consequently several layers of foliage. Some of the vertical diversity in Maine's uneven-aged forests results from horizontal patchiness of vegetation. Small natural disturbances such as windthrow, ice damage, and mortality from insects and disease, create gaps in the canopy that foster younger trees and increase the overall diversity of the stand. Three general silvicultural approaches are available to enhance vertical structure in even- and uneven-aged stands (Franklin et al. 1997):

1. Longer rotations — Extending the time period between harvests allows structural elements to develop naturally within the stand. These include a range of tree sizes and ages as well as vertical structure. However, if used without structural retention (see 2.), the value of longer rotations will be more limited as important structural features do not occur until late in the rotation.
2. Structural retention — Trees are left on site after a harvest or thinning to retain structural elements as a legacy for the new stand. In essence, retention brings multi-aged characteristics to even-aged systems. This strategy can support greater biodiversity (compared to stands of the same age without retained structure), maintain refugia for organisms and processes in harvested areas, enhance connectivity of the managed landscape, and structurally enrich the next forest stand. Retained structures include living trees of various species, sizes, and conditions as well as standing dead trees and fallen logs. Retained structures can be dispersed throughout the stand or be aggregated in clumps.

   Retained patches of forest provide a broader variety of stand structural elements than individual trees retained across the harvested area. They offer undisturbed forest-litter layers, multiple layers of vegetation, and more-stable microclimatic conditions. Trees dispersed across the site can provide habitat for species that are strongly territorial or that require specific structures such as cavity trees. Their value for biodiversity increases as the stand surrounding these trees matures.
3. Structural enhancement — Silvicultural treatments can enhance the development of vertical structure in forests. For example, thinning accelerates understory development and succession while moving the stand into the understory reinitiation

stage (DeBell et al. 1997). Frequent and light thinnings, creating snags and openings in the canopy, can enhance vertical structure in a stand, as can choosing trees to leave during thinning to increase species diversity and variation in tree size. A shelterwood cut done over several stages will create a range of ages within the stand, especially if several overstory trees are left after the final overstory removal.

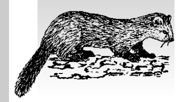
Another key aspect of vertical structure, referred to as crown closure, is the degree to which the overstory foliage fills the growing space. It affects the amount of sunlight reaching the various layers of the forest. Crown closure also affects the amount and pattern of precipitation within the canopy and reaching the forest floor, as trees intercept the moisture and redistribute it through stem flow, throughfall, or evaporation. The canopy also affects the amount of heat, moisture, and snow cover near the forest floor. Greater degrees of crown closure are generally related to deeper litter layers and a darker, cooler, moisture microenvironment on the forest floor—conditions important for some amphibians, invertebrates, small mammals, plants, and fungi. Lesser degrees of canopy closure are often essential to regenerate intolerant tree species. In hardwood forests, cuts leaving less than 70 square feet of basal area may result in changes in forest-floor microclimate with consequent effects on species composition, e.g., regeneration of intolerant species such as raspberries (Barrett et al. 1962). Under full canopy closure, animals are less subject to extremes in temperature, solar radiation, windspeed, humidity, rain throughfall, snow accumulation, and predation.

Different wildlife species are adapted to differing crown closures and structures as part of all of their habitat requirements. DeGraaf (1992) estimates that 35 species of New England wildlife use habitats with minimum canopy closure (less than 15%), as can be found in old pastures, recent clearcut stands, and some shelterwood or seed-tree cuts; 50 species use habitats with partial canopy closure (15% to 70%), as can be found in clearcuts, open shelterwoods, sugarbush stands and low-density pine stands (partial-canopy conditions can be short-lived, with an overstory filling in after several years); and 43 species use closed-canopy habitats (70% or greater closure) such as uneven-aged hardwoods, and in even-aged stands where stocking is maintained at these levels.

Crown roughness is another feature of vertical structure. Crown canopies are relatively smooth in even-aged stands, rougher in mixed-species stands, and roughest in uneven-aged stands.

CONSIDERATIONS

- Landowner objectives will guide whether and how much timber is left for structural retention within a stand. In even-aged systems, structural retention of trees can increase harvest and regeneration costs, decrease income for landowners and loggers, create safety issues for woods workers and affect the regeneration of intolerant species (Hanson and Hounihan 1996).
- In even-aged systems, the overall timber quality of trees retained in clumps after overstory removal may be low. Trees in the center of the clump will be slow-growing with small diameters and limbs. Trees growing on the edges of the clumps become tapered with large limbs on one side and a tendency to become wolf trees (Oliver and Larsen 1996).
- New stands are typically not at risk from diseases and pests spreading from older trees retained in the stand. The retained trees are much older and have a different set of insect pests than the younger, managed component of a stand (Franklin et al. 1997).



- Repeated thinnings, if too light, can encourage the development of a mid-story of shade-tolerant species that shade out understory plants, reducing the amount of forage available to ungulates and other animals.

RECOMMENDED PRACTICES

General

- Avoid thinning a stand in only one stratum, as it may reduce stand vertical structure and species richness, especially in even-aged, stratified stands of mixed species.
- During thinning operations, retain trees that will increase species diversity and variation in tree size in the stand. When possible, strive to keep the lower, mid, and overstory layers approximately equal in foliage volume (Crawford and Frank 1987).
- Irregular shelterwood harvests help enhance vertical structure by creating two-story stands. Three-stage shelterwood cuts create more vertical structure than two-stage shelterwood cuts (Crawford and Frank 1987). After regeneration has established, retain some shelterwood trees to produce large overstory trees and a multi-layered stand.
- Maintain softwood inclusions in hardwood stands and hardwood inclusions in softwood stands.
- Crown thinnings create an open canopy that enhances the development of herb and shrub layers and promotes the development of deeper crowns, maintaining plant-species richness and vertical diversity (Hunter 1990). Carefully choose trees for removal so as not to decrease tree-species diversity.
- Retain a variety of vertical structures over the landscape, i.e., some stands with closed canopies and a sparse understory, some with open-crowned canopies of intolerant trees with an understory of tolerant saplings, and some with foliage evenly distributed among all vegetation layers. A significant portion of the landscape should be managed for uneven-aged structure (Hunter 1990).

Even-aged Management

- Retain some overstory trees during harvest. The number or percent of trees retained will depend on landowner objectives and the conditions of the stand, but from a biodiversity standpoint the more trees retained the better. Where possible leave several large trees (> 12” dbh) following harvesting or thinning. Combine patches of trees with individual trees dispersed across the site to gain the ecological benefits of both. In clearcuts of greater than 10 acres, patches are preferable to dispersed trees (Woodley and Forbes 1997).
- When removing overstory trees, some deep-rooted trees, such as white pine, American beech, and red oak, can be retained as individuals dispersed across the site; shallow-rooted species, such as red spruce, may need to be left in clumps (Seymour 1992).
- Retained patches should be representative of initial stand conditions in terms of species composition and diameter distribution, and provide intact forest understories and soil organic layers. Patches can be oriented around potential snag trees.
- Leave trees that can naturally degrade into snags and standing deadwood, such as trees damaged by natural disturbances or previous harvests (i.e., broken tops, scarred boles, or lightning strikes). However, some healthy large trees that are not hollow or damaged should be retained. They ensure a healthier genetic and structural composition for the future stand as well as potential snags.

- Trees retained on the site need to be windfirm. Leave trees on the windward side of clearcuts away from shallow soils, ridges, and saddles to avoid windthrow (DeGraaf et al. 1992).
- Vertical structure can be maintained in plantations by planting a variety of species at spacings wide enough to maintain final volume but still allow a more-open canopy.

Uneven-aged Management

- Selection harvesting will produce uneven-height forests with more vertical diversity (Hunter 1990). In spruce-fir, single-tree selection provides more canopy layers per acre than any other silvicultural system (Crawford and Titterington 1979). Uneven-aged management using the group-selection system will increase horizontal diversity across the stand. Large group cuts may favor wildlife species that depend on stand openings and decrease habitat for crown-dependent species (Crawford and Frank 1987).
- Create small openings or gaps in the canopy, as in group-selection methods.

CROSS REFERENCES

General Principles; Downed Woody Material, Snags and Cavity Trees; Habitat Patch Size

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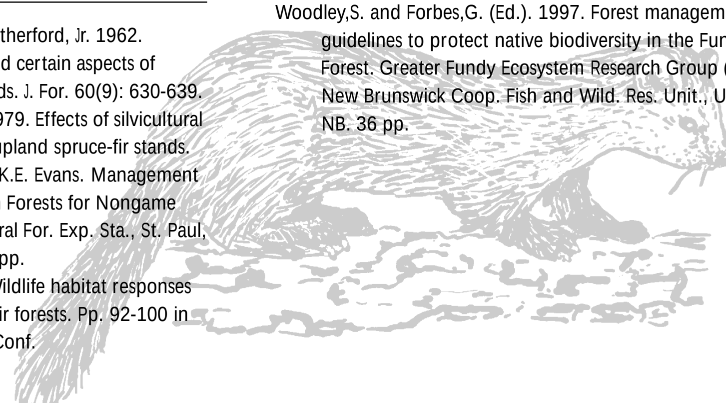

Stand Characteristics:

Native Tree-Species Composition

By Carol R. Foss

DEFINITION

Native tree-species composition refers to the combinations and proportions of indigenous native tree species that constitute a stand.

IMPORTANCE TO BIODIVERSITY

Each tree species provides different types of habitat for other plant and animal species, and influences other trees in the stand. Maintaining native composition in stands has the potential to reduce susceptibility to some catastrophes.

GOAL

Maintain natural tree-species composition as appropriate to site and successional stage of the stand.

BACKGROUND AND RATIONALE

Trees determine the character of forest stands. As the largest plants in the forest, they dominate the vegetation and provide the structure on which many other forms of life depend. Of Maine's 64 species of forest trees (Appendix B), about half are considered common to abundant, and most of these occur throughout the state. Many of the state's rare and uncommon species, such as shagbark and bitternut hickories, black birch, and scarlet and chestnut oaks, are restricted to the southern counties (MFS 1995, Gawler et al. 1996). Several tree species have declined in abundance or distribution in the past century. Disease has reduced populations of some, such as American elm, American chestnut, and butternut. Slippery elm and American sycamore, both inhabitants of riparian areas, may have disappeared from Maine in recent decades (Gawler et al. 1996). Some species (e.g., white pine, red spruce) have remained abundant in the state but have become uncommon in particular stands from past harvesting practices (Seymour and Hunter 1992). No tree species are known to have been threatened with or become extirpated because of timber harvesting.

Tree species influence their environment in a number of ways, creating different habitat conditions for tree seedlings, understory plants, and animals. Crown shape and foliage size, type (i.e., deciduous or coniferous), and orientation affect light infiltration and canopy interception of rain and snow, creating a variety of light and moisture conditions at the understory and ground levels. Chemical composition of litter also differs among tree species, and influences soil pH, organic-layer development, and nutrient availability. These factors not only have important effects on tree seedlings and herbaceous plants, but also on the distribution and abundance of forest-floor fauna, including invertebrates, amphibians, and small mammals.

The dense shade and acidic litter under conifers are unsuitable for vernal herbs such as trout lily and spring beauty, but acceptable for goldthread and bunchberry. Although relatively few herbaceous and non-vascular plants are tightly associated with particular tree species in the Northeast, some close associations do exist. The association between beechdrops and American beech is a good example. A rare liverwort, Grullania selwyniana, apparently grows only on the bark of northern white cedar (Miller 1996). Some saprophytic fungi occur more commonly on a particular species or genus of tree, and one fungus species grows only on the decaying hulls of hickory nuts and walnuts. Three species of mycorrhizal Lactarius appear to be specifically associated with hemlock, birch, and black spruce, respectively (Phillips 1991). In some situations, sugar maple seedlings grow best under yellow birch trees, and beech seedlings grow best under sugar maples (Forcier 1975).

Tree-species distributions affect foraging and nesting opportunities for a number of bird species. Golden- and ruby-crowned kinglets nest almost exclusively in the tips of spruce branches, and pine warblers nest and forage in pines. The presence of yellow birches in northern hardwood, mixed, and spruce-fir stands affects foraging distribution of a number of forest songbirds. Holmes and Robinson (1981) found that the 10 most common foliage-gleaning bird species preferred yellow birches for foraging, possibly because this species supports a greater diversity of foliage insects than any other tree species in northern New England forests (Foss, unpubl. ms.).

Although many foliage insects use a wide variety of hosts, some are limited to one or two species of food plant. Some bark beetles also are limited to one or a few tree species (USDA Forest Service 1985). Tree-species diversity within stands can reduce the effects of insect outbreaks. For example, spruce budworm outbreaks occur most severely in forests with relatively low species diversity (Mott 1963). Lower diversity also may contribute to lower resistance to stress (Hunter 1990). Some tree species are more tolerant of drought or flooding than others, and a diverse species mix, especially on extreme sites, is likely to experience better overall growth and survival over time.

The combination of species that occur in a stand and the relative proportions of those species define the forest community type. A given species may be present in a stand as a dominant member of the overstory, as an inclusion (a small patch of overstory distinct from the surrounding stand), or even as a single individual. The relative proportions in which species occur in a stand determine their influence on other organisms.

Species assemblages within a particular stand vary naturally over time in response to disturbances and succession. As the tree species change, so too do the communities of other forest plants and animals. Altering relative abundances of tree species within a stand can change the distributions of some organisms if the density of a given tree species falls below a critical level. Dispersal distances may become too great for some invertebrates and fungi, and there may no longer be sufficient food within a reasonable distance for some birds and small mammals.

Overstory inclusions, such as a patch of yellow birch in a spruce-fir stand or a patch of hemlock in a hardwood stand, occur in some stands because of disturbance history (e.g., an intact patch within a large burned area) or small-scale differences in soil or topography. Inclusions provide habitat features different from those in the surrounding stand, and can be important to many species of birds and mammals (DeGraaf et al. 1992).

Last, but by no means least, because different tree species use resources differently, greater tree-species diversity enables fuller use of available resources. Mixed stands, with species of different rooting characteristics and light needs, are able to extract nutrients from multiple levels in the soil and use a range

of filtered sunlight. Some experiments with simplified ecosystems suggest that overall ecosystem productivity (the accumulation of matter and energy in biomass) is greater in more diverse systems (Naeem et al. 1994, 1995). More-complete use of resources also has implications for sustainability, because the amount of nutrients susceptible to leaching from the system would be reduced. Studies in several ecosystems have documented greater loss of nutrients through leaching in plots with lower plant-species diversity (Tilman 1997). There is no reason to expect northern forests to behave differently.

CONSIDERATIONS

- Maintaining uncommon species that occur naturally in managed stands may require a commitment of growing space to non-commercial species.
- Recognizing that many stands have been, and will be, managed, it is more important to reflect the natural diversity that is already present rather than create artificially diverse stands.
- Overstory inclusions that result from site conditions such as soil and topography are more practical to maintain than those that result from disturbance history.
- Treating overstory inclusions differently than the surrounding stand may not be practical in some situations.
- Little is known about management practices to encourage shrubs and herbs. The Maine Natural Areas Program may be able to provide general advice for different community types.

RECOMMENDED PRACTICES

- Retain rare and uncommon species in stands in which they occur, and maintain conditions suitable for their regeneration.
- Maintain natural species composition as appropriate to the site and successional stage of the stand.
- Avoid eliminating naturally occurring species during selective harvests.
- Maintain naturally uniform stands, such as hemlock slopes or black spruce bogs, rather than converting to more diverse systems.
- Maintain overstory inclusions, such as hardwoods in a softwood stand or softwoods in a hardwood stand, whenever possible.

CROSS REFERENCES

General Principles; Vertical Structure and Crown Closure; Distribution of Native Forest Communities; Age Structure of the Landscape; Diseases Agents, Insect Pests, and Weeds

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Stand Characteristics:

Downed Woody Material, Snags, and Cavity Trees

By Steven K. Pelletier

DEFINITION

Downed woody material refers to logs and slash of all decay stages. Snags are standing dead or partially-dead trees that are relatively stable. Cavity trees are live or dead trees with existing cavities. Collectively, downed woody material, snags, and cavity trees are often referred to as coarse woody debris.

IMPORTANCE TO BIODIVERSITY

Both downed and standing woody materials are important for maintaining biodiversity because they provide habitats, at various scales, for microorganisms, insects, and a variety of vertebrates, as well as for mosses, liverworts, and some vascular plants and trees. Downed woody material, snags, and cavity trees are important shelter, resting, nesting, denning, foraging, perching, displaying, and basking sites for 20 percent of bird, 50 percent of mammal, 44 percent of amphibian, and 58 percent of reptile species in Maine (Appendix C). Downed woody material is also an important component of stream structure and a source of nutrients to aquatic systems.

GOAL

Maintain a range of sizes and types of downed woody material, snags, and cavity trees and retain or provide downed woody material, snags, and cavity trees in sites where they are lacking.

BACKGROUND AND RATIONALE

Downed Woody Material

Downed woody material consists of a variety of residues that accumulate naturally or are deposited after timber harvesting, including logs, large limbs, stumps, upturned tree roots, and slash. Woody debris is an integral component of forest ecosystems, providing food, cover, and nursery habitat for a diverse succession of flora, fauna, and fungi (Harmon 1986). Although large wood is the most visible debris on land and in streams, fine wood also contributes substantially to energy flows and nutrient cycling throughout the course of secondary succession. In terms of availability, the nutrient pool provided by fine woody material is intermediate between that of leaf litter and coarse woody debris. Fine woody material plays a distinct role in nutrient cycling on the forest floor, and often enhances water quality and conserves soil loss by limiting soil erosion.

The role of downed woody debris in providing habitat for wildlife is dependent on the physical distribution, size, amount, degree of decay,

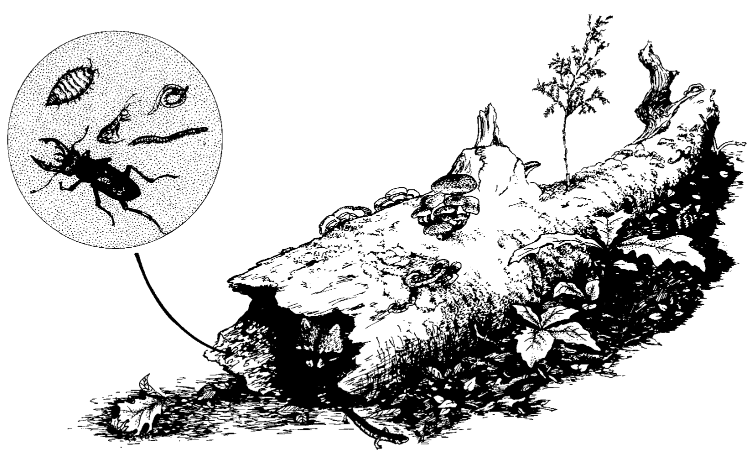
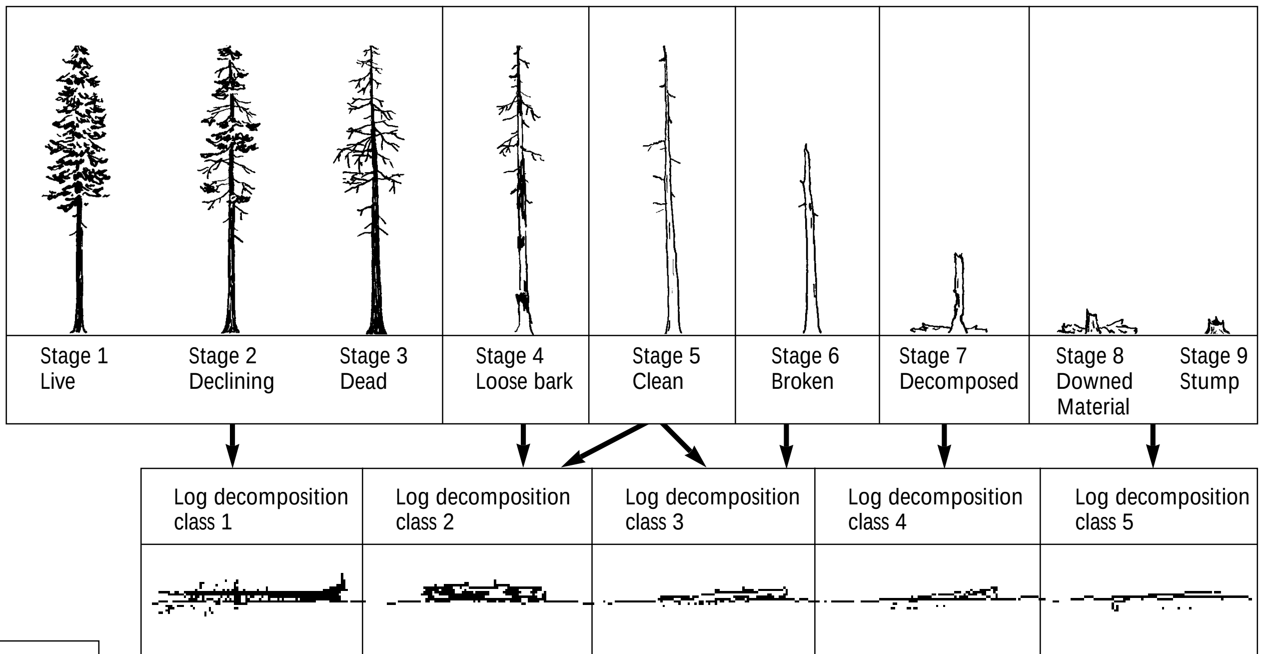


Figure 2
Downed woody material is used by many organisms in the forest, from microscopic bacteria and fungi to black bears. (First published in Hunter 1996.)

stage of decay, and orientation of the debris relative to slope and exposure (Triska and Cromack 1980, Chandler 1987, Hunter 1990). Downed woody material is used for nesting and cover; as thermal and drought refuges; as a source of and place to store food; as lookout, drumming, sunning, and preening sites; and as natural bridges across openings and streams (Figure 2, Appendix C). Vertebrates and various macro- and microorganisms that use downed woody material are important links in the forest food chain and in nutrient cycling.

In general, the more even the overall distribution of downed woody material, snags, and cavity trees, the greater the habitat diversity and use. Conversely, a lack of downed woody debris over large areas may reduce or eliminate species dependent upon woody debris for some stage of their life cycle. Logs oriented along contours are more likely to serve as runways for small animals (Olszewski 1968) and will also capture soil and organic debris, slowing erosion and increasing nutrient retention (Triska and Cromack 1980). Large (>16” diameter) logs



Log Characteristics	Log decomposition class 1	Log decomposition class 2	Log decomposition class 3	Log decomposition class 4	Log decomposition class 5
Bark	intact	intact	tract	absent	absent
Twigs < 3 cm	present	absent	absent	absent	absent
Texture	intact	intact to partly soft	hard, large pieces	small, soft, blocky pieces	soft and powdery
Shape	round	round	round	round to oval	oval
Color of wood	original color	original color	original color to faded	light to faded brown or yellow	faded to light yellow or gray
Portion of log on ground	log elevated on support points	log elevated but sagging slightly	log is sagging near ground	all of log on ground	all of log on ground

Figure 3

The stage of decay of cavity trees, snags, and logs will largely determine their availablity for use by different organisms. (Adapted from Thomas 1979.)

are a particularly valuable forest component; they are more-persistent landscape features and decay slowly because of their low surface-to-volume ratio.

The role of logs as habitat for forest flora and fauna depends on, and shifts with, the degree of decay. In the Northeast, the species of the tree also plays a role because hardwood limbs and boles will typically decay more rapidly than those from conifers. Because of slower decay, softwood stands accumulate more coarse woody material than hardwood stands. Logs supported above the ground by branch stubs or roots provide shelter, feeding, and display sites for many terrestrial vertebrates. Large logs with hollow portions may be used as dens by large mammals. Dens are used for many types of critical activities (e.g., rearing offspring, providing shelter), thus providing crucial microhabitat sites. Inability to access these microhabitats could limit the ability of some log-dependent species' populations to persist or expand.

As a log further decays and settles, there is a progressive decrease in wood density. Bark loosens and vegetation surrounding the log develops. As decay advances, the log becomes more important as habitat for tunneling invertebrates and small mammals. Moist microhabitats become inhabited by amphibians and are used with greater frequency as runways, nest sites, and shelter, as well as a source of food for invertebrates and fungi. Decay and the buildup of organic material around the log eventually results in its almost complete burial, but tunnels within and beneath the log continue to be used for a long time.

In addition to providing wildlife habitat, downed woody material also provides nursery logs for regenerating trees and understory plants. Although woody debris is a nutrient-poor substrate compared to most mineral and organic soils, it often becomes a more-favorable substrate for rooting as it decays, probably because of increasing nutrient availability and water-holding capacity. Decaying logs are good colonization sites for fungi, including mycorrhizal fungi that provide nitrogen to many tree species. The rate of decomposition of downed woody material varies with the species of tree, degree of exposure, and size of material (Figure 3).

Snags and Cavity Trees

Tree cavities are an important habitat component for many forest-dwellers. Cavities can be found in dead, dying, or live trees. Birds and mammals use larger trees extensively as nest and den sites, perches, and roosts (Figure 4, Appendix C). The size (diameter and height), state of decay, species, and location of snags and cavity trees influences their use by cavity-dwellers (Elliott 1988, Hunter 1990, Paragi et. al. 1996). Many of these animals have very specific minimum-size requirements for the trees or snags they will use for cavities (Appendix D); they can use larger trees but are unable to nest in trees below a minimum size. Compared to smaller trees, larger trees provide more thermal insulation, protection from predators, perches, and room to house large clutches, and will persist longer in the stand. A shortage of

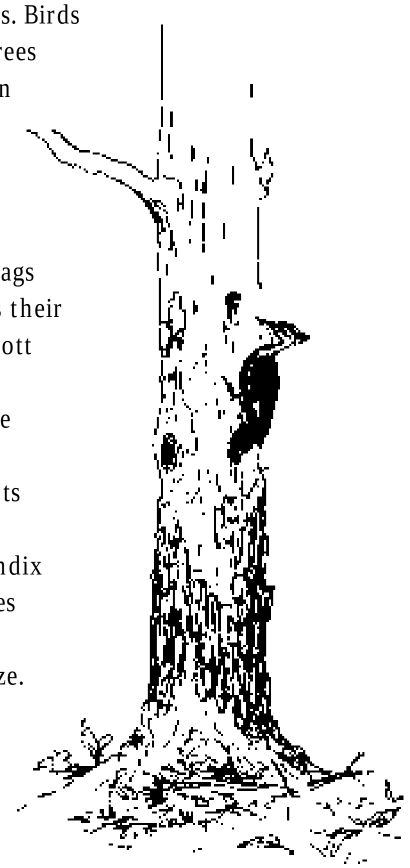


Figure 4

Snags and cavity trees are used by many birds, mammals, and other organisms for feeding, nesting, denning, perching, and shelter. (Adapted from Elliott 1988.)

large trees may affect nesting success and result in reduced populations or the complete loss of some species.

Natural stands contain an abundance of dead, standing trees or culls. About 10 to 15 percent of northern hardwood stands are composed of dead, standing trees; about 20 to 35 percent of spruce-fir stands are dead, standing trees (Tritton and Siccama 1990). On the whole, deciduous species are more likely to develop decay cavities than conifers. Estimates from recent forest inventory data for Maine indicate 6.7 percent of trees in Maine's forests are cull, and 14.5 percent are standing dead (Griffith and Alerich 1996). Wildlife species use many of the larger trees, as well as live or partially-live trees with heart rot or defects that lead to decay. Live or partially-live trees often persist in a stand longer than snags.

The state of decay is important in determining which species are able to inhabit snags or cavity trees (Figure 3). Hard snags (Stages 1 and 2) usually have some limbs remaining and firm, sound sapwood. Soft snags (Stages 3+) usually have no limbs and are in advanced stages of decay (Hunter 1990). Primary excavators and secondary users use both hard and soft snags. Primary excavators, mainly woodpeckers, create the initial cavities; secondary users rely on primary excavators and natural processes of disease and decay to provide them with suitable cavities. Other species, such as brown creepers and bats, also use spaces beneath the loose bark of dead or dying trees.

Snags, Cavities and Safety

Any discussion about retaining snags and cavity trees must include a word about safety. In the logging industry, approximately 16 percent of all logging fatalities (25 deaths per 100,000 non-managerial workers per year), are the result of falling logs, limbs, or snags (APA 1996). The U.S. Occupational Safety and Health Administration (OSHA) has regulations for danger tree removal prior to harvest. These regulations may conflict with the recommendations of this section because they require the removal of all snags within the work area by mechanical means. OSHA defines a "danger tree" as a ***standing tree that presents a hazard to employees due to conditions such as, but not limited to, deterioration or physical damage to the root system, trunk, stem or limbs, and the direction and lean of the tree. It further states: Each danger tree shall be felled, removed or avoided. Each danger tree, including lodged trees and snags, shall be felled or removed using mechanical or other techniques that minimize employee exposure before work is commenced in the area of the danger tree. If the danger tree is not felled or removed, it shall be marked and no work shall be conducted within two tree lengths of the danger tree unless the employer demonstrates that a shorter distance will not create a hazard for the employee.***

For safety reasons it is sometimes advantageous to leave clumps of wildlife trees rather than scattered trees. When safety concerns preclude opportunities to leave snags, the logger should leave large, live cull trees that over time will be utilized by wildlife as decay progresses (CLP 1992).

CONSIDERATIONS

- Management of downed woody material, snags, and cavity trees requires not only conserving existing stocks but also planning for a continual supply. Poorly formed trees are good candidates for recruitment as future snags and cavity trees, as are trees damaged by natural disturbances or previous harvests.
- Unless specifically planned for, plantations are likely to have significantly reduced downed woody material, snag, and cavity-tree input with each successive rotation.
- The larger the diameter of the log and the longer its length, the greater the value to wildlife, but small logs are better than none at all.
- Slash, both scattered and piled, provides cover, nesting, and foraging sites. Slash

is particularly important in recent cuts, allowing more-complete use of the site as the vegetation regrows.

- Downed woody material, snags, and cavity trees can be evenly distributed on the landscape or clumped.
- Riparian zones, roadside buffers, scenic areas, and small uncut patches contribute opportunities for meeting snag-retention goals for an ownership.
- OSHA regulations affect the management of snags and cavity trees.

RECOMMENDED PRACTICES

- Avoid damaging existing downed woody material during harvesting, especially large (16”+) hollow logs and stumps.
- Leave downed woody material on site after harvest operations when possible.
- Leave several downed logs of Decay Classes 1 & 2 (Figure 3) well distributed on the site, where possible; these could be culled from logs of less-desirable timber quality and should be as large and long as possible; especially important are logs >12 inches dbh and >6 feet long. Hollow butt sections of felled trees are also good choices (Elliott 1988). Retain as many logs as possible of Classes 3, 4, & 5. Culls bucked out at the landing can be hauled back into the woods on return trips.
- If snags must be felled before operating on a site, leave them in place rather than removing them.
- In areas under uneven-aged management, consider designating 3 to 5 percent of total stocking as potential cavity trees and a source of future snags. Retain a minimum of four secure cavity or snag trees per acre, with one exceeding 24” dbh and three exceeding 14” dbh. In areas lacking cavity trees, retain live trees of these diameters with defects likely to lead to cavity formation.
- In areas under even-aged management, consider leaving an uncut patch within the harvest area for every ten acres harvested, with patches totaling at least 5 percent of the area. Patch size may vary from a minimum of 0.25 acre. Use cavity trees exceeding 18” dbh or active den trees as nuclei for uncut patches.
- To create a supply of longer-lasting woody material, maintain natural softwood inclusions in hardwood forests (DeGraaf et al. 1992).
- Retain as many live trees with existing cavities and large unmerchantable trees as possible.
- When possible, avoid disturbing cavity trees, snags, and upturned tree roots from April to July to avoid disrupting nesting birds and denning mammals.

CROSS REFERENCES

General Principles; Forest Soils, Forest Floor and Site Productivity; Riparian and Stream Ecosystems.

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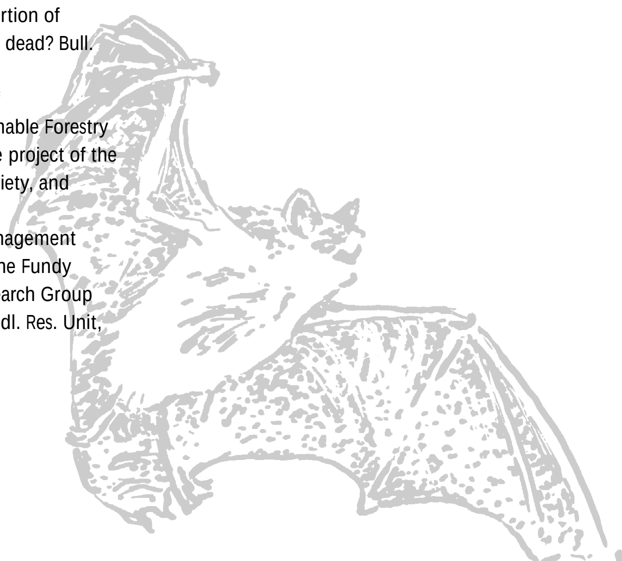

Stand Characteristics:

Mast

By Carol R. Foss

DEFINITION

Mast includes nuts, seeds, berries, and fruits. Nuts and seeds are referred to as "hard mast," fruits and berries as "soft mast."

IMPORTANCE TO BIODIVERSITY

Mast provides critical food for many wildlife species.

GOAL

Maintain a variety and abundance of native mast-producing plants in the landscape.

BACKGROUND AND RATIONALE

All trees, shrubs, vines, and herbaceous flowering plants produce nuts, seeds, berries, or fruits that are potential sources of food for wildlife. However, certain species, such as oaks, beech, and raspberry, are especially important because of the volume and nutritional value of mast produced. Of more than 350 species of woody plants native to Maine, 16 produce nuts and more than 80 produce fruits or berries (Fernald 1950). Different plant species produce seed at different times during the growing season, so maintaining a variety of hard and soft mast sources ensures a continuous mast supply (Appendix E).

Some trees and shrubs produce seed crops that vary in quantity from one year to another, and may alternate a bumper crop year with several years of low production. Mast-dependent wildlife species, such as squirrels, mice, blue jays, and red-breasted nuthatches, respond to these variations in food supply with local population fluctuations. Some bird species, such as white-winged and red crossbills, move long distances to breed where mast is abundant.

The value of mast to various wildlife species differs with the size, abundance, production frequency, accessibility, palatability, and nutritional content of the mast. Mast is particularly important in the diets of mammals such as squirrels, white-tailed deer, and black bear. Some bird species that migrate in late summer and early fall rely heavily on fruits and berries for food during migration; mast is important to some resident songbirds during winter when other food is scarce. Hard mast has high fat and protein content (Appendix F) that helps birds and mammals store extra fat for migration or hibernation, and contributes to the survival of newly independent young.

Hard mast

Important sources of hard mast in Maine forests include American beech and red, white, and black oaks. American chestnut was another important mast tree in southern Maine before succumbing to chestnut blight. The three oaks differ in frequency of heavy acorn crops, with red oak producing a heavy crop every two to five years, white every four to ten years, and black every two to three years (Downs and McQuilkin 1944, Burns and Honkala 1990, Leak and Graber 1993). They also differ in the age at which they begin peak production, with northern red oaks the youngest at 25, followed by white oak at 40, and black oak at 40 to 75 years (Burns and Honkala 1990). Acorns of white oak contain less tannin than those of red and black oaks, and are more palatable to wildlife (Pekins and Mautz 1987). Beech trees begin substantial nut production at about 40 years of age and produce heavy crops of nuts every two to eight years (Burns and Honkala 1990, Leak and Graber 1993). Individual trees vary in production. Beechnuts are especially important in northern Maine where oaks are uncommon (Schooley 1994a, 1994b). The effects of beech bark disease are a concern in maintaining adequate mast production in this area of the state

The seeds of maples, birches, ashes, and conifers provide important hard mast for small mammals and numerous songbirds (Martin et al. 1951). Red squirrel populations respond to fluctuations in conifer seed crops, and birds such as white-winged and red crossbills, pine grosbeaks, black-capped and boreal chickadees, and red-breasted nuthatches move southward during fall and winter if cone crops fail over a large geographic area (Bock and Lepthien 1976, Ehrlich et al. 1988).

Soft mast

Black cherry is the only canopy-level tree in Maine that produces soft mast. Bears, small mammals, and 28 bird species include cherries in their diet. Because individual trees vary widely in fruit production, knowing the fruiting history of specific trees can maximize the wildlife value of those retained as mast sources.

Numerous understory trees and shrubs produce soft mast. Mountain ash, serviceberries, blueberries, chokecherry, and pin cherry are among the most widespread and abundant. Numerous apple and crabapple trees planted by early settlers have survived and become naturalized on abandoned farms now reverted to forest. These introduced trees also provide important food sources for many wildlife species. Barberries have become naturalized locally and provide abundant soft mast.

More than 30 species of herbaceous plants in Maine forests produce soft mast. The largest and most obvious berry-producers are the various “brambles,” including raspberries, blackberries, and black raspberries. Other common examples include wild oats, false Solomon’s seal, bluebead lily, and Canada mayflower. Use of berries within the herb layer, by birds and small mammals, has received little attention in northeastern forests (Whitman 1992). Berries of species such as wild strawberry, wild sarsaparilla, and painted and red trilliums often disappear quickly after ripening, suggesting intense use by many species.

Many fruits and berries are relatively perishable, but others persist through the winter, providing a long-term food source. Woody species such as mountain ash and winterberry holly, and herbs such as partridgeberry and wintergreen are examples of species with persistent fruits. Berries of common juniper take two years to ripen, and may persist for three years (DeGraaf and Witman 1979).

CONSIDERATIONS

- Individual mast-producing trees, particularly beech and black cherry, may have poor timber quality, but nonetheless may be important sources of mast. Poor-quality trees may have greater value if left standing for mast production than if harvested for forest products.
- Raspberry and pin cherry, which compete with desired tree species in the early years after heavy harvests, are important mast sources for many animals.
- A number of mast-producing species, including some grapes and shadberries, are most common on the moist, rich soils of riparian ecosystems.

RECOMMENDED PRACTICES

- Manage stands with multiple species of mast-producing trees and shrubs to maintain a diversity of mast sources.
- When harvesting in stands that contain >30 percent basal area of oak or beech, retain some mast production by using strip, patch, or selection harvests.
- Manage oak stands on long rotations to maximize acorn production by growing large trees with large crowns (Elliott 1988, Burns and Honkala 1990).
- Retain beech trees with smooth or blocky bark or raised lesions to promote resistance in the stand; kill standing trees with sunken cankers and dead patches to reduce sprouting of diseased individuals. Retain some large beech trees in the stand, regardless of disease condition, that have the potential to produce mast.
- Retain productive beech and oak trees when they occur as single or scattered trees in stands of other species.
- Retain black cherry trees with good fruit production or evidence of use by bear.
- Retain wild apple trees. They should be pruned cautiously and gradually released from competition (Elliott 1998).
- Maintain a component of openings dominated by raspberry and pin cherry, on the landscape.
- Use thinnings or uneven-aged management to maintain areas with a diverse and productive herb layer.

CROSS REFERENCES

General Principles; Native Tree Species Composition; Riparian and Stream Ecosystems; Disease Agents, Insect Pests, and Weeds

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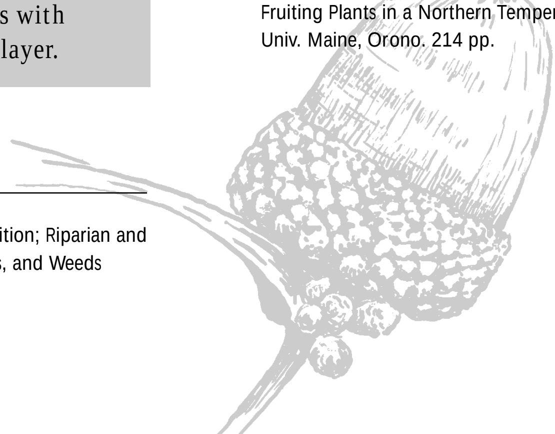


Stand Characteristics:

Forest Soils, Forest Floor, and Site Productivity

By Steven K. Pelletier

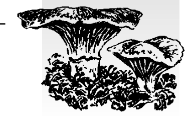
DEFINITION

Forest soils refers to mineral and organic components that support plant growth and whose characteristics are affected by biological activity and climatic conditions. Forest soils extend up to and include the undecomposed litter of leaves, twigs, and small branches found on the forest floor.

Site productivity is the ability of a forest soil to support plant, animal, and microbial life. The structural characteristics of the forest floor, including litter composition, depth and density of the organic layer, microtopography, and microclimate, also affect site productivity and hence biodiversity.

IMPORTANCE TO BIODIVERSITY

Biodiversity is greatly influenced by geomorphology and climate, which also affect soil development and site productivity. Soils are fundamental to supporting forest ecosystems. All plants have a range of soil fertility conditions needed for growth and survival. In turn, forest fauna depend on plants as their initial energy source. More-fertile sites tend to have a richer variety of fauna, but some of the rarer species of flora and fauna are found on very infertile sites. Structural characteristics of the forest floor are important because they support soil macroinvertebrates and microorganisms (e.g., soil fungi and bacteria, insects, and other invertebrates), as well as larger burrowing and ground-dwelling vertebrates such as amphibians, small mammals, and birds. Forest-floor inhabitants influence soil processes that ensure the availability of nutrients for plant uptake.



GOAL

Maintain the physical and chemical soil parameters that affect site productivity. Maintain the natural structure and composition of the organic layer; improve or restore the organic layer of disturbed sites. Maintain the natural spectrum of soil productivity necessary to support viable, healthy populations of native biota across the landscape.

BACKGROUND AND RATIONALE

Maine soils are relatively young, having started to form 10 to 12 thousand years ago after the last glaciation. The complex pattern of soils now found throughout the state was derived from glacial till, sands, gravel, and fine marine sediments (Rourke et al. 1978). Each of these soils has different physical, chemical, and biological properties, and varying combinations of mineral particles and organic matter. Maine’s forest soils have developed through long-term interactions among the parent material, climate, time, topography, and vegetation. The forest floor has developed in response to these same processes.

The role of soil in forest management cannot be underrated. Forest soils are a dynamic medium capable of supporting complex physical, chemical, and biological exchanges, all of which play key roles in plant germination, regeneration, and overall stand composition (Steubing, 1970, Wallace and Freedman 1986, Martin 1988, Facelli and Pickett 1991, 1992, Pu Mou et al. 1993).

The organic layer provides a buffer to protect soil structure (Donnelly and Shane 1986) and minimize erosion. It also contributes to the water-holding and infiltration capacity of the soil, and contains a bank of buried seeds vital for regeneration (Bormann and Likens 1979, Martin 1988). The organic layer provides habitat for lichens, bryophytes, and fungi, each of which serve in critical support roles for forest processes (e.g., initial colonizers, nursery habitat for seedlings, and ecto- and endo-mycorrhizal fungi) (Gawler et al. 1996). Physical, chemical, and biological activities within the litter and upper soil layers play a vital role in maintaining fertile and productive forest ecosystems.

Processes that occur on and within the forest floor depend on the overhead canopy and the underlying soils. Type and age of the standing forest, degree of canopy closure, and landscape position (e.g., slope, aspect, and position in the watershed) are influential above the surface; local parent material, and soil texture, structure, depth, and drainage class are recognized as dominant, below-ground factors. Sub-surface processes are further influenced by local microtopography, the amount of available organic material, and past management practices on the site (Beatty 1984).

When trees fall as a result of windthrow or other natural causes, they either break somewhere along the trunk, leaving intact stumps, or they are uprooted. Fallen and uprooted trees can create a “pit and mound” structure on the forest floor. Pits occur where uprooted trees have pulled up soil; mounds develop from rotting tree roots, stumps, and logs. Pit and mound structure influences characteristics of soil microhabitat, including moisture, temperature, organic matter, and nutrients, and can lead to more-diverse plant and animal communities.

When trees are uprooted, subsoil may be brought to the surface, bringing with it previously buried nutrients. The exposed soil in the pits is a favored habitat for seedlings of some plant species, such as red maple. However, seedlings in newly created pits are often subjected to stress from repeated frost heaving. Recent mounds are also favored sites for seedlings of a number of tree species to become established, including red spruce, hemlock, and black birch. These mounds offer less competition, thinner litter cover, greater porosity and aeration, lower bulk density, higher temperatures, and fresher organic materials than on the surrounding forest floor. Old mounds can become unfavorable sites for regeneration because of lower concentration of calcium and magnesium, lower pH, and less moisture (Schaetzl et al. 1989). In addition, rotting tree trunks and roots in mounds can be favored habitats for many animal species, including ants and other invertebrates.

Fungi that form a symbiotic relation with plants by penetrating into and extending their root systems are referred to as mycorrhizal fungi. The fungi increase the plant’s uptake of nutrients, such as nitrogen and phosphorus. In return, plants supply the fungi with carbohydrates. Individual trees may have dozens of different fungal partners that change as the tree ages. The fungi get most of their nutrients from litter, decaying wood, and other organic matter. Decaying logs are also habitat for small mammals, such as mice or squirrels, that eat the fungi and spread the spores with their feces, inoculating other forest areas. Recent research has found that mycorrhizal fungi can connect individual trees to a community of trees, even those of other species (Simaid et al. 1997). In these instances, mycorrhizal fungi can take carbon from trees growing in the sun and distribute it to trees growing in the shade, thus lessening the effects of competition.

Annual litter production in Maine's temperate forest ecosystem may range from 1.1 to 1.6 tons per acre (Edwards et al. 1970). Invertebrates, including earthworms, millipedes, sowbugs, fly larvae, springtails, and mites, initially fragment forest litter. The resulting physical substrate is suitable for colonization by microflora and soil bacteria that in turn process available nutrients and make them available for plant uptake (Edwards et al. 1970, Steubing 1970). The activities of the soil biota are complementary and intricately interrelated, and where soil macroorganisms are very numerous microorganisms (especially bacteria) are also abundant (Figure 5).

The properties of forest-floor litter (e.g., physical and chemical properties of leaves from different tree species including individual carbon:nitrogen ratios and levels of cellulose and lignin) influence the biological communities that feed on it, and play a key role in determining rates of decomposition (Facelli and Pickett 1991). There is considerable evidence that forest litter decomposes at a rate directly related to the number of macro- and microinvertebrates in the litter and the underlying soil, although the rate at which organic material breaks down varies among seasons and specific site conditions. Decomposition also varies between hardwood (mull-type) soils and softwood (mor-type) soils — in hardwood soils invertebrates and bacteria are dominant, decomposition is more rapid, and the buildup of organic material is less; in softwood soils fungi are dominant, decomposition is slower, and there is more organic matter (especially humus) buildup (Brady 1984).

Deep, well-drained and moderately well-drained soils typically provide the highest site quality for most commercial forest-tree species (Briggs 1994). These sites are characterized by well-aerated soils with relatively shallow accumulations of leaf litter. They provide a wide range of management opportunities and harvesting options. Tree growth on poorly and somewhat-poorly drained sites (Figure 6) is normally confined to species capable of tolerating higher groundwater and lower soil oxygen levels, and is generally characterized by limited growth rates. For these sites, a relatively deep layer of accumulated organic matter, shallow roots, pit and mound microtopography, and windthrow mounds dominates the forest floor. Harvesting in these stands is usually infrequent and restricted to snow-covered or frozen ground or dry periods.

The forest floor is susceptible to disturbance during harvest operations, the effects of which are ultimately determined by existing soil type, timing and type of harvest, and skill of the logger. Soil exposure, compaction, and rutting combine to reduce biodiversity by disrupting the recycling of soil nutrients, reducing groundcover, limiting regeneration, eliminating

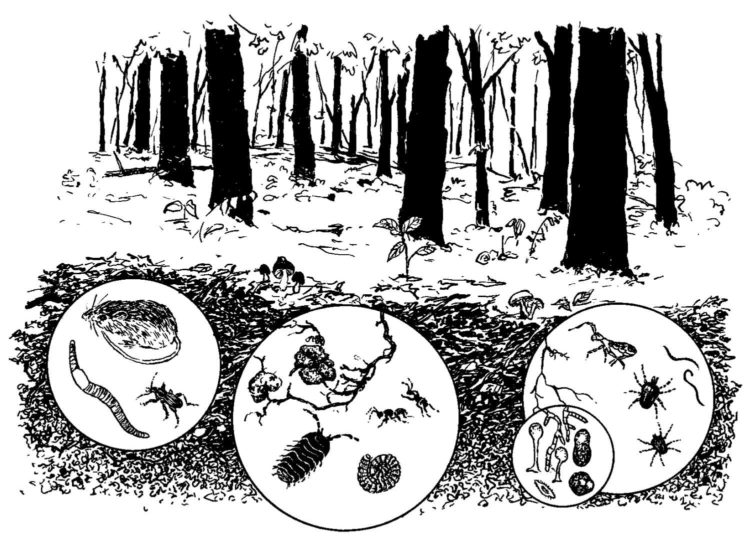


Figure 5.

Macroorganisms (e.g., small mammals, earthworms, and beetles) and microorganisms (e.g., millipedes, ants, springtails, mites, nematodes, and mychorrizal fungi) present in upper soil layers are critical to the breakdown of leaf litter, soil nutrient processes, and subsequent uptake of nutrients by plants.

habitat opportunities for soil biota, and creating opportunities for increased soil erosion. Exposed mineral soils can also become crusted and compacted solely from the impact of rainfall, to the point where it may be difficult for seedling roots to penetrate the soil (Martin 1988).

Careless or poorly planned logging operations may disturb the structure and, subsequently, the function of forest soils. Soil compaction by logging equipment can reduce pore space in the soil, which can reduce seedling germination, root penetration, and subsequent growth. Compaction also affects infiltration, leaching, and the storage of soil water (Martin 1988). Compaction is most severe in truck roads, landings, and major skid roads, and can take large areas of land out of production for many years unless appropriate measures are taken during site preparation. Studies indicate that loss of production in skid trails can reduce total volume yield 6 to 16 percent for as much as the whole second rotation, that more than eight years is required for natural forces to repair soil compaction sustained during logging in wet weather, and that up to 18 years are required for compacted log landings to return to conditions found in undisturbed areas (Holman et al. 1978, Gjedtjernet 1995).

Compaction problems are also exacerbated if logging operations are not properly timed (Turcotte and Smith 1991). Studies in Maine (Holman et al. 1978) demonstrated that bulk densities in skid trails after wintertime, mechanized, tree-length harvest operations were restored after two over-wintering periods. Skid trails on summer harvests, however, were not restored to pre-harvest levels after three complete overwintering periods, and might require as much as 5 to 10 years to recover after harvesting (Gjedtjernet 1995). Deep ruts (>12 in.) are usually detrimental to regeneration and frequently present a severe erosion threat because they can divert and channelize surface and subsurface water flows (Martin 1988). Ruts may also form pools of standing water that disappear only through evaporation, resulting in waterlogged soils (Pierce et al. 1993). Surveys of natural regeneration have demonstrated that conifers rarely, if ever, dominate on rutted and mounded soils following harvest operations (Turcotte and Smith 1991). Equipment modifications, such as large feller-forwarders with wide, high flotation tires or tracks have resulted in less soil compaction; however, these modifications alone cannot eliminate site disturbances if harvesting is conducted when soils are wet. On the other hand, long-term harvest effects on soils that are at least moderately well-drained may be minimal (Donnelly et al. 1991, Turcotte and Smith 1991).

The effects of timber harvesting on soil nutrients depends on the forest type as well as type, frequency, and intensity of harvesting (Freedman 1981, Hendricksen et al. 1989, Hornbeck et. al. 1990, Pierce et al. 1993, Pu Mou et al. 1993). Nutrient loss is a particular concern on low-fertility sites (i.e., shallow to bedrock soils, coarse sands, and wetlands or areas with high water tables) (Tyrrell and Publicover 1997) or with short rotations (Freedman 1981, Hornbeck et al. 1986, Smith 1990, Pierce et al. 1993). Soil leaching may cause an additional loss of nutrients (Hornbeck et al. 1990, Pierce et al. 1993). Following harvest or site preparations, changes in the distribution of organic matter within the upper soil horizons may have long-term effects on soil fertility and productivity by altering properties of the organic matter (Johnson et al. 1991). Disturbance of the forest floor and exposure of mineral soil can reduce infiltration of precipitation and atmospheric gases or increase evaporative losses of moisture (Turcotte and Smith 1991). In addition, herbicide application may cause additional

leaching loss of soil nutrients, particularly nitrogen, because of nitrification processes (Pierce et al. 1993).

Regional studies have shown that careful logging practices can keep major disturbances (i.e., major skid roads and landings) to less than 10 percent of a harvested area. Forest harvesting practices and equipment that better preserve soil properties can improve the short-term composition of regenerating forest stands and increase long-term economic benefits. They also help conserve biological diversity by avoiding disruptions to soil nutrient cycling, increasing ground cover and regeneration, providing habitat opportunities for soil biota, and decreasing opportunities for soil erosion (Turcotte et al. 1991, Pierce et al. 1993, Gjedtjernet 1995).

CONSIDERATIONS

- Forest soils in the glaciated Northeast have relatively low fertility compared to grassland soils (Martin 1988), with the upper organic layers generally containing the major concentrations of available nutrients.
- The forest floor is a major source of nutrients for many shallow-rooted seedlings. Protecting the organic layer and minimizing exposure of the mineral soil can reduce adverse effects on soil structure and site productivity.
- Track-mounted fellers with low centers of gravity operate efficiently on slopes up to 20 percent, and usually cause less soil disturbance than rubber-tired equipment. On slopes exceeding 20 to 30 percent, cable systems may cause considerably less damage than fellers and skidders (Pierce et al. 1993).
- Some scarification may be beneficial to the regeneration of certain species; compaction and exposure of mineral soils may neutralize those benefits.
- Although the growth of vegetation immediately following clearcutting is usually rapid, losses of dissolved substances in runoff may still occur.
- Clearcutting may increase the rate of organic-layer decomposition and off-site movement of nutrients (Covington 1981, Hornbeck et al. 1987). Use of herbicides may delay recovery of the system and hence the duration of decomposition and off-site movement of nutrients.
- Although quite a bit is known about the specific nutrient requirements of forest tree species, the long-term effects of changes in soil nutrients are not well understood in Maine, and do not include the possible influence of acid deposition and other types of air pollution.

RECOMMENDED PRACTICES

- When available, use maps and soil descriptions from local Natural Resources Conservation Service offices together with on-site inspections to determine the fertility, drainage, potential for erosion, and other characteristics of forest soils on a site.
- Avoid whole-tree removal, particularly on low-fertility sites (i.e., shallow to bedrock soils, coarse sands, wetlands, and areas with high water tables), unless replacement of nutrients and organic matter is considered.
- Conduct harvest operations during the season of the year that is most appropriate for the site. Operating on snow or frozen ground, whenever possible, minimizes effects on the soil and forest floor.
- Choose harvest equipment to suit the site and minimize disturbance. For example, in dry conditions, and in some wet conditions, consider using tracked vehicles to reduce rutting.

- Prepare a preharvest lay-out of skid trails and yards to minimize total area of compaction and rutting to less than 15 percent of the harvest site.
- Keep to moderately well-drained or drier soil when ground is not frozen and during wet times of the year.
- To reduce mineral soil exposure, use forwarders that transport wood cut to length rather than dragging whole trees.
- Minimize skid-trail width using techniques such as bumper trees when appropriate.
- Establish skid trails that follow land contours where possible rather than directed straight uphill (Martin 1988). When safety issues require a straight uphill access route, the use of water bars, skid humps, and drainage dips should be employed as needed to eliminate or reduce erosion. Dropping slash in these steep roadway areas is another effective means of reducing the effects of compaction and erosion. Implement erosion control recommendations when needed as described in the Maine Forest Service Field Handbook Best Management Practices (MFS 1995, Briggs et al. 1996, Cormier 1996).
- Refer to Maine Forest Service (1995) Best Management Practices for managing log landings.
- When possible, conduct whole-tree harvests of hardwoods during dormant leaf-off season to retain nutrients on site.
- Limit short-rotation regeneration harvests as much as possible unless replacement of nutrients and organic matter is considered.
- When possible, delimb trees where felled or return slash to woods to maintain nutrient levels, and place slash in skid trails to reduce soil compaction and exposure of mineral soil.
- Use controlled yarding techniques to minimize soil compaction.
- Suspend harvesting operations if deep rutting occurs on wet soils, or move equipment until drier or frozen ground conditions prevail; winter logging and converting from wheeled to tracked vehicles can reduce effects on soil.
- Avoid or minimize practices that disturb the forest floor, remove the organic soil or cover it with mineral soil, except as necessary to accomplish silvicultural goals and to regenerate certain tree species.
- When herbicides are used, minimize the length of time that the site remains unvegetated. Apply no more often than necessary to achieve silvicultural objectives.

CROSS REFERENCES

General Principles; Downed Woody Material, Snags, and Cavity Trees

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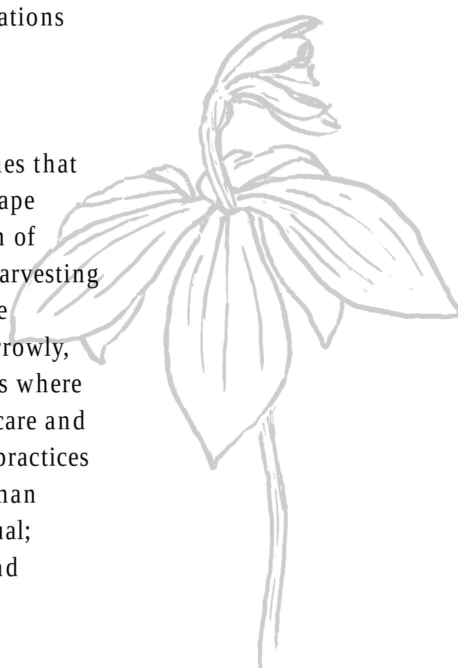
Site-Specific Considerations:

Special Habitats and Ecosystems

By Carol R. Foss

SPECIAL HABITATS AND ECOSYSTEMS ARE places within a landscape that make unique contributions to biodiversity. They require special consideration during forest management activities. This section includes 10 special habitats or ecosystems. Some chapters (e.g., nest sites for woodland raptors, nesting areas for colonial wading birds, rare plant or animal sites) address the habitats of particular groups of vulnerable species; other chapters address ecosystems that are rare (e.g., rare natural communities, old-growth and primary forests). Several chapters address ecosystems that play a particularly important role in supporting species that use multiple habitats, and may be critical for some species during part of the year (e.g., riparian and stream ecosystems, deer wintering areas, vernal pools, beaver-influenced wetlands, woodland seeps and springs). Although they play an important ecological role, emergent wetlands are not addressed here because of this manual's focus on managed forests. Relevant information and recommendations may be found in riparian and stream ecosystems and other chapters.

Much of this manual provides guidelines that are widely applicable across the landscape and contribute broadly to conservation of biodiversity regardless of forest type, harvesting system, or management objectives. The chapters in this section focus more narrowly, spotlighting the most vulnerable places where conserving biodiversity requires extra care and attention. Some of the recommended practices in these chapters are more restrictive than those presented elsewhere in the manual; however, they apply to very specific and limited sites. This section also includes recommendations to confer with Maine Department of Inland Fisheries and Wildlife and Maine Natural Areas Program biologists. In the case of special habitats, combining the expertise of foresters and biologists may be the most effective and efficient strategy.



Special Habitats and Ecosystems:

Riparian and Stream Ecosystems

By Steven K. Pelletier

In this chapter, riparian ecosystems and stream ecosystems are presented separately except for the recommended practices, which apply to both ecosystems.

RIPARIAN ECOSYSTEMS

DEFINITION

Riparian ecosystems refer to the area adjacent to water bodies and non-forested wetlands. They often include zones of gradual transition from water to upland ecosystems.

IMPORTANCE TO BIODIVERSITY

Riparian ecosystems are areas of great species richness and constitute a dynamic and sensitive portion of the landscape. They serve several functions depending on size of the water body:

- buffering aquatic and wetland plants and animals from disturbance;
- preventing wetland and water-quality degradation;
- providing important plant and animal habitat; and
- providing organic matter, nutrients, and structure to aquatic ecosystems.

GOAL

Protect the function of riparian ecosystems. Maintain or restore natural riparian ecosystem structure and functions.

BACKGROUND AND RATIONALE

Natural riparian ecosystems are the most diverse, dynamic, and complex biophysical habitats on land (Naiman et al. 1993, Gregory 1996). Although they make up a small percentage of the landscape, riparian ecosystems are among the areas of the greatest species richness (Odum 1979, Thomas 1979) and represent particularly important parts of any forest ecosystem. As an interface between terrestrial and aquatic systems, riparian ecosystems encompass an unusually diverse mosaic of land forms, sharp environmental gradients, and natural communities within the larger forested landscape. The ecological diversity associated with riparian ecosystems is related to the size of the water body, variable flood regimes, geomorphic channel processes, watershed position, and upland influences on the water body (Naiman et al. 1993).

Riparian ecosystems are areas that influence, or are influenced by, aquatic ecosystems such as lakes, rivers, streams, ponds, and wetlands. They often are defined based on characteristic vegetation that may vary from a narrow band of shrubs along small rivers or lakeshores to floodplain forests hundreds of yards wide along large rivers (Figure 6). These ecosystems frequently include wetland floodplains, upland floodplains, and adjacent upland forests. They are, in fact, broad ecotones with no discrete boundaries (Gregory 1996).

Riparian ecosystems may also be defined by function, such as providing plant and wildlife habitat, filtering eroded soil particles, or shading a stream. In these instances, the size of the riparian ecosystem depends on the function being considered. For example, the width needed to provide shade to a stream may be one tree height or less, whereas riparian wildlife habitat may extend several hundred feet into upland forests alongside large rivers or lakes (Elliott 1988, Meiklejohn 1994). Research studies in Hancock and Washington Counties found that streams and rivers can influence plants and animals in riparian communities for distances of up to 985 feet (Noble 1993, VanderHaegen and DeGraaf 1996). Research has demonstrated the importance of wide riparian forest ecosystems for neotropical migratory breeding-birds (Hodges and Krementzt 1996), and as much as 656 feet of vegetated buffer has been recommended to accommodate the breeding-territory requirements of most songbirds (Stauffer and Best 1980).

Riparian ecosystems create unique habitats that support a great diversity of vegetation, particularly vascular plants (Naiman et al. 1993). Many of Maine's rare plants are associated with this ecosystem (Gawler 1988, Gawler et al. 1996). The complexity of streamside vegetation associated with riparian ecosystems provides unique habitats that support a great diversity and abundance of wildlife. Riparian ecosystems are utilized by over 90 percent of the region's wildlife species in some significant way during their life cycle and provide the preferred habitat for over 40 percent of these species (DeGraaf et al. 1992). For instance, studies in Maine have documented that 85 percent of deer wintering areas are in riparian conifer stands (Banasiak 1961), and that black bears make extensive use of riparian areas (Schooley 1990). Other studies in Maine have indicated that retaining forest cover in a management zone adjacent to streams and water bodies, will provide valuable habitat for a number of wildlife species (DiBello 1983, Small and Johnson 1985, Johnson 1986, Noble 1993, Mickeljohn 1994, Vander Haegen and Degraaf 1996). This dependence on riparian resources often extends across the full width of the riparian zone and as far as 984 feet (300 meters) away from the water body into upslope terrestrial habitats (Noble 1993).

Figure 6.

Cross-section of a riparian ecosystem. The riparian system to the left illustrates an abrupt transition from stream to upland, while that on the right illustrates a gradual transition and includes a wetland floodplain, upland floodplain, and upslope forest.

Beyond those already mentioned, riparian ecosystems serve other notable functions that include:

1. protecting water quality by filtering sediment and pollutants from upslope areas and preventing bank erosion;
2. controlling floods and regulating streamflow through the dispersal, absorption, and slow release of floodwaters;
3. recharging groundwater and providing discharge flows during low stream-flow periods;
4. protecting and enhancing the aquatic environment by creating structure in the water body through input of logs and fallen trees and contributing energy in the form of leaves, twigs, fruit, and insects (especially important in headwater streams and small rivers);
5. providing wildlife travel corridors (linear areas of habitat);
6. protecting wetland wildlife species from disturbance; and
7. providing recreational and scenic opportunities.

Because of these multiple functions, forest management activities within riparian ecosystems have the potential to affect more species than anywhere else on the landscape, with both direct and indirect effects (Darveau et. al. 1995, Trettin et al. 1995, Vander Haegen and DeGraaf 1996, Trettin et al. 1997). As a result, no-cut and restricted-cut policies are regularly recommended because they are a simple and effective means of protecting riparian values and creating or maintaining old-growth stands that are usually in short supply. Along with natural disturbances (e.g., fire, insect outbreaks, wind, ice), forest harvest practices in riparian areas can alter aquatic and floodplain ecosystems, including changes in the amount of downed woody material, water temperature, siltation, nutrient availability, and stream hydrology. In turn, these factors can affect the abundance and viability of fish, amphibians, invertebrates, and aquatic vegetation (Moring and Garman 1986, Troendle and Olsen 1994, Vuori and Joensuu 1995).

Timber management can also be used to restore the values of previously degraded riparian ecosystems by establishing diverse and structurally complex riparian communities (Gregory 1996). For example, snags, cavity trees, and cull trees can be left to provide nesting and perching habitat and long-term sources of downed woody material. Where short-term canopy recovery is required, hardwood species can rapidly re-establish vegetative cover; species such as alder generate nutrient-rich and rapidly processed litter. Coniferous species can re-establish more-complete shade conditions, enhance deer wintering habitat, and provide more-persistent wood and needles in stream channels (Banasiak 1961, Cummins 1980).

Ideally, the optimum management strategy for any given riparian ecosystem is determined by such things as size of water body or stream width, water quality, topography, soil type, adjacent cover type, hydrologic regime, and management objectives. This usually favors small-scale management, long rotations for individual trees, and maintenance of a natural assemblage of plant species including trees of various species, age, and condition. However, this type of management requires forest managers to have a substantial understanding of the riparian ecosystem being considered. Therefore, more-generic recommendations that can be tailored to meet site-specific conditions are usually preferred and more practical.

CONSIDERATIONS

- Riparian ecosystems are likely to become increasingly important in conservation efforts to counteract the effects of habitat fragmentation on wildlife populations.
- The width of an appropriate riparian buffer is a source of debate (Tyrrell and Publicover 1997). Width is an important factor in determining how well or to what extent the riparian buffer can provide plant and wildlife habitat and water quality functions. Width is also a factor in the degree of wind firmness of the buffer.
- Specific training may be necessary to ensure accurate identification of wetland and riparian boundaries. On questionable sites, the forester should schedule a field consultation with a field biologist prior to harvest (Donovan 1997).
- Loggers may need additional training to effectively conduct biodiversity-friendly harvests in or adjacent to riparian ecosystems.
- Wetland permits or other legal requirements may apply to forestry operations in riparian ecosystems (i.e., Maine Department of Environmental Protection, Land Use Regulation Commission, Municipal Shoreland Zoning Ordinances).
- Riparian areas are often extremely productive; limiting harvest in these areas may entail economic loss to riparian owners (Ellefson and Miles 1985).

STREAM ECOSYSTEMS

DEFINITION

Stream ecosystems include rivers, streams, brooks, and their associated flood plains, as well as their chemical, physical, and biological characteristics.

IMPORTANCE TO BIODIVERSITY

Stream ecosystems provide habitat for a wide variety of terrestrial and aquatic species.

GOAL

Maintain or improve stream characteristics by:

- minimizing siltation;
- maintaining appropriate levels of downed woody material and other organic debris;
- maintaining flows within their natural range of variation;
- maintaining temperatures within their natural range of variation;
- maintaining stream channel integrity; and
- maintaining biological diversity.

BACKGROUND AND RATIONALE

Streams are dynamic landscape features, influenced to a great degree by the terrain and cover conditions through which they flow (Cummings 1980). Their structural, physical, and chemical characteristics create habitats for aquatic and riparian species, and, therefore, influence biodiversity.

Streamside vegetation and, to a large extent, the type and density of vegetation throughout the watershed affect stream flows and influence stream structure and nutrient availability. Forest vegetation retains a large percentage of precipitation and reduces the magnitude of peak flows by physically slowing or trapping surface runoff. Vegetation also binds the soil and reduces sedimentation and nutrient export from a site (Cummins 1980, Johnson et al. 1995). For example, the amount of runoff entering a stream can affect the grain size of the stream's substrate. Greater flows tend to scour stream channels, exposing coarser materials and transporting fine sediments and organic matter downstream.

When erosion occurs, runoff containing fine soil material may cause temporary or long-term changes in the turbidity or clarity of the stream and add excess nutrients such as phosphorus. Excessive sediment deposited by runoff into a stream can interfere with the feeding and reproduction of fish and aquatic insects by clogging open pore spaces between coarse-grained sediments. Streamside vegetation influences water chemistry, biotic processes, and species composition by providing shade and limiting increases in stream temperature. Although the removal of an individual streamside tree may not be harmful, a more-severe loss of tree cover along a stream can reduce shading enough to raise water temperature.

Clearing along stream banks can also remove critical sources of downed woody material (i.e., fallen logs and branches) that modifies the stream channel and provides specialized habitats such as cover for fish and insects and basking sites for otter, turtles, and waterfowl (Figure 7).

Downed woody material and other organic debris are critical to processes within the stream itself and support the aquatic food chain (Figure 8). Branches and twigs provide habitat and a source of food for stream-dwelling bacteria, fungi, and invertebrates that feed on detritus. In small, steep streams, woody debris is especially valuable for creating habitat that might not otherwise exist. In these sites, small riffles and pools are formed behind debris, providing diverse conditions for a variety of aquatic communities. In small, well-shaded streams, fruit, limbs, leaves, and insects that fall from the forest canopy may supply much of the organic food base. Biological communities in small streams are effective at processing particulate matter and even altering nutrient concentrations in the water (Cummins 1980, Davies and Sowles 1984).

Haul roads, skid trails, and water crossings can increase runoff and erosion into streams. Improperly constructed and maintained drainage structures along roads, particularly on approaches to water crossings, can divert sediment-laden runoff directly into streams.

Figure 7.
Logs and other downed woody material create structure in streams that is used by fish, turtles, and other aquatic organisms.

Over prolonged periods, substantial soil can wash into the stream channels, with detrimental effects on aquatic communities. Diversions that increase surface runoff into a stream increase base flows and flooding, resulting in altered channel morphology, substrate type, amount of woody debris, and ultimately, changes in biotic communities.

Timber harvesting and road-construction activities have the potential to alter the structure and function of streams, even though the streams themselves may be left untouched. Studies in Maine have documented that harvesting on unfrozen soils may disturb the soil surface sufficiently to increase the potential for erosion and runoff of sediments, the effects of which are discussed in other chapters. In addition, depending on compliance with Best Management Practices (BMPs), the amount of biomass removed, and the degree of soil compaction, harvesting may increase water yield by up to 80 percent, and increase summer surface water temperatures by 5 to 27°F (Moring and Garman 1986, Troendle and Olsen 1994). Nitrate concentrations in streams have been documented as high as 90 mg/l after harvesting, compared to near-zero values before harvesting. Nitrification can also lead to soil and stream acidification and aluminum concentrations that may be toxic to seedlings, roots, and aquatic organisms (Kahl 1996). Pesticide residues and other pollutants may also be carried into streams by excess runoff, with possible detrimental effects on biotic communities. Many of these effects are diminished to near pre-clearcut levels when vegetative cover is reestablished after the first few years (Bormann and Likens 1979).

Headwater streams may be particularly sensitive to changes in land-use practices within the watershed (Cummins 1980, Brinson 1993, Kahl 1996, Vuori and Joensuu 1996). These often unmapped and lower-order streams set the nutrient content of the larger, downstream drainage network, further emphasizing the importance of riparian cover (Brinson 1993).

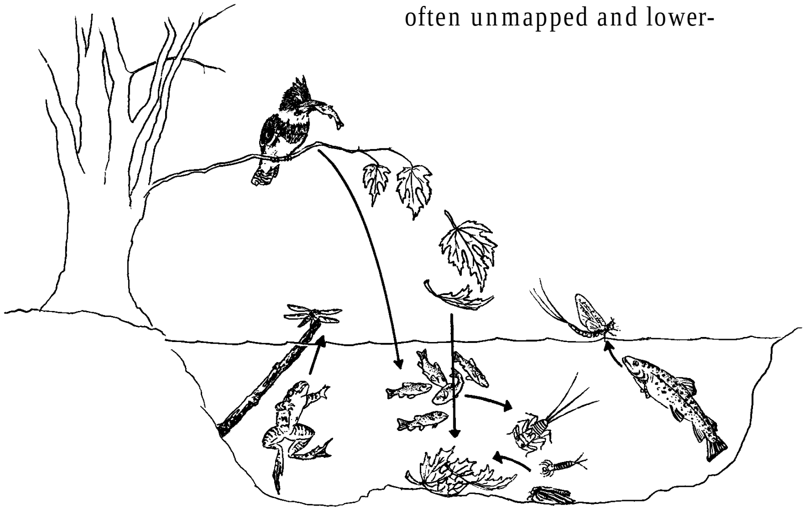


Figure 8.
Aquatic food chains are dependent on the input of organic material from the riparian area.

CONSIDERATIONS

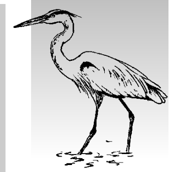
- Many of Maine's current land-use regulations relating to forest management are designed to protect the integrity of stream ecosystems and to maintain water quality. A recent review of Maine's BMPs indicated that their use reduces soil loss and sedimentation of surface water bodies.

RIPARIAN AND STREAM ECOSYSTEMS

RECOMMENDED PRACTICES

- Establish riparian management zones along streams, rivers, ponds, and lakes. These are not intended as no-harvest zones. Forest management systems, such as single-tree or small-group selection cuts, that retain relatively continuous forest cover in riparian areas (65-70 percent canopy cover) can help maintain biodiversity by protecting water quality, providing shade, supplying downed woody material and litter, and maintaining riparian wildlife habitat conditions.

  The width and continuity of riparian management zones will vary depending on the size of the stream or water body, its drainage area at that location, the land-use regulations in effect, and the landowner's management goals for riparian ecosystems. Recommendations for riparian management zone width vary; narrower for lower-order streams and small ponds, and wider for higher-order streams and large ponds (MCSFM 1996, Chase et al. 1997, Donovan 1997, NHFSSWT 1997, Tyrell and Publicover 1997). Recommendations also vary depending on whether water quality and soil erosion



are primary issues or whether wildlife habitat, continuity of forest structure, and maintaining riparian ecosystems conditions are also addressed. Table 2 presents examples of three, relatively recently developed sets of recommendations that include wildlife habitat considerations.

- No-cut zones of 16 to 100 feet are recommended by several management guides (Elliott 1988, NHFSSWT 1996, Woodley and Forbes 1997) on river or pond shores containing wet seeps, shallow or poorly drained soils, or areas with slopes greater than 8 percent. Limited single-tree cutting can occur on other sites within this zone, with cabling from outside the zone suggested (Elliott 1988, NHFSSWT 1996).
- Survey the immediate watershed (i.e., the larger, local drainage area) prior to harvesting and identify important hydrologic features such as streams, ponds, wetlands, seeps, and vernal pools, in early spring. Avoid laying out buffer zones, skid trails, and haul roads during winter because small streams may not be visible.
- Consider management at the watershed-level as an approach to avoiding stream channel degradation from excessive runoff. For example, in National Forests no more than 25 percent of a watershed can be regenerated within a 10-year period.
- Consider implementing management policies that maintain hydrologic connectivity between riparian management zones on a watershed, or basin-wide, basis. This means that improved riparian protection efforts must occur in headwater streams as well as in the broad floodplain wetlands downstream. The area of land typically affected is estimated to be <10 percent of the total land base, but offers an unusually diverse array of ecological functions far in excess of the extent of its area (Naiman et al. 1993).
- Within riparian management zones, consider using uneven-aged management systems such as single-tree or small-group selection cuts, and maintaining 65 to 70 percent crown closure in the residual stand.
- Road construction, stream crossings, skid trails, log landings, and all phases of timber-harvesting operations should conform to Maine Forest Service's BMPs for erosion control (MFS 1995), as well as applicable rules and regulations of the Maine Land Use Regulation Commission (LURC) and the Maine Department of Environmental Protection (MDEP).
- Use streams as stand boundaries to reduce the need for stream crossings.
- Bridges and culverts should be large enough to pass peak and flood flows without damage to the structure, and should not constrict the stream channel. Culverts, preferably with flat bottoms, should be installed at the level of the original streambed to provide fish passage at all flows. Disturbance to stream banks at the crossing should be minimized, and channelization of the streambed above and below the crossing should be avoided.
- Retain trees with cavities, standing dead trees, downed logs, large trees, and large

Table 2

Variations in recommended width of riparian management zones as presented in three publications.

	New Hampshire[1] (feet)	Maine Council[2] (feet)	Forester's Guide[3] (feet)
First- and second-order streams	100	75	-
Third-order streams	300	250	100-330[4]
Fourth-order streams	600	250	100-330[4]
Ponds < 10 acres	100	-	-
Ponds > 10 acres	300	-	100-330[4]

[1] New Hampshire Forest Sustainability Standards Work Team 1997

[2] Maine Council on Sustainable Forest Management 1996

[3] A Forester's Guide to Managing Wildlife Habitats in Maine, Elliott 1988

[4] For water courses draining 50 square miles or less the management zone is 100 feet; for watercourses draining greater than 50 square miles, the management zone is 330 feet.

supercanopy trees in the riparian management zone to the greatest extent possible.

- Avoid adding woody material to streams or disturbing material that is already in place.
- Avoid using fertilizers, pesticides, and other chemicals within riparian management zones.
- Avoid creating long, abrupt edges along narrow riparian management zones. Riparian areas adjacent to clearcuts may be subject to increased edge effect and risk of blowdown. One approach to minimize these risks is to limit the harvest within the riparian management zone, increase the width of the zone, or feather the edges of the clearcut (Figure 9).

CROSS REFERENCES

General Principles; Downed Woody Material, Snags, and Cavity Trees; Forest Soils, Forest Floor, and Site Productivity; Special Habitats and Ecosystems; Habitat Patch Size

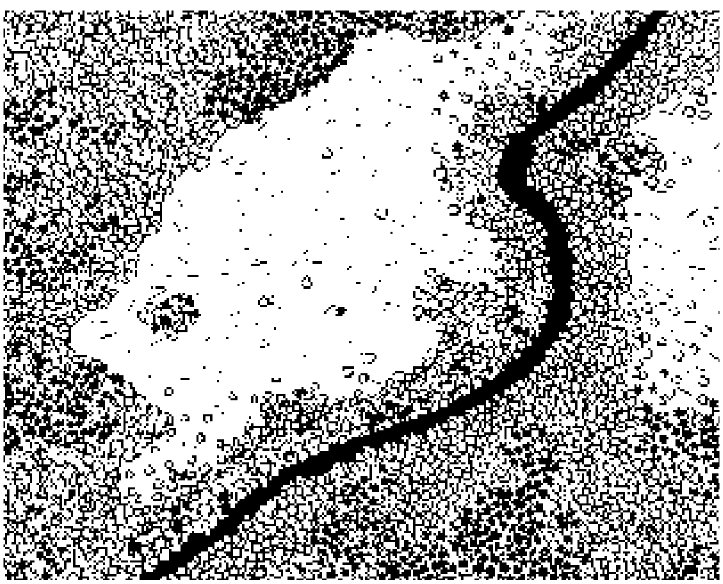


Figure 9.

An alternative to creating long, abrupt edges along narrow riparian management zones. Note the variable width of the zone, and the feathering of the edges at the upper and lower ends of the clearcuts.

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Special Habitats and Ecosystems:

Vernal Pools

By Carol R. Foss

DEFINITION

Vernal pools are naturally occurring, seasonal, semi-permanent or permanent bodies of water, free of adult predatory fish. They may occur in a variety of wetland settings or as isolated wetlands in an upland matrix. They provide breeding habitat for certain amphibians, reptiles, and invertebrates, including Maine's four vernal-pool indicator species: spotted salamander, blue-spotted salamander, wood frog, and fairy shrimp.

IMPORTANCE TO BIODIVERSITY

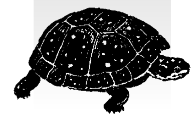
Vernal pools provide important breeding and foraging habitat for a number of animal species, particularly some amphibians, reptiles, and invertebrates.

GOAL

Maintain habitat for species associated with vernal pools and maintain the vernal pool depression in an undisturbed state.

BACKGROUND AND RATIONALE

Despite their small size (from less than 100 sq. ft. to about two acres) and largely temporary nature, vernal pools provide unique and important habitat for a number of animals. In Maine, 15 species of reptiles and amphibians breed or feed in vernal pools (Appendix G) (Colburn 1991, Hunter et al. 1992); two of these (spotted and Blanding's turtles) are on the state's list of threatened and endangered animals, and three (wood frog, spotted and blue-spotted salamanders) rely heavily on vernal pools for successful breeding (Maine Audubon Society 1997). Vernal pools play an important role in the life cycles of spotted and Blanding's turtles, providing habitat for feeding, courtship, mating, and hibernation (Joyal 1996). Other vernal pool inhabitants include aquatic insects and other invertebrates such as fairy shrimp, fingernail clams, and snails.



Vernal pools also provide important habitat for a wide range of visiting species. They can serve as "stepping stones" for reptiles and amphibians dispersing from one large wetland to another, providing temporary food and shelter during risk-laden overland journeys (Gibbs 1993). Typical wetland species (mink, great blue heron, wood turtle) visit these ecosystems to feed on the concentrated supplies of aquatic insects and amphibian eggs and larvae; numerous upland species of birds and mammals visit vernal pools to drink, bathe, and forage.

Typically vernal pools form when rainwater, meltwater, or groundwater accumulates in topographic depressions or low-lying areas; they usually lack a permanent inlet and outlet. The majority of vernal pools in Maine are small; a study of 273 pools in southern Maine found 58 percent less than 4300 sq. ft. and nearly 80 percent less than 15000 sq. ft. (Maine Department Inland Fisheries Wildlife unpubl. data).

Although many vernal pools form in the spring as their name suggests, some fill in the fall and hold water into the following summer. Some may hold water year-round, at least in some years. Forested wetlands, shrub swamps, wet meadows, marshes, and unvegetated pools are potential vernal pools. Water collecting in roadside ditches and tire ruts may also attract breeding amphibians. However, these pools tend to have greater exposure to sunlight than natural pools under a forest canopy, may become too warm and oxygen-poor, or may dry out too quickly for larvae to survive to adulthood. Research into the habitat value of these sites is currently underway.

Regardless of when they fill and how long they hold water, vernal pools share one key characteristic: fish cannot survive in them because they dry up for some period of time, because they lack sufficient oxygen in summer, or because they freeze solid in winter (Kenney 1995). Juvenile amphibians in vernal pools have better survival because predatory fish are absent, but total reproductive failure may occur during dry years.

Although the pools themselves provide important breeding habitat for vernal-pool indicator species, the adjacent upland habitat is equally important to their survival during the remainder of the year. Conditions in the immediate vicinity of the pool are critical for maintaining water quality, providing shade and litter, and providing suitable upland habitat for pool-breeding amphibians during the terrestrial portion of their life history. Dispersing juvenile amphibians may be particularly sensitive to intensive forest management practices in close proximity to breeding pools (deMaynadier and Hunter 1999).

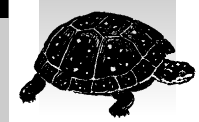
The area within a 500-foot radius of a vernal pool encompasses the average dispersal distance of spotted salamanders (Douglas and Monroe 1981, Kleeberger and Werner 1983, Windmiller 1996) and a portion of the average dispersal distance for blue-spotted salamanders and wood frogs (Williams 1973, Douglas and Monroe 1981, Berven and Grudzien 1990, Windmiller 1996). This upland area is habitat for the majority of Maine's vernal pool amphibian populations for the 50 weeks of the non-breeding season.

Areas of moist forest floor with loose, deep litter, downed woody debris, and patches of canopy shade are important for dispersal, migration, foraging, and hibernation of amphibians breeding in vernal pools (deMaynadier and Hunter 1995). Adjacent uplands are also important for spotted turtles, many of which spend the dry period from late June to August burrowed in loose soil within 200 feet of a vernal pool or other wetland (Joyal 1996).

Maintaining the many habitat functions of vernal pools requires careful forest management. Compaction of soil in a pool basin can damage eggs, larvae, or invertebrates buried in mud and leaf litter, and can alter the pool's ability to hold water. Although some amphibians attach their egg masses to small woody stems and debris near the water's surface, excessive woody debris, such as tops and slash, can restrict mobility of reptiles and amphibians within a pool. Siltation interferes with the development of eggs, and loss of shade increases water temperatures and may limit the availability of dissolved oxygen. Ruts in the pool bottom can change the distribution of water as the pool recedes, stranding eggs before they hatch, and ruts in the forest floor nearby can interfere with amphibian migration to and from the pool.

CONSIDERATIONS

- Some maps and aerial photographs can be helpful in locating vernal pools and identifying areas where they are likely to occur. Vernal pools often appear as wetlands or water bodies on National Wetlands Inventory maps, but are never



labeled as vernal pools. They rarely appear on topographic maps. Vernal pools in hardwood-dominated forests are often visible on 1:400 and 1:1000 aerial photographs taken during leaf-off. Maine Audubon Society (1997) provides detailed information on use of maps and aerial photographs to locate vernal pools.

- An ideal time to search for and map vernal pools is while timber cruising or marking. Vernal pools are most easily located in the field from March through June, when basins hold water and indicator species are present. During dry periods, look for matted and discolored leaves in depressions in the forest floor.

- The “Maine Citizen’s Guide to Locating and Describing Vernal Pools” (MAS 1997) provides detailed information on vernal pool identification and protection in Maine.

- The Maine Natural Resource Protection Act (38 MRSA §480) includes Significant Vernal Pools among the state’s Significant Wildlife Habitats as natural resources designated for protection. Protection of vernal pools under this act requires their identification and formal designation by the Maine Department of Inland Fisheries and Wildlife (MDIFW). Development of the MDIFW strategy for defining Significant Vernal Pools is currently underway. Both the definition and any resulting identification are subject to the state’s rule-making process.

- State and federal protection of vernal pools is weakest when regulated activities affect small areas (<15000 sq. ft. at the federal level and <4300 sq. ft. at the state level). Voluntary protection by responsible landowners remains the most effective means of maintaining these important habitats.

RECOMMENDED PRACTICES

- Best Management Practices (BMPs) for vernal pools are currently being developed by the Maine Department of Inland Fisheries and Wildlife. When completed, they will replace the recommendations presented here.

- Identify and mark vernal pool edges in spring when they are filled with water to prevent damage during harvests conducted when pools are difficult to detect.

- Document use of vernal pools by indicator species using methods described in the “Maine Citizen’s Guide to Locating and Describing Vernal Pools” (MAS 1997).

Within a vernal pool depression:

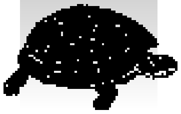
- Avoid any physical disturbance of the vernal pool depression.

- Keep the depression free of slash, tree tops, and sediment from forestry operations. If slash or other woody debris falls into the pool during the breeding season, it is best to leave it in place to avoid disturbing egg masses or other breeding activity that may already be occurring.

Near the edge of a vernal pool:

- Maintain a shaded forest floor, without ruts, bare soil, or sources of sediment, that also provides deep litter and woody debris around the pool.

- Conduct low-intensity harvests (e.g., uniformly distributed light selection harvesting), preferably when the ground is frozen.



In upland habitat around a vernal pool:

- Maintain deep, uncompacted, natural litter, a continuous supply of downed woody material of various size and decay classes, and a shaded forest floor.
- Avoid disturbing the organic layer or drainage patterns within the pool watershed.
- Whenever possible, conduct harvests when the ground is frozen or snow covered.

CROSS REFERENCES

General Principles; Riparian and Stream Ecosystems; Woodland Seeps and Springs; Rare Plant or Animal Sites

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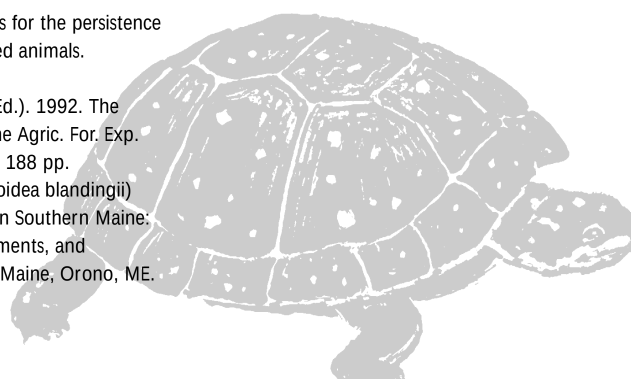


Beaver-Influenced Ecosystems

By Carol R. Foss

DEFINITION

Beaver-influenced ecosystems include temporary wetlands created by beaver dams that periodically cycle through successional stages from pond to marsh to shrubland and young forest then back to pond as beaver occupy and abandon sites over time.

IMPORTANCE TO BIODIVERSITY

Beaver-influenced ecosystems, or beaver flowages, support a great diversity of plants and animals during the course of their cycle from newly flooded pond to beaver meadow to young forest.

GOAL

Maintain a range of beaver-influenced ecosystem conditions distributed across the landscape, and minimize conflicts with human activities.

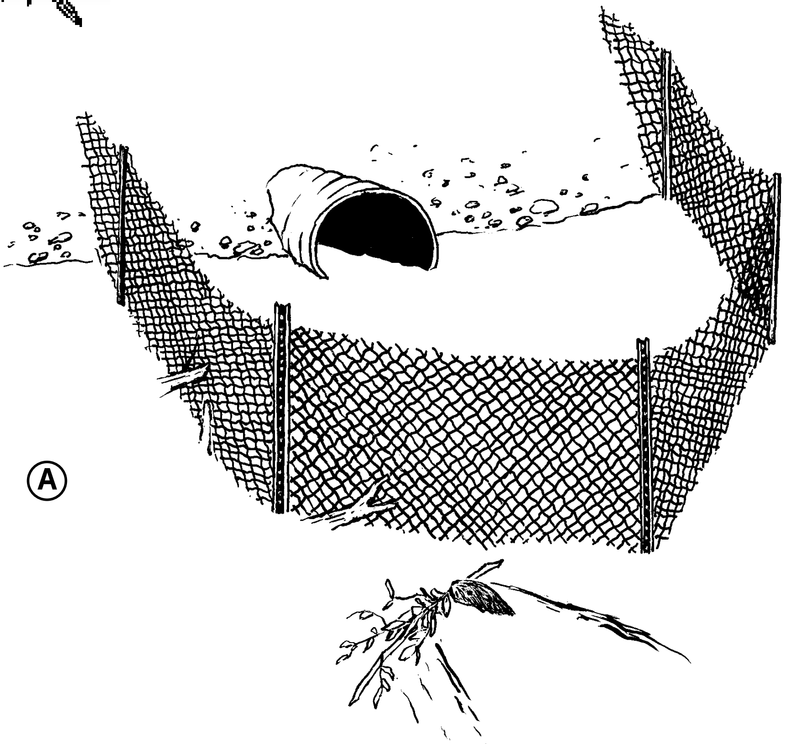
BACKGROUND AND RATIONALE

Beavers build dams on permanent streams, creating flowages of one to 15 acres (Hammerson 1994). Beavers are active where there is an adequate source of food (aspens, birches, and willows are preferred) as well as a suitable location for a dam. The most-favored sites for dams have a channel gradient of less than three percent and a valley width greater than 150 feet; beavers seldom occupy streams with channel gradients exceeding 15 percent (Olson and Hubert 1994). Abandoned dams and lodges indicate historical use and potential for future reoccupation. Aspen growing within 100 feet of a stream or wetland edge increases the likelihood of beavers occupying the site.

The first seven years after establishment of a new beaver flowage are biologically very productive. Nutrients released from the newly flooded soil support a diversity of plants and animals. Over time, organic material accumulates on the pond bottom and eliminates direct contact between soil and water, leading to a decline in productivity. When beaver have depleted their food supply, they move on to a new site, the dam falls into disrepair, and water level drops. As the pond drains, organic material decomposes and the soil is exposed to air. A new period of great productivity begins as grasses, sedges, forbs, and shrubs sprout on the newly available surface, forming a beaver meadow. Eventually saplings sprout in the meadow and grow to create a new food supply, again attracting beaver to the site and beginning the cycle anew.

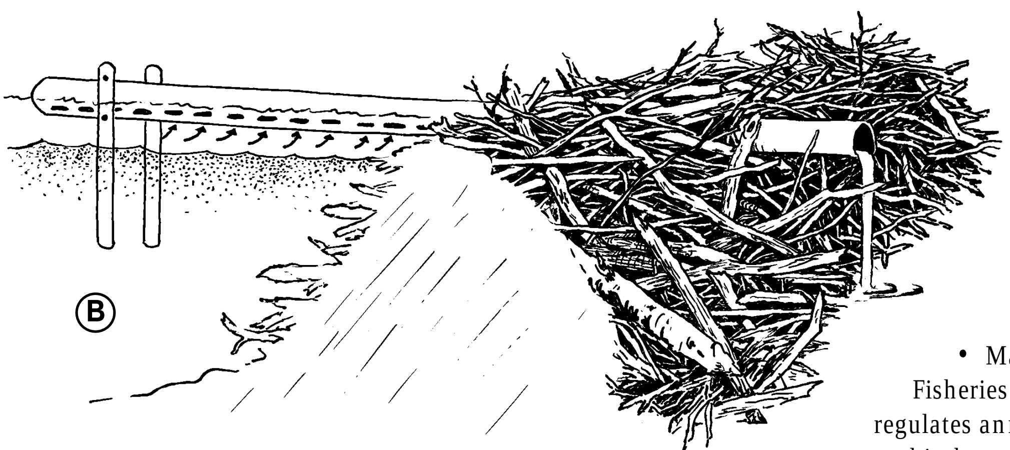
Each stage of the wetland's cycle provides habitat for a changing assemblage of wildlife. The pond stage supports fish, waterfowl, aquatic fur-bearing mammals, herons, osprey, swallows, flycatchers, and a great diversity of aquatic plants and invertebrates; the meadow stage provides forage for amphibians, snakes, grouse, woodcock, deer, bear, and various small mammals; and the shrub-sapling stage provides nesting habitat for numerous songbirds as well as continuing to provide browse for herbivores. These changing conditions provide habitat for many plant and animal species that are not adapted to unbroken forest.

Beaver have many beneficial effects on riparian and aquatic ecosystems (Olson and Hubert 1994). By creating and expanding wetlands, they increase plant and animal diversity and increase groundwater available for upland vegetation, subsequently enhancing forage and cover. Beaver ponds are important post-fledging roosting and foraging habitat for black ducks (Frazer et al. 1990). Beaver ponds also increase total aquatic productivity and aquatic invertebrate production that broadens the base of the food web for both aquatic and terrestrial systems. The presence of active beaver ponds in a watershed can be an important factor in habitat selection by otters (Dubuc et al. 1990). Beaver dams maintain more-even streamflows throughout the year by reducing peak flows and downstream flooding and retaining water for summer release. Chemical processes in beaver ponds can reduce the effects of acidic run-off from adjacent forests.



CONSIDERATIONS

- Beaver can become a nuisance to landowners when tree mortality from felling and flooding exceed acceptable levels, or flooding threatens roadways.



- Where appropriate, water-control devices provide longer-term solutions to beaver problems than removal of animals by live or lethal trapping (Figure 10).

- Maine Department of Inland Fisheries and Wildlife (MDIFW) regulates annual beaver harvest on a township-by-township basis. Allowable harvest is based on estimated carrying capacity for each township with a management goal of sustained yield (MDIFW 1988).

Figure 10.

Water-control devices for beaver. A. Fencing erected to prevent clogging of culverts by beaver. B. Perforated PVC pipe inserted through a dam to regulate water level without removing the dam. (Adapted from Elliott 1988.)

RECOMMENDED PRACTICES

- If beaver activity is likely to cause extensive tree mortality or provide a major constraint on access, evaluate waterways within the ownership for historical, current, and potential sites of beaver activity, and determine the maximum acreage of acceptable flooding in each active drainage.
- To limit flooding where road damage or excessive tree mortality are of concern, install water-control devices as necessary to maintain water at appropriate levels. Contact MDIFW for technical assistance.
- To the extent possible, locate new roads where they will not be at risk from flooding by beavers, or provide a base for the construction of new dams.
- In areas where blockage of culverts by beaver is likely to be an on-going problem, consult with Maine Department of Environmental Protection about the feasibility of using stone fords.
- Provide written or verbal permission for persons legally trapping beaver to access flowages by crossing private land.

CROSS REFERENCES

General Principles; Riparian and Stream Ecosystems; Age Structure of the Landscape

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Special Habitats and Ecosystems:

Woodland Seeps and Springs

By Carol R. Foss

DEFINITION

Woodland seeps are small areas, usually less than 1/4 acre, on headwater slopes where groundwater flows to the surface and saturates the soil for some or all of the growing season. Drainage from these areas may create small streams or may return underground. Woodland springs are sites where streams flow directly out of the ground.

IMPORTANCE TO BIODIVERSITY

Some species of plants and animals, such as water pennywort and spring salamander, are closely associated with seeps and springs. These sites also provide seasonally important sources of food and water for both resident and migrant wildlife. Ground-warmed, flowing water enables the soil in and adjacent to seeps and springs to either remain unfrozen throughout the winter or to thaw earlier in spring than surrounding soils. Unfrozen seeps and springs provide a source of water for local wildlife during winter months and hibernation habitat for some amphibians. These sites also provide early sources of green vegetation, earthworms, and insects to sustain early migrants such as robins and woodcock, especially after late snowfalls. Seep vegetation is important in the spring and early-summer diets of black bears (Elowe 1984), and predators such as skunk, raccoons, and otters often visit seeps in search of salamanders (Whitlock et al. 1994).

GOAL

Protect seeps, springs, and adjacent soils.

BACKGROUND AND RATIONALE

Woodland-seep vegetation is usually distinct from that of the drier soils of the surrounding forest. One or two plant species typically dominate and may occur in high densities, creating a dense tangle of herbaceous growth. However, the species involved may vary widely from one seep to the next. Typical seep dominants include water pennywort, jewelweed, and sensitive fern. Northern dusky, two-lined, and spring salamanders may inhabit woodland seeps and springs year-round (Hunter et al. 1992) and some frog species migrate to these sites for winter hibernation. Invertebrate communities of seeps and springs are not well documented.

Saturated soils and underground streams make woodland seeps sensitive areas in which to operate. Extensive cutting and operation of heavy equipment in these areas can change their drainage characteristics and degrade their habitat values.

CONSIDERATIONS

- Locating seeps and springs may require a thorough knowledge of the property or considerable field time. An ideal time to locate and map springs is while cruising or marking timber.

RECOMMENDED PRACTICES

- In stands containing woodland seeps or springs, schedule harvests to occur on frozen ground or during the driest season.
- In stands containing woodland seeps or springs, lay out roads and skid trails prior to the harvest and in seasons when seeps and springs are obvious.
- Avoid running heavy equipment within 50 feet of the edge of a woodland seep or spring.
- Avoid leaving slash in woodland seeps, springs, or associated wildlife trails.
- To the extent feasible, avoid interrupting groundwater flow above or below seeps and above springs. When seeps and springs can't be avoided, minimize flow interruption by strictly adhering to appropriate Best Management Practices for water crossings (e.g., culverts, portable bridges, or pole fords).
- Where feasible, use woodland seeps and springs as nuclei for uncut patches to retain snags, cavity trees, and other site-specific features.

CROSS REFERENCES

General Principles; Riparian and Stream Ecosystems; Vernal Pools; Rare Natural Communities

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Special Habitats and Ecosystems:

Nesting Areas for Colonial Wading Birds

By Carol R. Foss

DEFINITION

Nesting areas for colonial wading birds refer to their actual nest sites and the immediate vicinity.

IMPORTANCE TO BIODIVERSITY

The eight species of tree-nesting colonial wading birds that occur in Maine represent a unique component of bird diversity and are an important link between terrestrial and aquatic ecosystems. Seven species (snowy egret, cattle egret, little blue heron, tricolored heron, green-backed heron, black-crowned night heron, and glossy ibis) are at or near the northern edge of their breeding range in Maine (Adamus 1988). The eighth species (great blue heron) breeds throughout Maine and north into Canada.

GOAL

Protect existing colonies and avoid disturbance of nesting pairs.

BACKGROUND AND RATIONALE

Wading birds are a diverse group of species that feed and nest in coastal and inland wetlands (MDIFW 1990a). Bitterns, rails, coots, and moorhens nest in emergent vegetation of marshes and are not considered here. Herons, egrets, and ibis nest in trees that may be some distance from aquatic ecosystems. Wading birds that nest in coastal areas include snowy egret, cattle egret, little blue heron, tricolored heron, black-crowned night heron, and glossy ibis. These birds nest in trees on a limited number of offshore islands in mid-coast and southern Maine (Adamus 1988), with any given species nesting at fewer than 10 sites (MDIFW unpublished data). They often occur in mixed colonies that also may include green-backed and great blue herons (Osborn and Custer 1978, Erwin and Korschgen 1979).

Great blue herons are the most abundant of Maine's wading birds, with 15 nesting colonies (totaling more than 600 nests) along the coast and more than 30 inland (MDIFW unpublished data). These herons nest in supercanopy white pines, dead trees in beaver ponds, and in mature live hardwoods on upland sites, particularly on islands. Some heron colonies in Maine exceed 100 nests, but most are considerably smaller (Gibbs et al. 1987). An analysis of colony longevity in New Hampshire suggests that colonies of fewer than eight nests may be relatively short-lived, but larger colonies may persist for decades and generate most of the annual production of young herons (Audubon Society of New Hampshire unpublished data). Maine's great blue herons return to breeding colonies in March or April and prepare for nesting. Incubation takes about 28 days and eggs hatch in late May or early June. Adults often travel considerable distances from their nesting sites to feeding areas in wetlands and along shorelines. Young herons remain in the nest until fledging and dispersing in July or August.

Research suggests that distance from human settlements can be an important factor in heron colony site selection (Gibbs et al. 1987, Watts and Bradshaw 1994). Nesting herons, egrets, and ibis are quite sensitive to disturbance. Human activity near a nesting colony during the breeding season may reduce nesting success or cause abandonment (Bjorkland 1975, Werschkul et al. 1976, Simpson et al. 1987, Erwin 1989). Adults will flush from nests when intruders approach within 100 to 300 ft. during the incubation and nestling periods, and within 400 to 600 ft. earlier in the breeding season (Vos et al. 1985). Such disturbances can lead to predation of the eggs or young, or death from exposure. If alarmed, older nestlings may leap from the nest before they can fly, resulting in injury, starvation, or predation (MDIFW 1990b).

In addition to human disturbance, habitat loss and degradation also threaten the future of colonial waterbirds. Converting forests to other land uses, fragmenting large tracts into smaller parcels that are more accessible to humans, and managing timber on shorter rotations all can have negative effects on breeding populations of wading birds (Parnell et al. 1988).

CONSIDERATIONS

- Late June to mid-July is a good time to conduct aerial surveys for wading-bird colonies and to verify breeding activity at known sites. At this time, young are highly vocal and large enough to be visible in the nests.

- Constructing new roads in the vicinity of a heron colony may lead to nest abandonment. Nesting herons may tolerate vehicle traffic on existing roads, but pedestrians visible from nests are more of a problem (Carlson and McLean 1996).

- The Maine Natural Resources Protection law (38 MRSA §480) includes "high and moderate value waterfowl and wading bird habitats" among significant wildlife habitats eligible for protection under the Act. Significant wildlife habitats must be defined and mapped by Maine Department of Inland Fisheries and Wildlife (MDIFW) and adopted as rule by the Maine Department of Environmental Protection to receive legal protection, unless they are located within another protected natural resource. To date, MDIFW has not defined and mapped high- and moderate-value wading-bird nesting habitats. However, heron colonies located in protected wetlands are covered under this law. Federal laws protecting migratory birds also apply.

- The Land Use Regulation Commission (LURC) regulates activities within Fish and Wildlife Protection Subdistricts (P-FW), including some coastal nesting islands. On islands in these subdistricts, forest management activities, including timber harvesting and construction of land-management roads, require consultation with MDIFW and development of a mutually acceptable plan. When birds are present, only wildlife and fishery management practices approved by MDIFW or the U.S. Fish and Wildlife Service are permissible between May 1 and July 15 without prior LURC approval (LURC 1991).

RECOMMENDED PRACTICES

- Map locations of known wading-bird colonies on stand maps of the ownership.

- Consult with abutters to learn if a colony exists near your boundaries.

- Consult an MDIFW regional biologist when planning forest management activities within a quarter mile of a wading-bird nesting colony.

- When planning a timber harvest on a coastal island, visit the site to survey for

the presence of a wading-bird nesting colony before finalizing harvest plans.

- Avoid human activity within 330 ft. of active heron colonies during the breeding season (April 1 to August 15).

CROSS REFERENCES

General Principles; Vertical Structure and Crown Closure; Riparian and Stream Ecosystems; Beaver-Influenced Ecosystems; Public Access and Roads

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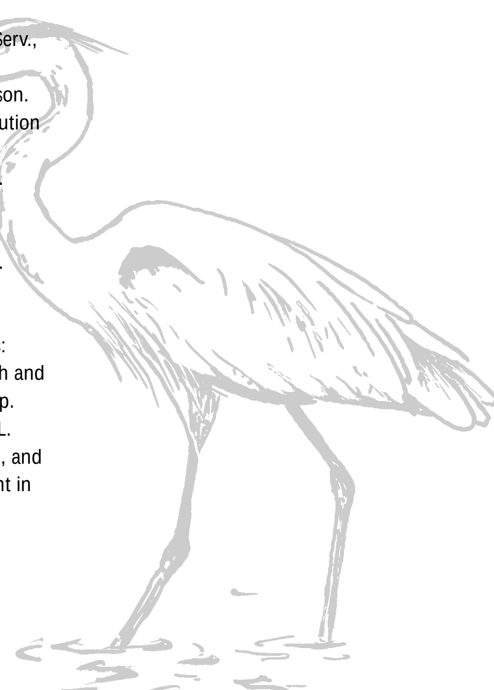

Special Habitats and Ecosystems:

Deer Wintering Areas

By Carol R. Foss

DEFINITION

Deer wintering areas are softwood stands that provide shelter and food for deer during the winter months, particularly when snow depths exceed 12 inches.

IMPORTANCE TO BIODIVERSITY

Deer wintering areas (DWAs) foster survival of white-tailed deer and provide important habitat for a number of other animal species in areas that develop deep snow packs. Recent research in Maine suggests that this type of forest may be an important component of fisher habitat in northern and western Maine (Krohn et al. 1995). More than 40 bird species breed in deer wintering habitat (DeGraaf and Rudis 1987), including 12 species that require conifer forest, five of which (merlin, three-toed and black-backed woodpeckers, rusty blackbird, pine grosbeak) are uncommon to rare in Maine (Gawler et al. 1996). Conifer forests also support a variety of herbaceous and non-vascular plants.

GOAL

Maintain functional values of deer wintering areas.

BACKGROUND AND RATIONALE

In Maine, deer are at the northern limit of their range, and winter mortality can be great (Hugie 1973, Potvin and Huot 1983). Low temperatures and strong winds increase energy requirements of deer; deep snow restricts travel, limits access to browse (Lavigne 1986), and increases vulnerability to predation by coyotes. Density of deer in different regions of the state reflects winter severity, with lowest densities in northern and eastern Maine, and medium to high densities in southern and central areas of the state (MDIFW unpublished data). Overpopulation of deer is a problem in a few areas of Maine (e.g., Swan Island and Cape Elizabeth). High densities of deer can limit species richness of herbaceous plants and the frequencies of particular plant species, including yellow birch, mountain maple, mountain ash, Canada yew, wild sarsaparilla, Canada mayflower, and bluebead lily (Balgooyen and Waller 1995).

Winter survival of deer in the Northeast requires access to special habitats that provide both food and shelter. Also known as “deer yards,” stands used as deer wintering areas (DWAs) typically have overstories with at least 50 percent in some combination of spruce, fir, cedar, and hemlock with >50 percent conifer crown closure, >100 sq. ft. per acre total basal area, and >35 ft. stand height (Figure 11) (Wiley 1988, Stadler et al. 1993). These habitats have less wind exposure, lower snow depths, and greater relative humidity and night temperatures than areas with more-open overstories (Ozoga 1968, Lavigne 1986). By wintering in these protective habitats, deer expend less energy both moving about and maintaining body heat, and are more likely to survive (Mattfeld 1974), reducing population losses to predation and starvation.

Availability of preferred browse plants in association with thermal cover is also important in DWAs. Cedar and hemlock provide food as well as cover. Red, sugar, mountain, and striped maples, hobblebush, white and yellow birches, and American yew are also important browse species (Wiley 1988).

Deer do not use all seemingly suitable conifer stands as wintering habitat. DWAs are often associated with riparian areas of lakes, ponds, rivers, streams, brooks, and wetlands. Because of the species' social system, successive generations of deer use traditional DWAs over many decades, and biologists have documented use of some sites spanning 50 to100 years (Stadler et al. 1993). Social tradition is nearly as important as habitat in determining the location of DWAs.

The Maine Department of Inland Fisheries and Wildlife (MDIFW) is currently working with industrial landowners to develop a comprehensive approach to DWA management that involves developing and implementing a long-term management plan for all known winter habitat for deer within a given geographic area, using management guidelines that are acceptable to landowners and provide adequate habitat for deer (Stadler et al. 1993). This planning effort also addresses management of areas immediately adjacent to core DWAs that are also important to long-term habitat availability for wintering deer (Marston, undated).

CONSIDERATIONS

- The absence of deer in a given winter is not conclusive evidence that an area is not a DWA. If snow conditions do not restrict travel, deer may not concentrate in sheltered areas.

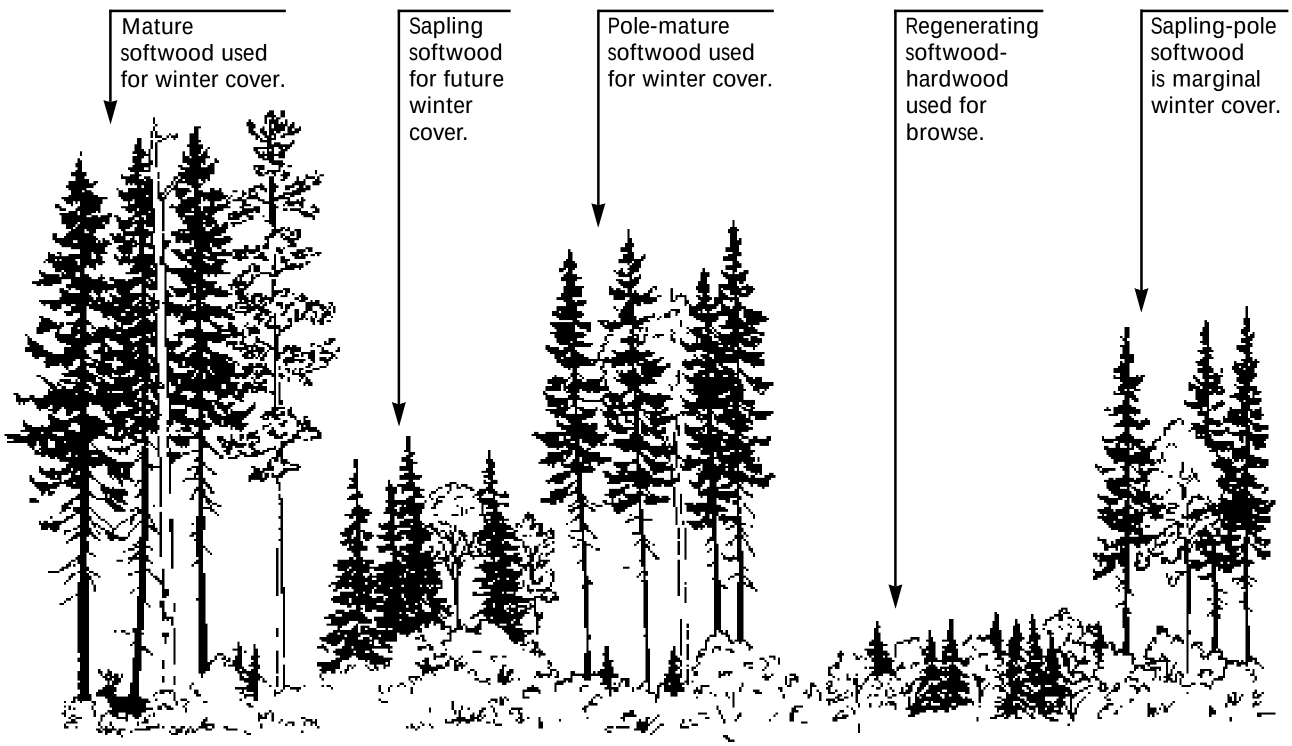

Figure 11.

Deer wintering areas in Maine are managed to maintain at least 50 percent of the area in softwood cover at least 35 feet in height; harvest plans are developed on a site-specific basis to regenerate cover and provide browse (Adapted from Elliott 1988).

- The Maine Natural Resources Protection Act (38 MRSA §480) includes “high and moderate value deer wintering areas” among significant wildlife habitats eligible for consideration as protected natural resources. MDIFW rules define high- and moderate-value deer wintering areas based on deer use, quality of shelter, and size. Significant wildlife habitats must be mapped by MDIFW to receive legal protection unless they occur within another protected resource.
- In unorganized towns, the Land Use Regulation Commission (LURC) regulates activities within Fish and Wildlife Protection Subdistricts, including certain deer wintering areas.
- A wide variety of harvest plans can meet the guidelines for DWA management. The goal is to have blocks and travel corridors of mature conifer forest comprise at least 50 percent of the DWA at any given time.
- Harvests conducted in DWAs in winter will protect advanced regeneration of softwoods and encourage vigorous sprouting of hardwood browse species, providing a source of browse for several years. Tops left on-site provide an immediate, additional food source for wintering deer. Roads and skid trails associated with winter harvesting operations create trails and facilitate travel for deer, coyotes, and other species.

RECOMMENDED PRACTICES

- Inspect LURC zoning maps and MDIFW town maps for DWAs, and use MDIFW deer survey information to determine historic use.
- Inspect aerial photographs of your ownership to identify dense stands of mature softwood as potential DWAs, particularly in riparian ecosystems. Fly over drainages during winter to observe and map deer tracks and activity. Coordinate identification with MDIFW.
- During non-winter periods, inspect suspected DWAs for accumulations of pellets, browse line on conifers, and successive years of browsing on hardwood saplings.
- Designate potential and confirmed DWAs on stand maps of ownership.
- Contact the MDIFW regional wildlife biologist (Appendix A) to coordinate a site visit and develop a DWA management plan. Collaboration provides the most efficient and effective way to simultaneously address landowner needs and objectives, deer habitat needs, and the unique characteristics of each DWA within the context of the larger landscape.
- Whenever possible, schedule harvests in DWAs during December through April.
- Protect advanced conifer regeneration during timber-harvesting operations.
- When conducting harvests in coniferous forest adjacent to watercourses, maintain an unbroken conifer canopy along shorelines to protect riparian travel corridors. Riparian travel corridors should be 330 feet wide on each bank, measured as the perpendicular horizontal distance from the aquatic-terrestrial edge. Where corridors abut open, wind-swept areas, such as lakes and large wetlands, they should be 660 feet wide.
- When planning harvests within any DWA, maintain a closed-canopy coniferous overstory over at least 50 percent of the area at any given time.
- Disperse harvest units over a DWA to avoid concentrating harvesting in any one area within a given period of time.
- Avoid constructing major haul roads within DWAs.

CROSS REFERENCES

General Principles; Vertical Structure and Crown Closure; Riparian and Stream Ecosytems; Age Structure of the Landscape

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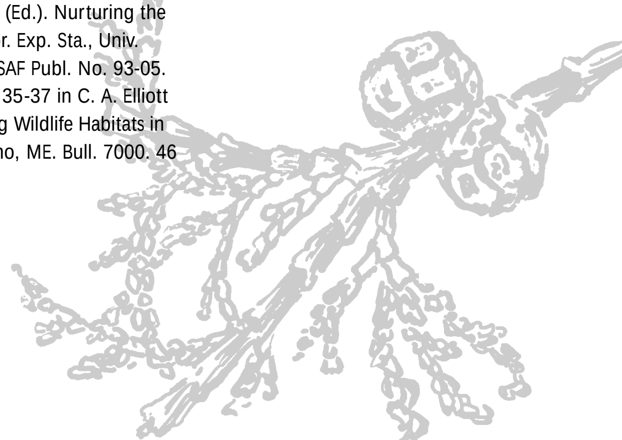

Special Habitats and Ecosystems:

Nest Sites for Woodland Raptors

By Carol R. Foss

DEFINITION

Nest sites for woodland raptors (hawks and owls) refers to the nest itself and the tree in which the nest is located. Both existing nest sites and trees suitable for supporting large stick nests are included.

IMPORTANCE TO BIODIVERSITY

Seventeen forest-nesting species of raptor are known to breed in Maine, and another three may nest in the state, at least in some years (Adamus 1988). Of these 20 raptors, eight build stick nests in forest trees and four use nests built previously by hawks or other large birds, such as crows, ravens, or great blue herons (Table 3). The other eight species of raptor (turkey vulture, northern harrier, golden eagle, American kestrel, peregrine falcon, eastern screech owl, short-eared owl, northern saw-whet owl) nest in cavities, on cliffs, on the ground, or in caves.

In Maine, golden eagles and peregrine falcon are listed as endangered and bald eagles are listed as threatened. Cooper's hawks, northern goshawk, eastern screech owl, and short-eared owl are species of special concern.

GOAL

Maintain suitable nesting sites for woodland raptors across the landscape over time, and avoid disturbing nesting pairs.

BACKGROUND AND RATIONALE

Because of their comparatively large body size and their position near the top of the food chain, raptors require relatively large home ranges (62 to >900 acres) to secure adequate food. Their nests are widely dispersed across the landscape, with densities of a given species typically measured in square miles per pair (Craighead and Craighead 1969).

Preferred breeding habitat of forest-nesting raptors varies with species and includes closed to open canopies, extensive tracts of unbroken forest to forest interspersed with large openings, floodplains to uplands, and young to mature stands. The northern saw-whet owl requires trees with minimum 12-inch dbh that have old woodpecker (especially flicker) cavities. Table 3 summarizes nest-site characteristics for Maine's forest-nesting raptors that use stick nests.

Raptor nest trees must be sufficiently large and have strong enough branches to support nests ranging in diameter from 18 inches (broad-winged hawk) to three feet or more (northern goshawk, osprey, bald eagle) (Harrison 1975, Harrison 1978). Three-pronged main forks of mature hardwoods, closely spaced large branches in mid-canopy whorls of white pines, and large-diameter broken stubs provide the most-secure and frequently-used nest sites for raptors using stick nests (Figure 12). Suitable three-pronged forks are not common in today's forests. Even in stands with numerous large hardwoods, the branching structure of most trees may not support a large stick nest. Many raptor species use the same nest for a number of years, remodel nests originally built by another species, or build new nests within a fairly small area in successive years (Johnsgard 1990). Therefore,

maintaining existing stick nests and additional potential nest trees can benefit an area's raptor population over a long period of time.

Many raptors begin nesting early in the year. Most great horned owls and some barred owls and red-tailed hawks are incubating by the end of March; most other species lay eggs in April or May (Bent 1961). For a given species, timing will be earlier in southern and coastal Maine, and later in the north.

Although tolerance varies among both species and individual pairs, nesting raptors can be vulnerable to human disturbance. Effects include nest abandonment during the early weeks of the breeding season or flushing of the female from a nest with eggs or young that then become susceptible to predation or fatal chilling (Fyfe and Olendorff 1976).

Figure 12.

Hardwood trees with three-pronged forks that can support large stick nests provide safe and secure nesting sites for many of Maine's raptors.

Active raptor nests can be distinguished by several clues even when no birds are visible. Before eggs are laid, some raptor species decorate the nest with a few fresh branches, usually from a conifer. After nestlings hatch, whitewash (excrement), regurgitated pellets, and prey remains may be visible on the ground in the vicinity of the nest. Raptor nests may be confused with squirrel nests, but squirrel nests are made primarily of dead leaves and are saucer-shaped, while raptor nests contain few, if any, obvious leaves.

The bald eagle is of particular concern during forestry operations because of its threatened status. Although peregrine falcons and golden eagles are endangered in Maine, they are of less concern because they nest on a very limited number of cliffs. Peregrines are little disturbed by activity below nesting cliffs, and logistics make harvesting on aerie summits unlikely. In the case of golden eagles, Maine Department of Inland Fisheries and Wildlife (MDIFW) biologists confer directly with affected landowners regarding potential effects of human activities near occupied nests.

CONSIDERATIONS

- MDIFW has designated areas within one-quarter mile of bald eagle nest sites as "Essential Habitat for Endangered and Threatened Species" through the rule-making process under the Maine Endangered Species Act (12 MRSA, Chapter 713, Subchapter V). Within "Essential Habitat," activities that require a permit also require MDIFW reveiw and approval.
- Several species of woodland raptors (e.g., broad-winged, red-shouldered and sharp-shinned hawks, northern goshawks,) often nest near water or forest

Table 3
Characteristics of nest sites for forest raptors in Maine that use stick nests. (Adapted from DeGraaf and Rudis 1986.)

Species	Breeding Habitat	Nest Tree Characteristics
Osprey	Riparian, islands, wetlands	Large dead or dead-topped tree with clear access and extensive view
Bald eagle	Riparian, islands	Large pine near water
Sharp-shinned hawk	Young coniferous or mixed forest	Mid-aged (40 to 60 years) conifer in dense stand; occasionally uses old nests of other species
Cooper's hawk	Open woodlands and mixed or deciduous woodlots adjacent to open land	Mid-aged to mature (50 to 80 years) conifer or hardwood; will re-use previous year's nest; may use old nest of other species
Northern goshawk	Mature or old-growth forest with small openings	Large hardwood or pine in closed canopy; may use old nest of other species
Red-shouldered hawk	Mature riparian forest or mature deciduous or mixed forest near wetland complex; mature deciduous upland forest	Large hardwood or pine in closed canopy; will re-use previous year's nest; occasionally uses old nest of other species
Broad-winged hawk	Extensive mid-aged to mature mixed or deciduous forest with water and openings	Mid-aged to mature pine or hardwood near opening
Red-tailed hawk	Open woodlands and mixed open and closed-canopy forest	Large hardwood or pine near open habitat
Merlin	Northern conifers near water	Mature spruce, fir, or pine; uses old crow or raven nests; may nest in cavities or on cliffs
Great horned owl	Mature deciduous or mixed forest near open habitats	Large broken stub or large hardwood or pine; uses old hawk, crow, or raven nests; may nest in cavities or on cliffs
Barred owl	Mature, closed-canopy forest	Large hardwood or pine; uses cavities; may use old hawk, crow, or raven nests
Long-eared owl	Dense conifer forest near open habitats	Live conifer; uses old crow, raven, hawk, or squirrel nest; occasionally uses cavities

openings such as old woods roads or stone walls (Johnsgard 1990, Speiser 1993). Although nesting hawks may tolerate closed-vehicle traffic on routinely-used roads, sporadic traffic by pedestrians and open vehicles (i.e., ATVs) on otherwise unused roads can disturb incubating birds (Speiser 1993).

- Great horned owls prey on both adult and nestling hawks, and their presence may discourage hawks from nesting. These owls generally avoid extensive forest, but may establish territories in forested areas with large openings (Craighead and Craighead 1969).
- Risk of nest abandonment is greatest during the early part of the breeding season, and decreases progressively, especially after eggs have hatched.

RECOMMENDED PRACTICES

- Consult with MDIFW biologists to maintain up-to-date maps of bald eagle nest sites designated as Essential Habitat within the ownership.
- Contact MDIFW biologists when planning forest management activities in the vicinity of a bald eagle nest.

- Inspect mature white pine and hardwood trees for large stick nests while cruising timber; retain trees containing large stick nests and hardwoods with three-pronged forks (NHFSSWT 1997).
- During the raptor nesting season (February to July), avoid forest management activities within 0.25 mi. (0.4 km) of known, active raptor nests, and avoid recreational use of logging roads within sight of active nests (Call 1979, NHFSSWT 1997).
- Maintain an uncut buffer of at least 66 feet around known raptor nest trees and retain 65 to 85 percent canopy closure within 165 feet of large stick nests in closed-canopy forest (Elliott 1988).
- Leave a patch of several large trees in each 5 to 10 acres of large clearcuts to provide future large-diameter nest trees as the stand matures (Elliott 1988).
- Retain several supercanopy pines near the shores of large lakes as potential future nest trees for bald eagles and ospreys.
- If a raptor nest can be positively identified as belonging to a common or tolerant species (e.g., red-tailed or broad-winged hawk), harvest scheduling and buffer zone guidelines may be relaxed. In the absence of positive identification, it is better to err on the conservative side and follow recommended guidelines.

CROSS REFERENCES

General Principles; Vertical Structure and Crown Closure; Riparian and Stream Ecosytems; Rare Plant or Animal Sites; Age Structure of the Landscape

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Special Habitats and Ecosystems:

Old-Growth and Primary Forests

By Carol R. Foss

DEFINITION

Old-growth forests are composed of long-lived or late successional species, and are usually 150 to 200 years of age or older. Ages of individual trees within these stands may vary, depending on the species (Appendix H). In addition, old-growth forests often exhibit characteristics such as presence of large snags, large downed woody material, and multiple age classes.

Primary forests are stands that have experienced little or no direct physical disturbance or alteration by humans since European settlement. Primary forests may consist of relatively young trees as a result of natural disturbances.

IMPORTANCE TO BIODIVERSITY

It is important to ensure an adequate amount of old stands and structures on the landscape to enable species dependent or closely tied to these areas to move and recolonize new stands. Studies in eastern North America suggest that there are more species and more individuals of birds and herbaceous plants in primary than secondary forest (Duffy and Meier 1992, Haney and Schaadt 1996, Meier et al. 1996). Although there is no evidence of old-growth dependence among vertebrates or higher plants, research in New Brunswick, northern Maine, New Hampshire, and Vermont suggests that 13 lichen species grow almost exclusively on old-growth hardwoods and another eight on old-growth conifers. Additional species are restricted to old growth, but occur on both hardwoods and softwoods (Selva 1996). Research in New Hampshire suggests that some forest-floor beetles are more abundant in old-growth forest than in younger, managed stands (Chandler 1987, Chandler 1991, Chandler and Peck 1992). Further research on distributions of invertebrates and non-vascular plants may yield additional species indicative of old growth forests.

GOAL

Protect existing old-growth stands and remaining primary forest, and allow some additional old growth to develop.

BACKGROUND AND RATIONALE

Human use of forest resources has substantially changed many characteristics of forests that developed prior to European settlement. Forest harvesting reduces the size and age to which harvested trees grow; reduces the total supply of downed and standing dead wood; changes the configuration of canopy gaps and vertical structure; and frequently alters plant and animal species composition. Although a number of characteristics have been suggested as indicators of old growth (Carbonneau 1986, Leverett 1996), the only consistent characteristics across most sites and species are relative age and actual history of disturbance (Cogbill 1996). Old-growth characteristics develop when catastrophic disturbance cycles are longer than pathological ages of individual trees.

Primary and old-growth forests now occur only as scattered remnants on the landscape. Of 93 identified examples of old-growth forests in Maine, only 11 exceed 50 acres, and 37 cover less than 10 acres (Maine Critical Areas

Program 1983, Pinette and Rowe 1988, Gawler et al. 1996). Another 131 potential old-growth sites await thorough evaluation. There may be more small pockets of old growth that have not been reported.

The largest known expanse of low- to mid-elevation old-growth forest in the state is in the 5000-acre Big Reed Pond Forest Preserve, that includes a mosaic of spruce-slope, mixed hardwood-conifer, maple-basswood-ash, beech-birch-maple, northern white cedar seepage forest, and northern white cedar swamp (Gawler et al. 1996). Limited cutting of scattered pine and cedar occurred at this site between 1886 and 1926, and there have been periodic natural disturbances by wind, insects, and diseases.

Much of Maine's remaining primary forest is at high elevations (Davis 1996) or on inoperable slopes. Current understanding of how biodiversity differs between primary and secondary forests of the same type in the eastern United States is limited. Although primary forest cannot be recreated, old-growth conditions can be restored over time. Both primary and old-growth forests can provide valuable lessons about maintaining components of forest biodiversity that require old-growth structures or long periods of vegetation development without disturbance. It is important to maintain representative areas of old growth and primary forest as benchmarks for scientific study. Although it is probably impossible to maintain all characteristics of old growth in managed forests, it is probably possible to maintain many of these characteristics.

CONSIDERATIONS

- Maintaining biodiversity requires a full continuum of forest ages on the landscape. Management activities provide extensive areas of younger-age classes, but there is a need for some component of the forest that remains unmanaged over the long term.
- Maintaining existing old-growth forests and restoring old-growth conditions both require commitment over multiple generations of forest managers and many generations of trees. Potential income may be sacrificed.
- Old growth may be difficult to distinguish from older stands that have had significant harvesting in the past but have remained undisturbed for many decades.
- Outstanding examples of common forest types are rare on the landscape but provide a good opportunity for restoring old-growth conditions.

RECOMMENDED PRACTICES

- Survey ownership and archival records for areas with old-growth characteristics or showing little or no evidence of past human activity.
- Use stand maps and aerial photographs to identify candidate areas for restoring old-growth conditions. Candidate areas that are adjacent to or near existing old-growth have a greater chance of successful colonization by a more-complete range of species.
- Where possible, buffer small stands of existing old growth within larger areas of mature intact forest to provide protection from edge effects and to enlarge the area of future old-growth forest.
- Document characteristics (tree species, ages, basal areas, sizes, conditions) of known and suspected old-growth stands and primary-forest remnants to preserve this knowledge even if site conditions change.
- Investigate options for long-term protection (easements, sales or transfers to conservation ownerships) of primary forest and old-growth stands based on landowner goals.

- Restore old-growth conditions to provide reference sites by avoiding active management in areas of inaccessible or inoperable terrain; some riparian ecosystems; sites of compatible rare plants or natural communities; and even some operable areas. Previously harvested stands that exhibit late-successional characteristics, such as dominance by shade-tolerant species, some large, live trees, and some large woody debris, are most suitable for old-growth restoration.

CROSS REFERENCES

General Principles; Riparian and Stream Ecosystems; Age Structure of the Landscape

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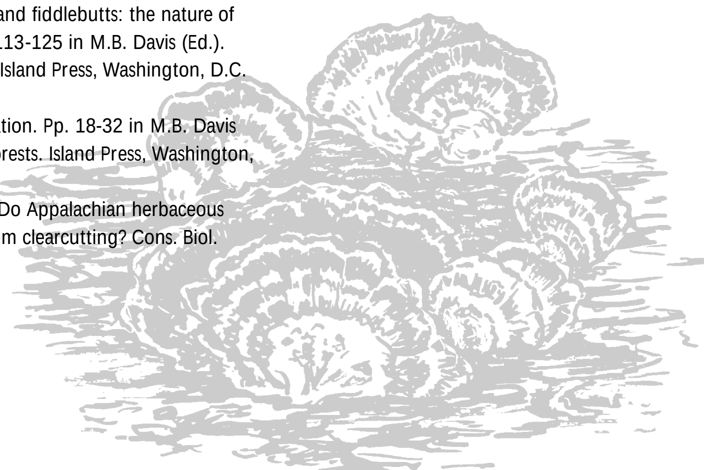


Special Habitats and Ecosystems:

Rare Plant or Animal Sites

By Carol R. Foss

DEFINITION

Rare plant and animal sites refers to the locations and important habitats of rare plants listed by the Maine Natural Areas Program (MNAP) and important habitats for rare animals listed by the Maine Department of Inland Fisheries and Wildlife (MDIFW).

IMPORTANCE TO BIODIVERSITY

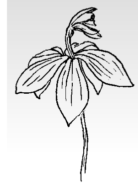
Rare plant and animal sites provide habitat for species that occur in relatively few places and may be particularly vulnerable to changes in environmental conditions.

GOAL

Protect rare plants and animals and their habitats.

BACKGROUND AND RATIONALE

Species diversity is an important component of biodiversity. Most species occur widely enough on the landscape that human activities of limited scope will not put them at risk; rare species, however, are exceptions. These species occur in relatively few locations and many require specialized habitats. Some rare species have been rare historically because availability of their habitats has always been limited in the state or because they are at the extreme northern or southern limit of their range in Maine. Others have become rare in recent times as human land uses, particularly development and agriculture, have usurped much of their traditional habitat. Rare species and their habitats require special attention to ensure their continued survival in a working landscape.



Application of the term "rare" to plants and animals can be confusing. The concept typically includes legal definitions of threatened and endangered species, and often encompasses additional species that occur in low numbers or in a limited number of locations. Maine's Endangered Species Law defines "Endangered" to mean: *any species of fish or wildlife which has been determined...to be in danger of extinction throughout all or a significant portion of its range,* and "Threatened" to mean: *any species of fish or wildlife which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range* (12 MRSA, Ch. 701). The likelihood that a species will be lost from Maine is based on an assessment of population viability, size, trends, distribution, and fragmentation, and on whether or not it is endemic (occurs only in Maine). MDIFW maintains an additional administrative category, "Special Concern," that confers no legal status but applies to animal species for which there is valid, but somewhat less, concern over long-term viability, or about which little is known of distribution or habitat requirements.

Maine has listed endangered and threatened plant species, but this list is 10 years old and is being revised. MNAP ranks plant and animal species according to their frequency of occurrence in the state (S ranks) and throughout the globe (G ranks). These rankings provide no legal protected status. State ranks are (Gawler et al. 1996):

S1 Critically imperiled in Maine because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because some aspect of its biology makes it especially vulnerable to extirpation from the state.

S2 Imperiled in Maine because of rarity (six to 20 occurrences or few remaining individuals or acres) or other factors making it vulnerable to further decline.

S3 Rare in Maine (on the order of 20 to 100 occurrences).

S4 Apparently secure in Maine.

S5 Demonstrably secure in Maine.

MNAP maintains records of rare plants and natural communities and MDIFW maintains records of rare vertebrates and invertebrates. This information is limited, however, as comprehensive, statewide surveys for rare species have only recently been initiated (deMaynadier 1997, deMaynadier and Hodgman 1998).

Animals

MDIFW initiated the first comprehensive review of the status of vertebrate species in Maine in 1984. A second comprehensive review, which included invertebrates, followed in 1994. Of the 284 vertebrates and 15132 identified invertebrates inhabiting Maine's upland and freshwater ecosystems, only a small proportion is considered rare (Appendix I). Maine lists 34 animal species (22 vertebrates, 12 invertebrates) as threatened or endangered. The U.S. Fish and Wildlife Service lists another 13 species (11 vertebrates, 2 invertebrates) that are currently or historically native to Maine but not listed by the state. Only 17 of these 47 species and 50 (29 vertebrates, 21 invertebrates) of 94 listed species of special concern use partial- or closed-canopy forests (Appendix I).

Plants

Of approximately 1432 species of native vascular plants now occurring in Maine, 254 are threatened, endangered, imperiled or rare (Gawler et al. 1996). These include 165 state-listed threatened or endangered species; MNAP classifies the remainder as imperiled (S2) or "rare" (S3). Seventy-four S1 or S2 species occur in forest or shrubland habitats, of which 55 species are threatened or endangered (Appendix J).

Mosses, liverworts, and lichens also contribute to the state's plant biodiversity. Maine's lichen diversity is among the greatest of any region in North America and includes a number of rare species (Gawler et al. 1996). Most rare mosses and liverworts occur in alpine or coastal habitats, but several rare mosses occur on rocks, bark, or bare soil in woodlands (Allen 1996). One rare liverwort occurs only on northern white cedar bark (Miller 1996). Rare lichens of forested ecosystems occur in pitch pine scrub forests, coastal fog forests, and old-growth forests (Hinds and Hinds 1996).

CONSIDERATIONS

- Some geographic areas harbor greater numbers of rare species than others because of ecosystem distributions, latitudinal limits, topography (alpine and sub-alpine areas), soils or parent materials (limestone regions), or hydrology (fens and bogs). Many rare plants are restricted to York and Cumberland counties (Gawler et al. 1996).

- Because they are small, easily overlooked, and difficult to identify, rare non-vascular plants (e.g., liverworts, mosses) are most readily conserved by protecting those natural community types in which they are likely to occur.

- In addition to the species listed in Appendix J, 63 rare plant species occur on river and lake shores (Gawler et al. 1996).

Protecting riparian ecosystems provides protection for these species.

- Proactive efforts to conserve habitat for rare species not currently listed as threatened or endangered (i.e., species of special concern) may help prevent a future need to list them in a legally protected category.

RECOMMENDED PRACTICES

- Document the location of rare plant and animal sites on stand or ownership maps by contacting MNAP and MDIFW for information.

- Be familiar with the habitats where rare plants and animals are likely to be present, particularly rare natural community types, and be alert for the presence of rare species while cruising or marking timber.

- Survey any community types on your ownership in which rare plants or animals are especially likely to occur. Don't hesitate to consult with botanical and zoological specialists for assistance in planning or conducting surveys for rare species.

- When planning forest management activities in the vicinity of a rare plant site, consult with MNAP regarding appropriate management strategies.

- Avoiding harvesting, road building, and other alterations may be the best approach in the vicinity of some rare plant sites. In others, harvesting or natural disturbance may be necessary to perpetuate suitable habitat conditions. Some rare plants are adapted to successional forests and may tolerate some selective removal of the canopy. For example, the U.S. Fish and Wildlife Service is experimenting with selective harvesting in the habitat of the federally threatened small-whorled pogonia. Other rare plants require periodic fire to reproduce successfully.

- If a rare plant adapted to undisturbed conditions occurs on your ownership, consider setting the area aside to perpetuate suitable habitat conditions.

- When planning forest management activities in the vicinity of a rare animal habitat, consult with MDIFW regarding appropriate management strategies.

- Rare vertebrates maintain home ranges of various sizes, and may require multiple habitat types within their home range. Management strategies to conserve them should consider opportunities for dispersal, migration, breeding habitat, and foraging habitat, as well as the specific microhabitat needs of each stage of the species' life cycle. For example, riverine dragonflies may require clean, swift-flowing streams for larval development and vegetated riparian areas for adult foraging.

CROSS REFERENCES

General Principles; Riparian and Stream Ecosystems; Woodland Raptor Nest Sites; Old-Growth and Primary Forests; Rare Natural Communities; Distribution of Native Forest Communities

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Special Habitats and Ecosystems:

Rare Natural Communities

By Carol R. Foss

DEFINITION

A natural community is an assemblage of interacting plants and animals in their common environment that recur across the landscape. Rare natural communities in Maine are classified primarily on the basis of plant assemblage and physical environment; they occur in 100 or fewer locations.

GOAL

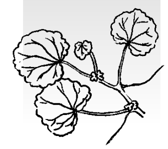
Maintain the presence, structure, composition, and function of rare natural communities.

IMPORTANCE TO BIODIVERSITY

Conservation of natural communities is important because they represent one level of biodiversity in and of themselves; conserving natural communities maintains unique assemblages of living things. Natural communities also encompass a substantial proportion of species-level diversity including individual species and the conditions and processes that enable them to survive. Rare natural communities require special conservation attention because they occur in so few places on the landscape.

BACKGROUND AND RATIONALE

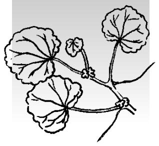
Community-level conservation, also called the "coarse filter" approach (Noss 1987), can be a highly efficient strategy that complements, but does not entirely replace, conservation at the species level (Noss and Cooperrider 1994). It is important to set aside examples of rare natural communities as scientific benchmarks to study the effects of natural disturbances and processes as a means of evaluating the relative effects of human management practices.



The Maine Natural Areas Program's (MNAP) community classification system was designed to assess biodiversity at the ecosystem and natural community level and is based primarily on plant assemblages and their physical environments. MNAP recognizes 25 closed-canopy (Appendix L) and 9 partial-canopy forest community types in Maine. Partial-canopy forest types have canopy closure of 25 to 66 percent (MNAP 1991). MNAP considers a community to be rare if it occurs at fewer than 100 locations in the state, and very rare if 20 or fewer sites exist (MNAP 1991). Ten closed-canopy and seven partial-canopy forest community types are considered rare or very rare in the state (Table 4, Appendix K).

Patches and Stands

"Patch" will be used here to refer to a contiguous area occupied by a given community, and "stand" to refer to a contiguous area that receives a given silvicultural treatment. Communities occur as landscape patches of different sizes. As described by The Nature Conservancy, "matrix communities" (e.g., maple-birch-beech, spruce-fir) naturally cover areas exceeding 100 acres, "large patch communities" (e.g., red maple swamp, black spruce bog) communities cover 10 to 100 acres, and "small patch communities" (e.g. talus slope forest, red pine summit) occupy <10 acres (Anderson 1996). Depending on community patch sizes and the scale and objectives of landowner operations, community patches and operational stands may or may not coincide. Matrix community patches are often more conveniently managed as several different stands that are harvested on different schedules. Alternatively, in very large-scale operations, single stands may encompass all or part of several community patches.



Some forest communities are naturally rare in Maine because their primary component species are at the northern edge of their range in the state, others are rare because the conditions they require rarely occur. Human encroachment has contributed to the rarity of some communities. All three factors contribute to the rarity of Atlantic white cedar swamp communities in Maine. Some forest types are common in the state as a whole, but rare in particular geographic areas. Examples include peatland forests in York and Cumberland counties and oak-pine forests in northern Maine. Ecologically mature examples of common forest types are rare throughout the state, as discussed in the chapter on old-growth and primary forests.

Understanding natural community dynamics will help in developing management strategies for rare communities. Some rare natural communities, particularly partial-canopy upland forest types, depend on periodic natural disturbance, such as fire, to maintain their structure and composition. Although carefully planned harvesting may simulate natural disturbance patterns in these forests, harvesting may not adequately substitute for natural disturbances in all instances. Other natural community types, such as maple-basswood-ash forests and northern white cedar seepage forests, are more vulnerable to alterations, and managers may want to avoid any management activities in these types. The MNAP may be able to offer recommendations for managing specific community types.

Table 4.
Rare forest community types in Maine (MNAP 1991).

Closed-canopy upland forest types	Closed-canopy wetland forest types
Oak-hickory forest	Perched hemlock-hardwood swamp
Maple-basswood-ash forest	Atlantic white cedar swamp
Sub-alpine spruce-fir forest	Northern white cedar seepage forest
White oak-red oak forest	Hardwood floodplain forest
	Outwash seepage forest
	Hardwood seepage forest
Partial-canopy upland forest types	**Partial-canopy wetland forest types**
Red pine woodland	Pitch pine bog
Pitch pine woodland	
Jack pine woodland	
Northern white cedar woodland	
Pitch pine dune semi-forest	
Pitch pine-scrub oak barrens	
Pitch pine-heath barrens	
Cold-air talus woodland	

CONSIDERATIONS

- Many tree species occur in common, as well as rare, community types. For example, the presence of basswood in a stand does not necessarily indicate the maple-basswood-ash community type (also known as Cove Forest).
- Rare forest communities occupy a tiny fraction of Maine's forest landscape.
- Accurate identification of some rare communities may require training and experience.
- Knowledge of forest management effects and specific management guidelines for most rare forest communities are lacking. Moreover, the value of a rare natural community as a benchmark is substantially reduced when any forest management occurs.
- Different harvesting strategies may be appropriate in different rare communities.

RECOMMENDED PRACTICES

- Document and map the location of rare natural communities on your ownership. Consult MNAP for existing information on rare natural communities in the vicinity of your property. MNAP may also be able to provide fact sheets on rare community types of interest.

- Be familiar with the species compositions, geographic distributions, and topographic situations of the rare forest communities presented in Appendix K. Consider an ecological inventory to locate rare natural communities on your property, particularly in planned harvest areas.

- In some rare communities, avoiding harvesting, road building, and other types of management may be the best approach because of the extreme rarity of these communities on the landscape. In other rare communities, harvests or natural disturbances may be necessary to perpetuate the type.

- If your ownership includes a known or suspected rare natural community, contact MNAP for advice.

CROSS REFERENCES

General Principles; Woodland Seeps and Springs; Distribution of Native Forest Communities; Old-Growth and Primary Forests; Rare Plant or Animal Sites

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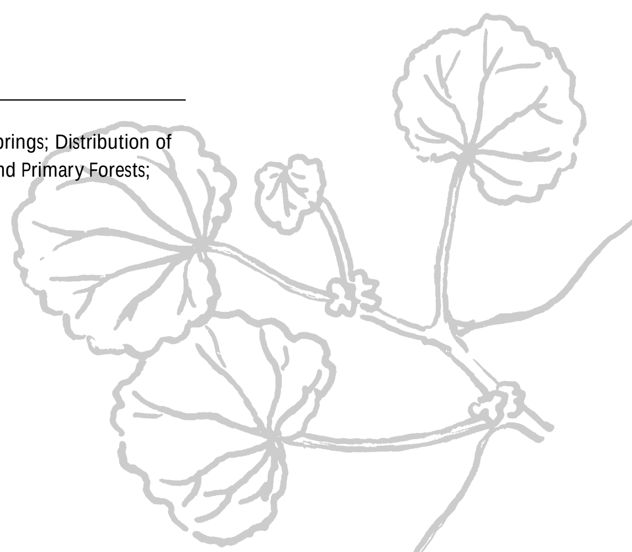


Landscape-Level Considerations:

Introduction

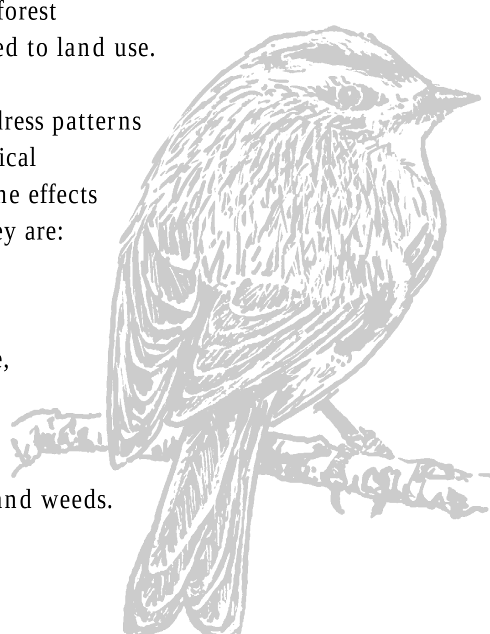
By Gro Flatebo

MAINTAINING BIODIVERSITY IN MAINE'S managed forest requires managing forests at a variety of scales, looking beyond individual stands and ecosystems to patterns, processes, and linkages across landscapes and regions. This section contains those aspects of biodiversity that are best discussed and managed at the landscape level. Although techniques are most easily applied by landowners with holdings of at least several thousand acres, landowners with smaller holdings can manage their forests for these characteristics in the context of surrounding forestlands or in cooperation with other landowners. The goal is to maintain an array of forest ecosystems that will, over time, support viable populations of all native plant and animal species currently occurring in Maine.

The first chapter describes an approach to landscape management, and introduces some of the tools and concepts needed to integrate and implement large-scale forest management. Then landscape-level considerations are described that include five issues related to forest management and two issues related to land use.

The forest management issues address patterns of community type and age, physical characteristics of the forest, and the effects of disease, insects, and weeds. They are:

1. distribution of native forest communities,
2. age structure of the landscape,
3. habitat patch size,
4. habitat connectivity, and
5. disease agents, insects pests, and weeds.



Some land-use issues are also effectively discussed at the landscape level. The two issues included are:

1. public access and roads, and
2. conversion to non-forest use.

Landscape-Level Considerations:

Managing at the Landacape Level: How to Begin

By Carol R. Foss

MAINE'S FOREST LANDSCAPE IS COMPLEX and heterogeneous. Natural landscape patches differ greatly in their timber productivity, wildlife habitat values, and influence on nutrient and water cycling. The scale of modern forestry not only changes conditions within patches, but can alter ecosystem patterns throughout entire landscapes.

Increasingly, landowners and foresters are making management decisions at the landscape and regional levels. Biodiversity is one of several issues that requires the perspective of multiple scales in space and time. Sustainability of the forest, one aspect of biodiversity, is another growing public and corporate issue that can only be addressed by considering the effects of management on entire landscapes, encompassing multiple entries and rotations.

Managers of both large and small ownerships should consider landscape factors because ecosystem functions and processes are not limited by boundary markers (Leak et al. 1997). On smaller ownerships, it is important to manage at the property level (i.e., integrate the management of all stands on the property), as well as consider how the property is influenced by and influences the surrounding landscape.

Landscape ecology is a new scientific discipline that studies the development, interrelationships, and patterns of patches on the landscape. Although much ecological information has yet to be collected and understood, new technologies, such as satellite imagery, geographic information systems (GIS) (Star and Estes 1990, Burrough and McDonnell 1998), geographic positioning systems (GPS), and sophisticated computer models provide unprecedented opportunities for learning.

These powerful new tools now make it possible to analyze specific landscapes and model effects of management actions over large areas and long time-frames. On small ownerships, where these new technologies are not yet cost effective, aerial photographs and soils, wetlands, and wildlife habitat maps can be used to integrate landscape factors into management decisions.

Landscape-level planning to maintain biodiversity requires an understanding of landscape structure and dynamics and the interactions between them:

- Landscape structure includes the size, shape, composition, and distribution of ecosystem patches both geographically and over time.
- Landscape dynamics include the types of human and natural disturbances that occur, their size distributions, and their ranges of frequency and intensity.
- Interactions between structure and dynamics include the effects of factors such as topography, climate, soils, and vegetation on disturbance frequency and intensity, as well as the effects of disturbance on soils, vegetation, and ecological processes.
- Ecosystem structure includes species composition, age classes, genetic diversity, soils, and dead wood.

- Ecosystem processes include nutrient and water cycles, population demographics, migration, dispersal, and species interactions, such as pollination, herbivory, and predation.
- Relationships between structure and processors can be maintained by using management techniques including variable rotation lengths, varying harvest levels at each entry and a broad range of cutting unit sizes.

Maintaining biodiversity also requires an understanding of the relationships between ecosystem structure and processes.

- Ecosystem structure includes species composition, age classes, genetic diversity, soils, and dead wood.
- Ecosystem processes include nutrient and water cycles, population demographics, migration, dispersal, and species interactions such as pollination, herbivory, and predation.
- Relationships between structure and processes can be maintained by using management techniques including variable rotation lengths, varying harvest levels at each entry, and a broad range of cutting unit sizes.

Any forest management, no matter how intense, creates habitat for some species of plants and animals. Habitat for those species using early-successional communities is easy to provide, quickly and in abundance. Habitat for late-successional species is often more difficult to provide and can take many years. Ensuring that there is adequate habitat to support viable populations of all native species over time requires landscape-level planning; ensuring that all factors that influence biodiversity, both site-specific and landscape-level, are maintained over time requires landscape-level planning as well.

Whether one is considering three stands or 300, a landscape approach first involves gathering and integrating basic information about the land, looking at how different stands fit together on the property, and how the property interacts with the larger landscape. Several techniques and tools can greatly facilitate landscape-level planning. These include:

1. Hierarchy of planning units: Although stands are an important operational unit for forest management, management at the landscape scale requires larger planning units to assess cumulative effects of stand-level management. Townships are useful units for large ownerships; small ownerships may use roads, streams, or other features to delineate planning units. Large watersheds incorporate many of the attributes needed to describe ecosystem function, have definite boundaries, and are easily aggregated into larger units to consider processes occurring at larger scales, but their use as planning units is not always practical. In the unorganized townships of northern and eastern Maine, landscape planning units may encompass up to 100,000 acres, but average roughly 25,000 acres, the typical size of a Maine township (MCSFM 1996). When making decisions on smaller ownerships, DeGraaf et al. (1992) suggest considering an area of the surrounding landscape that is up to 10 times the size of the property.

   Biotic (i.e., species richness) and abiotic (i.e., climatic and geomorphological) factors have recently been used to define hierarchical biophysical units for Maine (Krohn et al., in press). These units provide a framework for landscape planning because they become more homogeneous at finer scales and the factors used to define the units are related to Maine's animal and plant richness.

2. Geographic Information Systems (GIS): These systems, such as the widely used ARCINFO, make it possible to link descriptive information with map locations, and to view maps of ecosystem patches, linear features, and spot locations at multiple scales. If a computer is not available, base maps with mylar overlaps of cover types, topography, and other features work well, particularly for smaller land units.

   Databases for GIS are available from the Maine Office of GIS (http://apollo.ogis.state.me.us/homepage.htm) and from Maine Gap Analysis (http://wlm13.unit/gap/). Gap analysis data will also be available in digital form on CDs from the National Gap Analysis Program of the U.S. Geological Survey's Biological Resources Division (look under ME-GAP at http://www.gap.uidaho.edu/gap).

3. Spatial- and temporal-based decision models: Computerized models, such as the Scheduling and Network Analysis Program, or SNAP (Sessions and Sessions 1992), can be linked with a GIS to incorporate spatial and temporal relationships into management alternatives. These models are still fairly crude and do not yet represent complex forests very well.

4. Ecological information about each planning unit to integrate into the GIS and decision model: These data should include information on ecosystem and landscape structure and processes within the unit, as well as spatially explicit information about operational constraints (e.g., steep slopes, poorly drained soils, boulder fields) and special ecological values (e.g., riparian management zones, special habitats, rare organisms and communities). The National Council of the Paper Industry for Air and Stream Improvement (NCASI) is currently developing watershed assessment procedures for use on private lands.

Although these tools are important for large ownerships, traditional tools such as aerial photographs and paper maps work well for considering landscape issues on small non-industrial ownerships. Leak et al. (1997) outline a pragmatic approach to ecosystem management on small ownerships. Whether using new technologies or traditional tools, managers can begin to refine specific objectives for each land planning unit, reflecting each unit's unique features and constraints, and to develop management alternatives based on objectives. Although implementing landscape-level planning may differ for ownerships of different sizes, basic planning principles can be applied regardless of the extent of the land base.

By considering special features, physical management constraints, and long- and short-term changes in ecosystem conditions, on managed and unmanaged areas within and adjacent to the parcel, all landowners and managers can contribute to maintaining biodiversity in Maine's managed forest.

Biodiversity Thresholds

We know that the biodiversity in Maine's forests is very resilient to disturbances, both natural and human-generated, over a wide range of intensities, frequencies, and extents. We also suspect that there are thresholds beyond which that resiliency will break down, but in most instances we do not know what those thresholds are. Because natural disturbance regimes are clearly within the thresholds, they provide a useful yardstick for evaluating harvest patterns. We can expect that biodiversity will readily adapt to harvest patterns that fall within the range of natural disturbance regimes. The further from that range such patterns diverge, in frequency, intensity, extent, or any combination of the three, the greater the risk of jeopardizing some components of biodiversity, and the greater the need for planning and specific actions to ensure that biodiversity is maintained.

Even if we were aware of and had access to all the information needed to make the best decisions, there would be not be one right way to manage at the landscape level. In the absence of complete information, we can incorporate what we do know into management planning, and remain open to accommodating new tools and information.

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Forest Management Issues:

Distribution of Native Forest Communities

By Carol R. Foss

DEFINITION

Native forest communities refers to naturally occurring combinations of indigenous plants growing together in a given habitat, as defined by the Maine Natural Areas Program (MNAP 1991). Distribution of these communities refers to their arrangement on the landscape.

IMPORTANCE TO BIODIVERSITY

Native forest communities represent community-level biodiversity, and encompass a substantial proportion of species-level diversity. Conserving communities maintains not only unique assemblages of living things, but also individual species and the conditions and processes that enable them to survive. Many species are known to depend on particular forest communities or combinations of communities. Eliminating native communities from a portion of the landscape would decrease or eliminate some species. In addition, maintaining the natural distribution of communities at the local scale provides a variety of habitats close to one another, to meet the needs of species that use multiple habitats. The distribution of native forest communities on the landscape also influences gene flow and interactions among subpopulations, especially for habitat specialists with limited mobility.

GOAL

Maintain functional, representative patches of all naturally occurring native forest community types distributed throughout the ownership.

BACKGROUND AND RATIONALE

A “community” is an aggregation of interacting species, either at a specific location on the ground or as a group of species that commonly occur together (Perry 1994). Community classification systems differ according to the purposes for which they were designed, and community types may be narrowly or broadly defined. The Maine Natural Areas Program (MNAP) has defined 25 naturally occurring forest communities in Maine (Appendix L) that have both similarities with and differences from Society of American Foresters (SAF) forest types (Eyre 1980). MNAP types give greater consideration to understory and herbaceous plants; dominant trees define SAF types. MNAP types also consider understory and herbaceous plants, soils, geology, elevation, and climate.

Many factors influence the distribution of forest species on the landscape and the combinations of species that occur together. These factors include topography (elevation, aspect, slope), soil characteristics (texture, rock content, organic-matter content, aggregation, depth, pH, nutrient content), climate (precipitation, temperature), other organisms (competing species, herbivores, pathogens, pollinators, seed dispersers, mycorrhizal fungi), seral stage, disturbance history, and recent events.

Conserving biodiversity requires maintaining both natural species compositions within communities and distribution of different communities across the landscape. Simply having stands of a given forest type (such as spruce-fir or northern hardwood) is not the same as ensuring that all the habitats and communities connected with that forest type are present on the landscape. Harvesting practices can eliminate later seral stages and alter species composition of stands either deliberately or unintentionally, thus altering forest communities over the short or long term. Proportions of red maple and aspen in a stand increase as the frequency of disturbance increases. Repeated disturbances and uniform management of large stands may blur community boundaries over time.

Comprehensive data on long-term trends of forest communities in Maine are not available. However, forest statistics from 1982 and 1995 provide insight into some recent changes (Appendix M). Although the forest types do not conform exactly to forest communities as defined by MNAP, they are close enough to show trends. Of 19 forest types documented in both years, nine increased and 10 decreased in acreage over the 13-year period (Griffith and Alerich 1996). Northern white cedar, northern red oak, red maple-northern hardwoods, mixed northern hardwoods, and paper birch types increased in area and proportion by more than 25 percent; red spruce-balsam fir, black spruce, pin cherry-reverting field, and gray birch types decreased in area and proportion by more than 25 percent.

Maintaining native forest communities within the managed forest provides for many species whose ecology and habitat needs are poorly known (Noss 1987, Gawler et al. 1996). Although reserves will likely play an important role in conserving forest biodiversity in Maine, native communities within managed forests will make important contributions to long-term conservation of biodiversity (McMahon 1993).

The distribution and extent of different communities across a landscape is important for several reasons. Plant community patterns in space and time determine the distribution and survival of animal populations and govern the rate of gene flow among sub-populations. Species may exist as a collection of scattered populations (metapopulations), particularly when their associated natural communities occur in scattered patches. Populations within the group may disappear from time to time, but some productive populations remain. Individuals from the productive populations eventually recolonize the unoccupied patches as long as the productive populations are not too far away (Wiens 1996). Eliminating particular native communities from a significant portion of the regional landscape can lead to population decrease or elimination of some associated species.

The distribution of plant communities also strongly influences the intensity and spread of natural disturbances (Perry 1994). Community types differ in their vulnerability to different disturbances. Conifers are more vulnerable to fire and wind; hardwoods are more vulnerable to ice damage. Insects and diseases may be specific to particular species or groups of species. Some landscape patterns buffer the energy of natural disturbances such as fire, windthrow, disease, and insect outbreaks; others magnify their effects (Perry and Amaranthus 1997). Patchiness in landscapes tends to reduce the spread of disturbances (Formann 1995); uniform landscapes are more likely to experience catastrophic spread of disturbances (Perry 1994).

CONSIDERATIONS

- The effects of past harvesting practices may make it difficult to determine the potential natural vegetation of a site.

- As the frequency of disturbance increases, later-successional communities become more difficult to maintain.
- The more intensive management becomes, the greater the effects on community composition and distribution, and the greater the need for active mitigation to maintain native forest communities at the landscape scale.

RECOMMENDED PRACTICES

- Learn to recognize the native forest communities that occur on your ownership and understand their distribution on the landscape.
- Consider boundaries of native communities when defining stands and delimiting harvest boundaries.
- Base prescriptions on community characteristics rather than timber types.
- When discriminating against particular species in the management of a stand, avoid eliminating them from the stand completely.
- When planning harvests in communities that are rare or uncommon in a management unit but well distributed in the state, use harvesting strategies that will maintain the community type after harvest.
- In communities that are rare or uncommon within the ownership or in Maine, use management based on the natural disturbance regime for the community and avoid converting to other community types.
- Use natural regeneration on a significant proportion of the ownership.
- When converting a portion of an ownership to plantations or other intensively managed stands, maintain functional, representative patches of all naturally occurring forest community types distributed throughout the ownership.
- Minimize conversion of matrix communities to plantations.
- Maintain connectivity of matrix communities.

CROSS REFERENCES

General Principles; Vertical Structure and Crown Closure; Native Species Composition; Rare Natural Communities; Age Structure of the Landscape; Habitat Connectivity

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Forest Management Issues:

Age Structure of the Landscape

By Gro Flatebo and Carol R. Foss

DEFINITION

Age structure of the landscape refers to the diversity and spatial distribution of stand ages that are present across forest types.

IMPORTANCE TO BIODIVERSITY

Forests of varied structures and succession stages provide habitat for different plant and animal species. Some species prefer young forest and some species prefer older forest; some species prefer multi-aged forest structures and others prefer single-aged canopies (DeGraaf et al. 1992). Some species require different seral stages at various times in their life cycles. Maintaining healthy, well-distributed populations of Maine's native flora and fauna requires maintaining a complete and well-represented array of successional stages of different forest communities (MCSFM 1996).

GOAL

Maintain a range of ages of trees and stands to viably represent all successional stages on the landscape. Ensure that old stands are distributed across the landscape.

BACKGROUND AND RATIONALE

Age structure can vary within a stand (even-aged versus uneven-aged) and among stands at the landscape level. Historical disturbance patterns and their influence on forest age structure prior to human management gives insight into methods to support Maine's native biodiversity (Seymour 1992, Alverson et al. 1994, Attiwill 1994). Frequency, intensity, and scale define natural disturbance regimes. When compared with forest management, frequency correlates with rotation or entry period; intensity correlates with the percent of basal area removed; and scale correlates with the size of openings created by harvesting.

The major natural disturbance agents in Maine's spruce-fir forests prior to European settlement were small- and large-scale wind events and insect infestations. Limited historical evidence suggests that major fires were relatively rare, about every 700 to 2,000 years, and large-scale windthrow events occurred about every 1,150 years in northeastern Maine (Lorimer 1977). Insect outbreaks from spruce budworm and bark beetles recurred at intervals of several decades to over a century (Lorimer 1977, Seymour 1992), as did small gap-creating wind events. These events usually were not stand replacing, although budworm infestation in stands dominated by balsam fir may result in stand-replacing mortality, and a wide range of age classes developed across the landscape (Seymour 1992, Seymour and Hunter 1992).

The age structure of Maine's forested landscape has been altered greatly in the past 250 years, primarily through: agricultural clearing and subsequent abandonment and regrowth; several cycles of spruce-budworm epidemics; suppression of natural forest fires; and timber harvesting. Data from across the Northeast suggests that in Maine the pre-settlement forest was dominated (59 percent) by late-successional and old-growth stands over 150 years old, and that early successional stands, less than 75 years old, were a relatively small part (16 percent) of the landscape (Figure 13, Appendix M). Although some parts of Maine are still dominated by mature and overmature forest, over 65 percent of the forestland is in regenerating or pole-size stands.

Age structure within stands has also changed since European settlement. The relative proportion of even- and uneven-aged stands in the presettlement forest is uncertain (Seymour 1992). Lorimer (1977) estimates that 59 percent of forests in northeastern Maine were primarily uneven-aged and all-aged conditions in the late 18th and 19th centuries, and that these conditions were perpetuated through frequent small-scale windthrows and other natural disturbances.

The shift to younger forests introduces several issues related to biodiversity of Maine forests. First, species with preferred habitats that are associated with a particular seral stage (young, old, or in between) need to be able to move among those habitats, thus stands of similar types and ages need to be close enough to allow movement and dispersal. Species associated with older, more-mature stages or conditions need to have large enough stands that interior conditions prevail and are not influenced by edge effects.

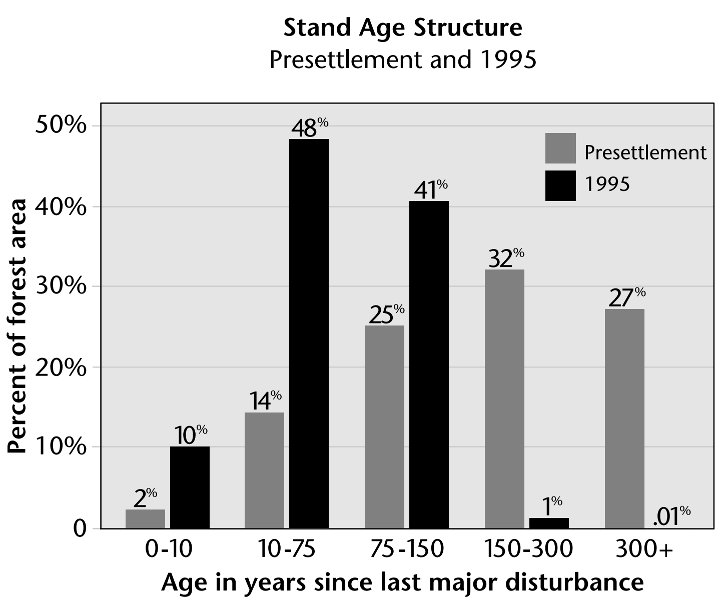

Figure 13.

Forest age structure in Maine, presettlement and 1995. (Adapted by M. Lansky from Lorimer 1977, Seymour and Lemin 1989.)

Ten percent of 257 inland wildlife species in New England that have a dependence on woody vegetation are closely associated with mature, overmature, or old-growth forest habitat types (Degraaf and Rudis 1986). Some of these species found in Maine forests are bay-breasted warbler (an important predator of spruce budworm), red-shouldered hawk, and northern goshawk. Barred owl and pileated woodpecker require very large trees for nesting and so have a strong association with older forests. There are few known old-growth obligate species currently in Maine; some species of fungi, lichens, beetles, and woodpeckers are thought to require old-aged forest (Chandler 1987, Selva 1996,Woodley and Forbes 1997). Existing old-growth stands are mostly small and isolated. It is possible that some old-growth obligate species that require large areas of habitat have been lost.

A related issue is the scarcity of habitat for many vertebrates (DeGraaf et al. 1992, Hagen et al. 1995) and a large number of invertebrates, herbaceous plants, fungi, lichens and other organisms that use older forests (MCSFM 1996, Selva 1996). The array of age classes across the landscape has shifted in certain regions. For example, in the late 1960s and through the 1970s much of northern Maine was dominated by mature stands; extensive clearcutting in some areas has shifted the age structure to predominantly regenerating forest (Seymour and Hunter 1992).

Forest stands progress from mature to late-successional to old-growth stages, with each stage occupying a smaller proportion of the landscape. Late-successional stands that have reached at least the pathological age for a given forest type, or for the dominant species, and old-growth stands, are rare in managed landscapes. Pathological age is the age at which a tree species normally dies of natural causes such as insect defoliation, disease, or other stress agents. Pathological ages for Maine's dominant forest-tree species range from 60 to 90 years for early-successional species (aspen, balsam fir, and paper birch), to 200 years or more for late-successional species (eastern hemlock, sugar maple, red spruce, and yellow birch) (Appendix H). In an unmanaged forest, old stands develop over long periods between stand-replacing disturbances. Forest stands managed on economic rotations do not reach pathological maturity.

Older habitats can serve as refugia (population sources) for other, recovering, forest stands. If refugia are well distributed throughout the landscape, with adequate connectivity, species can move among them as well as disperse to other habitats, ensuring viable populations within the landscape. Many species associated with older forest have more-limited dispersal capability and smaller home ranges than species of early seral stages. Therefore, it is important to ensure enough old stands and structures across the landscape to allow movement and recolonization by species dependent on this essential habitat (e.g., terrestrial salamanders and ephemeral understory forest herbs). Structural characteristics associated with older forests, such as large trees, snags, and downed woody material that are retained on a site during harvesting can help species disperse and move among older stands.

Forest species evolved and interacted in a pattern influenced by natural disturbance processes — in Maine mostly gap-phase replacement with major stand-replacing events every 700 to 2,000 years. The further forest management diverges from natural disturbance patterns, the more attention forest managers need to pay to maintaining elements and characteristics of natural disturbance regimes in managed stands.

In Maine, the industrial forest is divided into townships, many of which are in unorganized territories. The typical township size is approximately six by six miles (100 sq. km., or about 25000 acres). This spatial unit is considered a good scale at which to attempt to address age-structure objectives (Hagen et al. 1995, Champion International 1996, MCSFM 1996), although some advocate units as large as 100000 acres. These can be referred to as "land planning units," or LPUs. Keeping some of all habitat types and ages available within each LPU will likely accommodate most bird species, which are relatively mobile organisms (Hagen et al. 1995).

A portion of the landscape should remain in, or be restored to, pathologically mature stages and include all major forest types (MCSFM 1996, Woodley and Forbes 1997). This can be accomplished by establishing permanent reserves or through extended rotations (Curtis 1996) and a long-term commitment (150+ years) to silvicultural methods that restore and preserve old-aged forest characteristics.

CONSIDERATIONS

- Evaluating age-class structure requires detailed inventory data, stand age and stand type maps, and other technical information that may require a significant investment and professional interpretation.
- Landowners should evaluate age-class structure of their land in the context of adjacent forestlands. Where feasible, cooperative discussion among adjacent

landowners should be encouraged to develop landscape-scale age-class objectives, particularly within watersheds.

- Every forest landowner has different ownership objectives, tenure of ownership, and timetables for forest management. Coordinating age-class distribution across large areas is easier on the large ownerships of northern Maine than among the thousands of non-industrial private ownerships in central and southern Maine.
- Rotations are easy to shorten, but difficult to lengthen (Curtis 1996). Restoring age-class diversity to ownerships requires long-term planning over several generations and may sacrifice economic benefits for landowners and Maine during the transitional period.
- Extended rotations, combined with commercial thinning, is one way to increase the proportion of older forest. The advantages of longer rotations include (Curtis 1996):
    - a reduced frequency of drastic disturbance affecting biodiversity,
    - larger trees and better-quality wood,
    - an opportunity to adjust current age distributions,
    - habitat for wildlife species associated with mature stages of stand development,
    - hydrological and long-term site productivity benefits,
    - increased carbon storage associated with larger growing stock, and
    - greater options for future adaptive management.
- Carefully planned management of riparian ecosystems and other sensitive habitats, with minimal harvesting, can contribute to the overall proportion of older forest.

RECOMMENDED PRACTICES

All Ownerships

- Conduct a detailed timber inventory with a stand age and stand type map to determine the distribution and spatial lay out of age-classes on your lands. Air photos, particularly at a scale of 1:20000 or better, are useful in identifying stand ages.
- Retain or restore a significant proportion of the ownership to mature, late-successional forest. Sensitive areas, such as riparian ecosystems and high elevation forests, areas reserved from harvest, less-intensively harvested areas, and long rotation stands under uneven-aged management can contribute a portion of this age-class. Older stands should not be concentrated on poor, less productive sites. Where possible, landowners should set aside intact older stands in common forest types.
- Retain structures and characteristics of older forests, such as large live trees, downed woody material, and patches of older forest, when harvesting adjacent to older stands. In several decades these structures will increase the effective size of the older forest and aid dispersal of species dependent on older forest.
- In young, tolerant hardwood forests and other gap-replacing forest types, hasten development of old-growth characteristics by following a cutting prescription that matches a gap-dominated disturbance regime. Individual cut patches should be 50 to 100 square yards in canopy area, although a few large patches should also be created (Runkle 1991).
- Analyze how your cutting patterns differ from natural disturbance regimes. Where harvesting patterns diverge, maintain biological legacies and otherwise mitigate the effects of altered disturbance regimes.

- Where wind firmness is not an issue, shelterwood harvest with retention should be considered.

Large Ownerships

- Maintain a mix of both even-aged and uneven-aged stands. Maintain a range of stands in each age class.
- To avoid age-class homogeneity within localized areas of large ownerships, manage ownerships in landscape planning units. In southern Maine these might be as small as 500 acres; in the unorganized townships units of 25 to 100 thousand acres may be appropriate. To the extent possible, these units should conform to watershed boundaries, other natural features of the landscape, or ecological land classifications (Woodley and Forbes 1997). Within each unit, age-class goals should be set to achieve an array of successional stages.
- To ensure recolonization, maintain existing mature to late-successional stands adjacent to younger stands that are being managed as replacement mature to late-successional stands.
- To accommodate species with limited dispersal distances and slow recolonization rates, consider maintaining some mature forest blocks in consistent locations.
- To the extent possible, allow natural disturbance regimes to influence old-aged stands. When practical, avoid suppression of lightning fires and insect outbreaks in these stands, but only if the stand is large enough that it will not be entirely disturbed by a single event.

CROSS REFERENCES

General Principles; Vertical Structure and Crown Closure; Old-Growth and Primary Forests; Habitat Patch Size

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Forest Management Issues:
Habitat Patch Size

By Gro Flatebo

DEFINITION

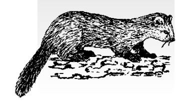
Habitat patch size refers to the range and variation in shapes and sizes of forest stands or groups of stands with similar characteristics. Forest-interior habitat is available in areas of forest large enough to support viable populations of species associated with sizable tracts of unbroken forest.

IMPORTANCE TO BIODIVERSITY

Habitat patch size is important because of the preference of some wildlife species for small patches of habitat of various ages and types, and the preference of other wildlife species for large areas of one age or type.

In some instances, species need large forested stands with relatively closed canopies because the interior of the stand insulates against the effects of the stand's edge, where there may be, for example, a modified microclimate or an abundance of predators. Here, stand shape is important as well, because in linear or irregularly shaped stands a larger portion of the stand is closer to an edge than in relatively circular stands. On the other hand, some species are positively affected by the edges between forest stands (especially between late- and early-successional stands) because they need easy access to two different types of stands or because they need the special conditions associated with a stand edge. These species favor small, irregularly-shaped stands.

From a landscape perspective, large tracts of contiguous forest can provide a population source, at both a local and regional level, to replenish animal populations that may be present but not successfully reproducing in fragmented or suboptimal habitats. Large tracts of contiguous forest can also provide a source for less-mobile forest organisms to recolonize nearby younger or disturbed forests.



GOAL

Maintain a variety of stand sizes and shapes, and design forest landscapes that are capable of supporting viable populations of species whose life-history requirements include large areas of contiguous forest.

BACKGROUND AND RATIONALE

Forests cover almost 90 percent of the landscape in Maine and occur as a mosaic of interconnected forest stands at different successional stages. Many of the effects of forest fragmentation — nest predation, nest parasitism, isolation — are dampened in a forested landscape as compared to isolated forest stands in a predominantly agricultural or developed landscape (Sabine et al. 1996). However, these effects are not well understood.

There are four stages of forest fragmentation (Hunter 1996). Roads and power lines can dissect a forested tract (Figure 14A), filtering and, in some cases, impeding movement across the break; the width of the road or right-of-way determines the species affected. Small harvests or development can perforate a tract (Figure 14B), creating edge and heterogeneity across the landscape. As perforation increases, the forest becomes more segregated by nonforested areas (Figure 14C) until the remaining forest is in small, isolated patches (Figure 14D). This may be temporary until a harvested forest reaches maturity, or may be permanent through forestland conversion.

Large forest tracts are more likely than small tracts to support wildlife species with large home ranges or special habitat needs, and those species that require forest interiors. Some wildlife species, particularly small carnivores, are area sensitive and require large territories to forage or range (Hunter 1990). In Maine, Chapin et al. (1998) documented that the presence of large, contiguous stands was a prerequisite for resident pine marten to occupy an area. Fifteen percent of the 338 forest-dwelling vertebrate species occurring in New England have average home ranges greater than 50 acres, some as large as 12 sq. mi., and a few that exceed 1000 sq. mi. These include most raptors, large-bodied woodpeckers, and medium- and large-size mammals (Degraaf et al. 1992).

Forest-interior species require the inner portions of relatively large tracts because their preferred habitat or food source exists only some distance from the forest edge.

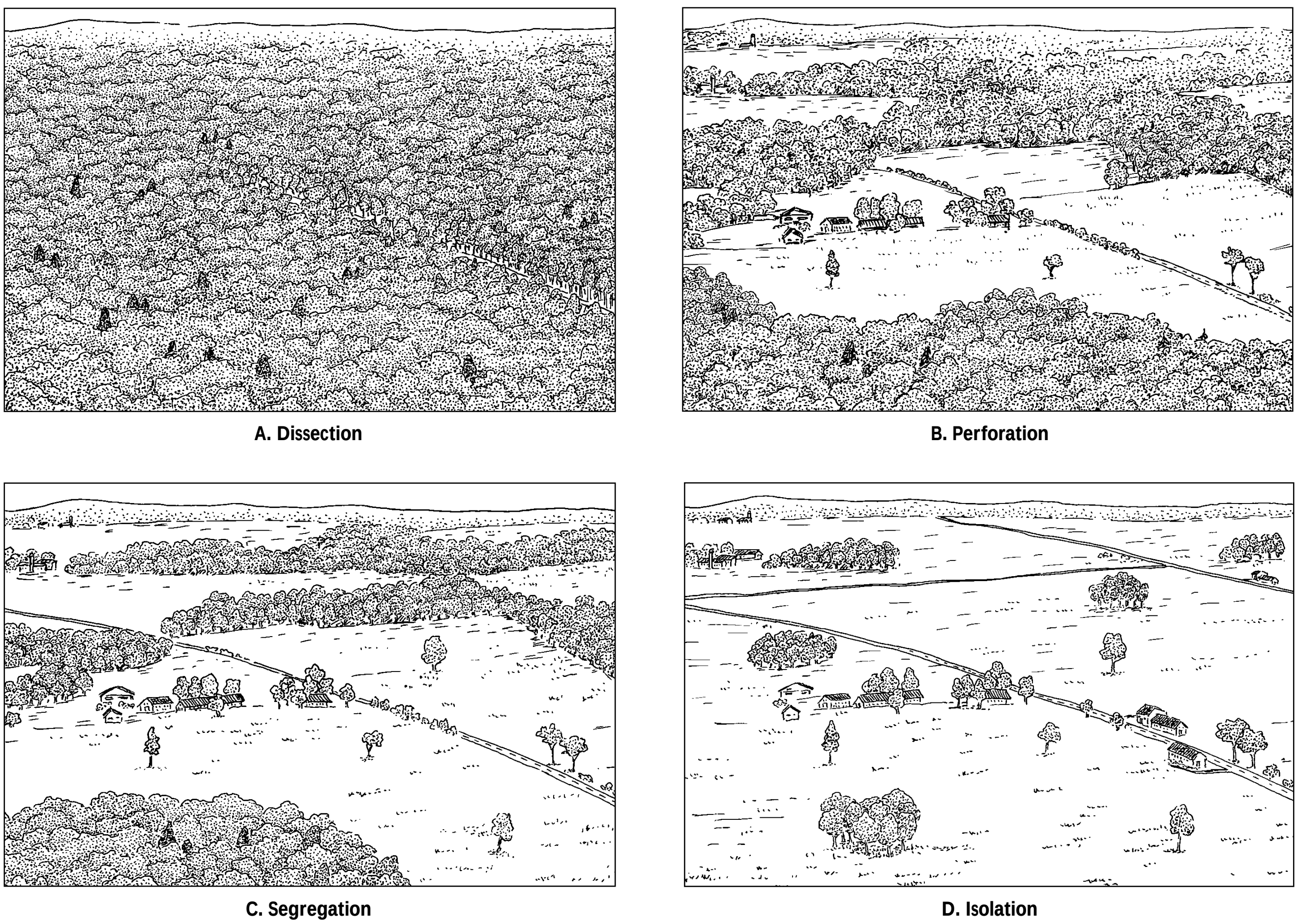
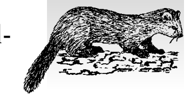


Figure 14.
Four stages of forest fragmentation. (First published in Hunter 1996.)



Microclimate, competition, predation, parasitism, and other edge effects play roles in defining habitat preferences of interior species. (The authors and Working Forest Committee members attempted to compile a list of vertebrate species associated with forest-interior conditions. The scarcity of data and, in some instances, conflicting data for many species led to the decision not to include such a list.)

In addition to the size of a stand, its shape can affect species diversity through the amount of "edge." The size and shape of forest stands reflect both natural and human-influenced factors including site variability (e.g., soils, topography, microclimate), natural disturbances (e.g., windthrow, insect outbreaks, fire), forest management, and agriculture. Pre-settlement surveys and a few large, uncut forest reserves provide evidence that natural forest stands in Maine were found in a great variety of sizes and many complex shapes (Lorimer 1977, Runkle 1982).

Stand shape can vary from nearly linear to circular (Figure 15), and is often quantified by the ratio of the stand's perimeter to its area (p/a). Many researchers have suggested that the p/a ratio is a measure of exposure to outside influences (i.e., small stands and long, narrow stands with high p/a ratios are most exposed and most vulnerable to outside disturbances). Round stands have the smallest p/a ratios and are subject to less effect from the edge, even in relatively small stands (Oliver and Larson 1996).

Species diversity of both plants and animals typically increases proportionately with the amount of edge in a stand, although these species tend to be habitat generalists. Small stands have proportionately more edge than large stands, and irregularly-shaped stands have more edge than those that are square or circular. Large, wide stands provide more-uniform habitat conditions overall and minimize forest edges. Some of Maine's upland-forest amphibian species, including red-backed and spotted salamanders and wood frogs, appear to avoid forest habitat adjacent to recent clearcut edges (deMaynadier and Hunter 1998).

Many nest predators (blue jay, American crow, common grackle, red squirrel, eastern chipmunk) and brood parasites (brown-headed cowbird) occur in higher densities near forest edges, particularly in isolated or fragmented stands. Studies in Maine's forested landscape suggest that the effect of edges and forest size on nest predation may not be as great as in agricultural landscapes (Small and Hunter 1988, Rudnicky and Hunter 1993a and 1993b). Patch size or amount of harvested forest in the vicinity of the remaining forest patch may be more important than edge in influencing predation rates in an industrial forest (Hagan et al. 1997).

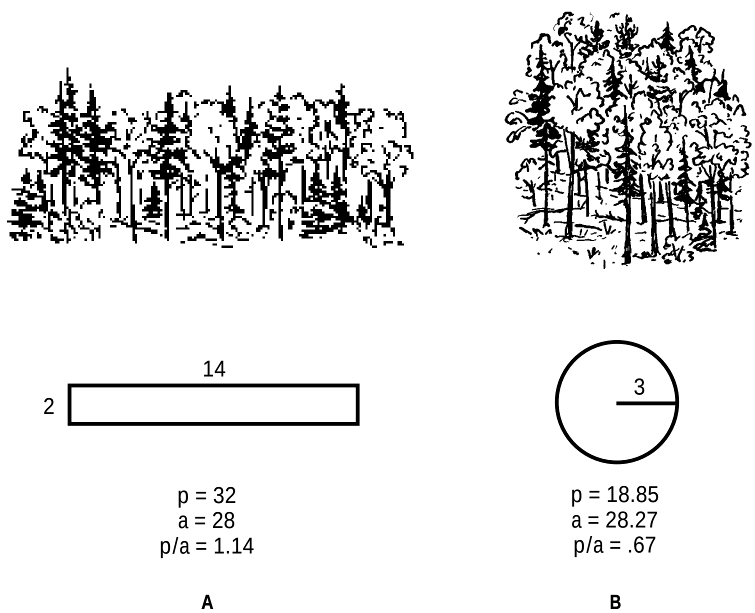


Figure 15.

Ratio of perimeter to area (p/a ratio) is greatest in long, narrow stands (A) and least in circular stands (B).

Fragmentation can reduce large ecosystems to small, isolated ecosystems, and can subdivide species with large regionwide populations into much smaller groups. If the species can disperse easily, it can persist as a group of patch populations or metapopulation; if the species does not disperse well, it may eventually disappear from all habitat patches (Hunter 1997). Where continuous mature forest has been converted to a mix of various successional stages of forest, populations of forest specialists will assume a patchy distribution, and that of forest generalists will retain a uniform spatial distribution (Hagan et al. 1997).

In parts of the forest that are managed on an even-aged basis, Maine's native biodiversity contends with a constant rearranging of late- and early-successional ecosystems. Large tracts of contiguous forest offer environments that are relatively free of the crowding effects in plant and animal populations that take place near new edges, including an inflow of individuals displaced by habitat loss. The crowding of species following harvest of a nearby parcel can focus more individuals into a remaining forest tract, increasing competition, disrupting behavior patterns, and reducing nesting success. Hagan et al. (1997) found that although they were more abundant, ovenbirds were less productive in forest fragments than in larger tracts. He attributed their abundance to displacement from recent timber harvesting, and their lower reproduction to dysfunctional behavior from crowding. Hagan et al. (1997) found that populations of bird species reached their highest abundance in landscapes that were more homogeneous in successional stage.

For some species of wildlife, large tracts of forest provide a source of individuals to repopulate a landscape. Studies in the Midwest found that fragmentation of habitat reduced local reproduction of neotropical migrants through nest predation and nest parasitism. Populations of migratory birds in a fragmented landscape appeared to be population sinks; populations in nonfragmented forest areas habitat provided individuals to disperse into these fragments (Donovan et al. 1995, Robinson et al. 1995).

From a landscape perspective, fragmentation in a forested landscape can limit the ability of less-mobile, mature-forest plant and animal species to reinvade nearby disturbed patches. Mature-forest species are less mobile and have a more limited ability to disperse (Harris and Silva-Lopez 1992).

CONSIDERATIONS

- Large forested properties (>10000 acres) offer more opportunities to retain large blocks of contiguous forest. Smaller properties that contribute to contiguous forestlands across ownerships are especially important in southern and central Maine; management for large-forest values can be enhanced by consideration of, and if possible coordination with, management of properties in the surrounding area.
- The amount of mature forest in the landscape is a consideration in determining how important it is to maintain large, contiguous forest tracts. As the proportion of mature forest in a landscape decreases, the importance of remaining areas increases. If the landscape is fairly homogeneous and has a majority of mature forest, forest-interior species may successfully occupy smaller patches. However, larger forested tracts are needed to support wildlife populations in heterogeneous, harvested landscapes (Hagan et al. 1997, Sabine et al. 1996) and in landscapes fragmented by non-forest habitat.
- Forest plant species that characterize a mature forest have intrinsically low dispersal capacities as compared to

early-successional species (Harris and Silva-Lopez 1992). As the proportion of early-successional forest increases around a mature forest tract, the remaining tract must be large enough to support viable populations of these species.

RECOMMENDED PRACTICES

- Retain large trees, snags, and uncut islands within clearcuts. The landscape will not appear as perforated and will recover from perforation more quickly from the perspective of some wildlife species because the important features they use are retained in the stand (Hunter 1996).
- To the extent possible, use uneven-aged management techniques to maintain a portion of holdings as large stands of relatively closed-canopy forest.
- Retain some large areas of late-successional forest. One approach is to spatially cluster or consolidate harvesting operations (Hagan et al. 1997).
- Consider the occasional use of even-aged management stands on longer rotations to produce large areas of relatively contiguous forest in the future.
- Keep road right-of-ways narrow and ensure that they have good vegetative cover.
- When constructing roads, use winter roads whenever possible. Winter roads are less intrusive and rely on frozen ground for stability rather than more substantial engineering and fill. Consequently, they can only be used seasonally.
- Conduct even-aged harvests in a way that produces “messy,” low-contrast edges by maintaining higher levels of crown closure in the harvest zone immediately adjacent to residual stands (deMaynadier and Hunter 1998).
- To aid dispersal of forest-interior plant species to regenerating stands, avoid a landscape where many newly harvested stands are isolated from mature stands by stands midway, or 30 to 40 years, through their rotation age.
- Determine the existing range of stand sizes and shapes in your region or area, and use this information to size individual stands and vary your management plans to provide a diversity of forest stand sizes and shapes.
- Where possible, use natural features and boundaries to define stands, for example, boundaries of existing forest types and age classes, rivers and water bodies, changes in slope and aspect, existing roads, or boundaries between different soil types. Features such as understory vegetation, tree density, and operability may also be used to define stand boundaries. Avoid creating stands with long, straight, sharply defined boundary lines.
- When mapping and planning for wildlife, combine stand types mapped for timber production with areas of similar age and structural characteristics to form larger management units.

CROSS REFERENCES

General Principles; Riparian and Stream Ecosystems; Habitat Connectivity; Public Access and Roads

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Forest Management Issues:

Habitat Connectivity

By Steven K. Pelletier

DEFINITION

Habitat connectivity refers to areas of suitable habitat that allow movement of animals and dispersal of plants to prevent their isolation from required habitats. For individual species, the physical requirements for habitat connectivity occur on both a temporal and spatial scale.

IMPORTANCE TO BIODIVERSITY

The ability of plants and animals to disperse is critical to an individual species' use of suitable habitats across the landscape. Habitat connectivity allows individuals of the same species to interact across the landscape, preventing fragmented, possibly less viable, populations. Riparian ecosystems often function as habitat connectors.

GOAL

Maintain habitat connectivity within and across the landscape.

BACKGROUND AND RATIONALE

The concept of habitat connectivity includes how suitable habitat is arranged on the landscape and the ability of organisms to use and move through those habitats. Connectivity provides safe movement, particularly for rare species that may suffer from inbreeding or loss of genetic variation if movements between isolated populations are restricted (deMaynadier 1996). Although frequently discussed in terms of wildlife use (i.e., wildlife corridors), habitat connectivity typically refers to a linear corridor (Figure 16A) imbedded in unsuitable habitat, connecting large blocks of suitable or core habitat (Csuti 1991). Connectivity includes proximity of habitat for plant, as well as animal, dispersal (Gawler et al. 1987, Gawler 1988, Menges 1990), and habitat

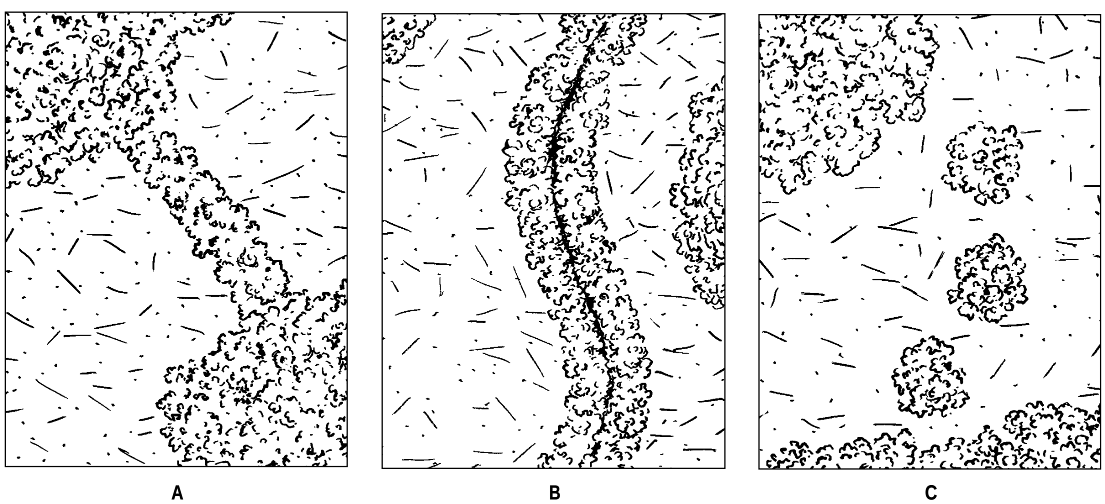


Figure 16.

Connectivity of habitats can be created using (A) linear corridors between patches of suitable habitat, (B) long, linear corridors not connecting habitat patches, and (C) patch or stepping-stone habitats.

required for different parts of the life cycle and population maintenance. Linear strips (Figure 16B) such as riparian management zones, as well as adjacent patches or “stepping-stone” islands (Figure 16C), can provide connectivity between larger, core dispersal centers (MacArthur and Wilson 1967, Harris 1984).

Corridors and connecting patches function on a local scale, providing movement among adjacent habitats, as well as on a regional scale that offers opportunities for species to expand their range. The suitability of the outside forest matrix as habitat often plays an integral role in habitat connectivity (Hunter 1997), because the need for connectivity is less critical when habitat patches are part of a larger forest matrix, particularly if the matrix is primarily in mid- to late-successional stage forest composed of appropriately sited native species. The importance of habitat connectivity becomes obvious in distinctly fragmented areas such as agricultural or suburban landscapes.

Connector Debate

Critics of connectors have emerged because so many factors influence corridor use and the fact that creating corridors for the benefit of one species may be to the detriment of another. These ecologists believe that detailed field studies supporting the benefits of corridors are lacking (Hobbs and Hopkins 1991, Beier 1997) and that the inception of wildlife-corridor management projects is premature and too costly (Simberloff and Cox 1987, Knopf 1992, Simberloff et al. 1992). They maintain that most studies investigating the effectiveness of corridors do not prove that a given species or individual animal is exhibiting corridor-specific movements. Others note potential biological disadvantages of corridors such as genetic drift (the loss of important genetic information from a population that can be of evolutionary significance to small populations) and the spread of fires, diseases, and exotic species (Simberloff and Cox 1987, Forman 1991, Hobbs and Hopkins 1991, Panetta and Hopkins 1991).

Conservationists agree that landscape or habitat connectivity is important for, if not critical to, population viability (Preston 1962, Rudis and Eck 1981, Beier 1997). If a given species cannot travel between forest patches, then those patches are considered disconnected. Connectivity, at both the local and regional scales, needs to exhibit several distinct characteristics to be effective. These include habitat structure (e.g., vegetative cover, density, uniformity), width, position of the corridor relative to habitat patches in the landscape, degree of human disturbance, and, to some extent, time (i.e., that point when abutting cover is capable of providing suitable habitat) (Noss and Harris 1986, McDowell et al. 1991). However, the exact specifications for each of these characteristics, and the effects of these landscape features for many taxa, are not well known and depend upon the species, their life histories, and the degree of landscape fragmentation.

The characteristics of a connector, or corridor, that make it suitable for one species may limit its use by another species. For example, although the majority of species show affinity for forested ecosystems, some species, such as northern harriers, eastern meadowlarks, and green snakes, inhabit open areas and use them for a variety of movement purposes, largely ignoring forested areas. These types of species may benefit from more-open habitat connectors.

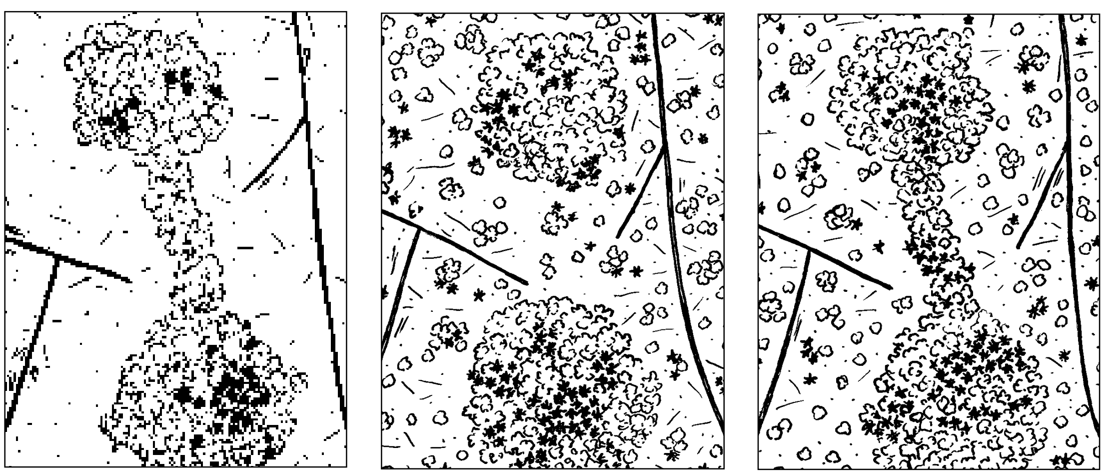
Effective habitat connectors allow four types of movement or dispersal:

1. daily movements for foraging,
2. seasonal or annual migrations,
3. movements by young organisms (e.g., juvenile animals, seeds, and plant propagules) away from their natal area, and
4. complete or partial geographic range shifts (Noss 1991, Soulé 1991, Hunter 1997).

At a minimum, habitat connectors need to fulfill some daily or seasonal habitat needs, such as food, cover, or appropriate soil conditions. Daily movements and some seasonal movements occur at a local scale; the remainder of the movements occur at a regional scale. Likewise, connectors can be used during periods of regional climate change for species to expand or retract their range limits.

The connectivity and continuity of a habitat connector are also important (Harris and Atkins 1991, Pace 1991). Connectivity refers to the configuration of the corridor for the habitat islands it connects. A highly connective corridor is relatively straight and extends across the shortest distance between habitat islands (Figure 17A); a corridor with low connectivity may be more serpentine or may only pass near an island rather than connect to it. Continuity refers to the configuration of the corridor for the integrity of the habitats it contains. Therefore, a corridor with great continuity has uniform habitat distribution along its length and very few breaks or gaps in habitat. Roads, clearings, and other types of breaks can create a discontinuous corridor (Figure 17B). Some discontinuity, however, may be acceptable to some species. For example, wolves have been known to move through farmland and other areas with greater human density and cross four-lane highways during long-range dispersal movements (Harrison and Chapin 1997). Connectivity and continuity may be enhanced when the surrounding habitat is fairly similar to that of the connector (Figure 17B and 17C).

To determine whether or not corridors are effective (see sidebar), resource managers need to judge whether species are able to move over the landscape. In most forestry situations, these disconnections between habitat patches are temporary and disappear as soon as the forest grows enough to provide habitat. Core movement areas may be reduced in width if surrounding areas outside the core (i.e., the matrix) provide sufficient and suitable habitat conditions (Seymour and Hunter 1992).



A B C

Figure 17.

Connectivity is greatest when connectors are relatively straight and cover the shortest distance between habitat patches (A and C). Continuity is greatest when the habitat within the connector is of uniform habitat without breaks (A and C) and less when there are breaks or changes in the composition of the connector (B). Connectivity and continuity may be enhanced when the habitat within the connector is similar to that outside the connector (B and C).

CONSIDERATIONS

- Because many different organisms use a variety of patches on the landscape, maintaining connectivity among them is essential. The goal is to maintain functional connections on the landscape rather than have ribbons of habitat connecting patches of habitat. Guidance for the overall system of habitat patches and connectors needs to be provided at the policy level, and then integrated with decisions regarding specific stands and corridors made by field foresters (Harris 1984).
- The importance of habitat connectivity is increased in landscapes where interruptions or breaks between habitat patches have occurred. Conversely, maintaining viable landscape conditions outside habitat connectors allows more uninhibited movement and dispersal between patches, diminishing the need to maintain connector functions.
- Habitat connectors do not need to be permanent features if adjacent areas grow to equal standards and then maintain the connection.
- Wide, intact habitat connectors serve as primary habitat themselves, e.g., riparian ecosystems and structurally complex upland corridors.
- Riparian ecosystems represent some of the most biologically productive and diversified faunal and floral systems and are often important habitat connectors.

RECOMMENDED PRACTICES

- Be aware of sensitive plants and animals located within land-management boundaries, particularly those prone to isolation or seasonal disruptions because of limited mobility or range restrictions.
- Avoid harvests that isolate streams, ponds, vernal pools, deer wintering areas, or other sensitive habitats.
- Maintain the matrix of the landscape in relatively mature, well-stocked stands. Where even-aged management is practiced, consider the cumulative effects of multiple cuts and include wider habitat connectors as necessary. As an example, Woodley and Forbes (1997) recommend working toward implementing and maintaining forested connections a minimum of 1000 feet wide with a maximum length of 1.9 miles to help maintain biodiversity in the Fundy Model Forest. Forested connections should have a closed canopy of any species, with a minimum canopy height of 40 feet.
- Consider opportunities for coordinating habitat connectivity with other, on-going land-management efforts that maintain linear forested ecosystems, such as hiking-trail corridors and natural buffer strips retained to protect water quality. This may require expanding the physical size of the connector habitat and increasing structural values (i.e., canopy and plant density, number of snags) to fulfill multiple management goals. Also consider the potential for effects that may arise because of incompatible uses (e.g., heavily-used ATV or snowmobile routes around and through deer yards).

CROSS REFERENCES

General Principles; Special Habitats and Ecosystems; Riparian and Stream Ecosystems; Distribution of Native Forest Communities; Habitat Patch Size

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Forest Management Issues:

Disease Agents, Insect Pests, and Weeds

By Carol R. Foss

DEFINITION

Disease agents include native and introduced species of fungi, bacteria, and viruses that affect the health of other organisms. Insect pests and weeds include native and introduced species that adversely affect the economic, ecological, or aesthetic value of forests.

IMPORTANCE TO BIODIVERSITY

Large-scale, intensive outbreaks of diseases and plant-damaging insects can dramatically affect forest conditions over wide areas and alter habitat suitability for many plants and animals. Weeds can reduce populations of other native plants through competition. Introduced organisms, to which native species may have little resistance, are of particular concern.

Insects and diseases are a natural part of disturbance cycles that maintain biodiversity. Early-successional, non-commercial plant species, such as raspberries and pin cherries, play important roles in natural succession (Marks 1976, Lansky 1992). Exotic or off-site insects, diseases, and plants can become a problem in stands that have not developed resistance to these novel life forms. Native species can become a problem as well when the resistance or resilience of the forest is somehow impaired, leading to an increase in intensity, size, and frequency of natural disturbance patterns.

GOAL

Minimize adverse long-term effects of diseases, insect pests, weeds, and their control measures on host species, the forest ecosystem, and biodiversity.

BACKGROUND AND RATIONALE

Numerous disease-causing agents (pathogens) and tree-damaging insects occur in Maine's forests. They play important roles in forest development by selectively eliminating less-vigorous and genetically inferior individuals, and influencing the abundance and distribution of tree species at both large and small scales (Barbosa and Wagner 1989, Manion 1991, Castello et al. 1995). In many natural forests, species diversity, age diversity, and genetic diversity of trees buffer the spread of insects and disease agents. However, large, uniform stands of trees, occurring naturally or as a result of harvesting patterns, can foster disease epidemics or insect outbreaks. Naturally occurring outbreaks of spruce budworm have been affecting northeastern spruce-fir forests for centuries (Blais 1985), although there is some evidence that human influence has increased the extent, severity, and frequency of outbreaks in the 20th century (Blais 1983). Introduced insects and pathogens may multiply rapidly and cause epidemics on susceptible hosts (Barbosa and Wagner 1989, Manion 1991).

Native diseases and pests, such as rot fungi and foliage-eating insects, are natural and essential parts of the forest ecosystem. Introduced diseases have nearly exterminated some tree species and their associated ecosystems (e.g., chestnut, elm), and modified the abundance or biological function of others (e.g., beech, larch). Both native (e.g., spruce budworm) and introduced (e.g., gypsy moth) pests can have a great effect on economic productivity and tree mortality, causing ripple effects throughout the ecosystem when they reach epidemic proportions. Weeds affect desired crop species through competition rather than direct physical damage.

Protecting forest economic production has often involved the extensive use of insecticides. These chemicals have both known and unknown effects on forest and aquatic ecosystems. Insecticides that kill many non-target insects, including beneficial species such as predators, parasites, pollinators, and decomposers, can lead to resistant pest populations and resurgence of outbreaks, and provide poor control for some forest pests (Speight and Wainhouse 1989). In some instances, use of insecticides can convert the boom-and-bust cycles of outbreak species to more chronic, long-term infestations (Blais 1983). Even when insecticides are not lethal to vertebrates, some have sub-lethal effects, and their use significantly alters food supplies for insect- eating birds and mammals. For these reasons, insecticides are best applied to protect selected, high-risk, and high-value stands, rather than to try to eradicate the pest over a large area.

Vigorous trees, in dominant positions and growing under site conditions to which they are well-adapted, are less susceptible to damage from insects and diseases than trees that are under stress from suppression or unfavorable site conditions. Stands with a diverse species composition are less vulnerable to species-specific diseases or insects than pure or nearly pure stands.

Pathogens

Plant pathogens include viruses, bacteria, and fungi. Pathogens influence forest composition at multiple scales, and at multiple stages of forest development. Disease organisms can determine which seedlings survive during stand initiation (Grubb 1977), facilitate natural thinning during stem exclusion (Smallidge et al. 1991), and contribute to canopy-gap formation in mature and old-growth forests (Castello et al. 1995). White pine blister rust and beech bark disease influence species distribution at the local, within-stand scale. Chestnut blight and Dutch elm disease have changed the species composition of forest stands across a broad geographic region (Castello et al. 1995).
Tree diseases also affect the distribution and abundance of other forest species. For example, tree mortality from chestnut blight, butternut canker, and beech bark disease have locally reduced the distribution of nut-producing trees in northeastern forests, reducing available food for mast-consuming birds and mammals. Conversely, heart rot fungi create suitable excavating conditions for cavity-nesting birds.

Viruses

The role of viruses in tree and forest health is poorly understood. Viruses drain energy and nutrients from the plant cells they infect. Some viral infections cause localized tissue damage and others produce no visible symptoms; plant viruses seldom cause mortality (Manion 1991).

Bacteria

Most bacteria in forest ecosystems recycle nutrients from dead organic material back into the soil for uptake into living plants. Many species play crucial roles in carbon, nitrogen, and sulfur cycles. Relatively few species of bacteria are plant pathogens, and even fewer affect trees. Bacteria that cause disease in plants secrete toxic substances and enzymes that dissolve cell walls. Bacteria also can interfere with the division and differentiation of cells. Bacteria cause yellows and scorch diseases, some blight diseases, and some stem cankers and galls.

Fungi

Fungi are very diverse and contribute to decomposition by breaking down cellulose and lignin in dead plant residues, help plants absorb essential nutrients and water through mycorrhizal relationships, and associate with algae to form lichens. Relatively few species are pathogens. Fungal pathogens cause canker, wilt, and wood decay, as well as foliage and root diseases. Ecologically or economically significant fungal diseases in Maine include white pine blister rust, beech bark disease, chestnut blight, Dutch elm disease, heart rots, and Armillaria root rot.

Insect Pests

Forest insects are impressively numerous and diverse (Borror and DeLong 1971). Different kinds of forest insects feed on different parts of trees, including buds, twigs, seeds, cones, foliage, wood, bark, roots, cambium, phloem, and fluids (Barbosa and Wagner 1989). Foliage-eaters are the largest group of species, and are more diverse on hardwoods than on conifers; bark and wood-boring beetles are more diverse on conifers (Foss 1994). Some insects (e.g., larch case-bearer) feed only on a few closely-related species, although others (e.g., gypsy moth) consume a wide variety of plants.

Despite the many tree-damaging insects occurring in Maine, only a few cause serious damage. Most forest insects occur at low densities and have small population fluctuations (Barbosa and Wagner 1989). Estimates of foliage consumed by endemic populations of forest insects are in the range of 5 to 15 percent per year (Speight and Wainhouse 1989). Only a small proportion of herbivorous forest insects are outbreak species (Perry 1994), but these are significant ecological disturbance agents and have substantial economic effects. In Maine forests, outbreak species include spruce budworm, eastern spruce beetle, gypsy moth, forest tent caterpillar, pear thrips, Bruce spanworm, fall cankerworm, balsam wooly adelgid, hemlock looper, larch sawfly, and saddled prominent.

Weeds

Early successional species, such as raspberry, may aggressively colonize recently harvested sites and out-compete desired crop species, particularly spruce and fir. Some landowners routinely use herbicides to control these species on the best production sites. Other instances of weed control in forest management include eliminating hardwoods on sites being converted to softwoods, control of woody species on sites managed as permanent wildlife openings, and control of roadside vegetation to improve visibility and maintain open travel lanes.

Introduced plants constitute another category of weeds in forest ecosystems. Many introduced species of herbaceous plants are sun-loving pioneers that rapidly colonize exposed soils in open areas such as roadsides and harvest sites. These species play a useful role in stabilizing soils and retaining nutrients, but their effect on distribution and abundance of native species is unknown.

CONSIDERATIONS

- Stresses such as drought, prolonged flooding, rapid temperature changes, extreme low temperatures, unseasonal frost, and exposure to some forms of air pollution can directly damage trees and can increase their susceptibility to insects and diseases.
- Healthy and rapidly growing trees resist invasion by rot fungi; old, suppressed, off-site, or genetically inferior trees are more susceptible to infection.

- In northeastern hardwoods, Armillaria fungi are most likely to cause disease in trees previously weakened by drought, insect defoliation, or other stresses (Manion 1991).
- Many species of native birds and insects are important predators of defoliating and wood-boring insects (Appendix N). These predators help maintain problem insects at endemic population levels, and can extend the period of time between outbreaks (Holling 1973, Crawford et al. 1983, Jennings and Crawford 1985, Allen and Hoekstra 1992).
- Road-building and seeding of landings can introduce disease agents, insect pests, and weeds into interior forest landscapes (Schowalter 1998).

RECOMMENDED PRACTICES

- Utilize silvicultural systems that reduce the vulnerability of stands to disease, insects, and weeds by using techniques such as favoring resistant species, promoting conditions that enhance natural predators, and diversifying forest structure, composition, and age-class.
- Apply integrated pest management (IPM) techniques, including survey and detection, monitoring and predicting, risk-rating systems, and targeted control with biological or chemical agents (Speight and Wainhouse 1989).
- Avoid introducing non-native plants, animals, or pathogens into the environment without careful research into their characteristics and potential effects.
- When pesticides are required, use the narrowest-spectrum, least-persistent materials that are available and appropriate for the job.
- Operate equipment carefully to minimize bole wounds and root damage on residual trees when harvesting.
- Regenerate white pine under an existing overstory to reduce losses from blister rust and weevils. This minimizes moisture formation on the needles needed for rust infection and discourages weevil survival. Avoid regenerating white pine in small openings in low areas and at the bases of slopes, where conditions are ideal for rust infection. When growing white pine in open plantations, maintain high densities until the trees are 24 to 30 feet tall to reduce weevil damage. If weevil infection occurs, prune leaders to reduce damage and subsequent weevil populations (Katovich and Mielke 1993).
- To minimize damage from beech bark disease, encourage species diversity in beech stands and thin stands to maintain proper stocking. Retain beech trees with smooth or blocky bark or raised lesions to promote resistance in the stand; kill standing trees with sunken cankers and dead patches while standing to reduce sprouting of diseased individuals.
- To reduce mortality in stands susceptible to gypsy moth defoliation, conduct thinnings or shelterwood harvests that remove suppressed trees and retain those with large, healthy crowns (Gottschalk 1997). Protect the vigor of residual trees by avoiding mechanical injury to boles and operating on frozen ground to avoid root damage and soil compaction. Vigorous trees are more likely to survive defoliation and provide a seed source for regeneration. Young stands experience lower mortality rates than mature stands with the same level of defoliation.
- To reduce the susceptibility of mixed stands to gypsy moth, reduce basal area of hardwoods, especially oaks, to 15 to 20 percent (Gottschalk 1997).
- To reduce damage from spruce budworm outbreaks: manage for diverse age classes among adjacent spruce-fir stands; manage spruce-fir stands to favor spruce and reduce

the proportion of fir; maintain a mixed-species composition whenever feasible; maintain vigorous, rapidly growing stands; and consider enrichment plantings of spruce or shortening rotations in existing single-species fir stands. When outbreaks occur, protect selected high-risk stands with biological or chemical agents to maintain age-class diversity in the next rotation (Blum and MacLean 1985).

- To minimize the need to use herbicides, use management techniques that favor desired species or species that are adapted to the site. Avoid severe soil disturbance and creating large openings devoid of advanced regeneration; these practices encourage early-successional species that are often considered weeds.

CROSS REFERENCES

General Principles; Native Tree Species Composition; Distribution of Native Forest Communities; Age Structure of the Landscape

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Land-Use Issues:

Public Access and Roads

By Steven K. Pelletier

DEFINITION

Public access is the ability, opportunity, or ease by which the public can physically reach areas of the landscape. Roads are access routes through and to forested areas, including wide, permanent, high-traffic thoroughfares; narrow, grassy, woods trails; and temporary trails used to remove wood.

IMPORTANCE TO BIODIVERSITY

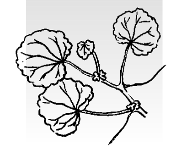
Both disturbance to and consumptive use of resources can severely affect plant and animal populations. Increasing access greatly facilitates consumptive use (hunting, fishing, trapping, and collecting) and disturbance. Although all roads impose some restrictions to movement and dispersal, large road openings and roadside yards represent definitive obstacles to many species. Small and temporary roads will generally have less of an effect on biodiversity. As roads become larger or more permanent with greater use, their effects on biodiversity increase.

When populations become isolated and reduced in size, they are more prone to genetic, demographic, and environmental disruptions, and thus to higher extinction rates.

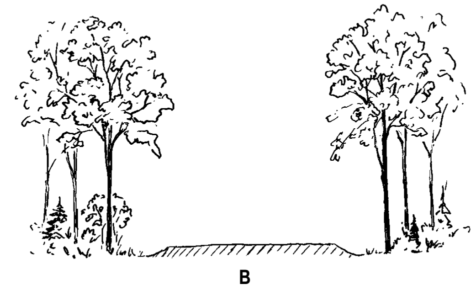
GOAL

Forest landowners should develop public-access plans that allow needed forest management access while minimizing effects on sensitive species and communities. Design, construct, and maintain road systems to minimize negative environmental effects.

BACKGROUND AND RATIONALE



Roads are the primary means of accessing and transporting raw forest resources. They are essential to the infrastructure of the managed forest, and thus require proper planning, design, construction, and maintenance to lessen potentially harmful effects and allow access to fight forest fires. The effect of forest roads on biodiversity varies considerably, depending on their size, type, location, and proximity to resources and other travel routes, as well as their frequency and nature of use (Figure 18) (Hunter 1990, deMaynadier 1996).



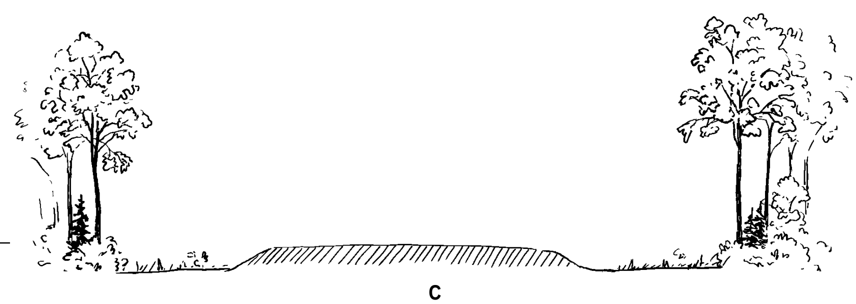


Figure 18.
Size and type of road will determine its effect on biodiversity. Narrow trails that do not break the canopy (A) have less effect that wider roads that do create a break in the canopy (B). Major roads, with significant clearing of the roadside (C), have the potential to fragment habitat and disrupt movement of wildlife species and other organisms between habitat patches.

Public Access

The State of Maine has relatively little public land. Consequently, private lands and road networks play an important role in providing recreational opportunities. Although some roads are gated or blocked, the majority are open to the public for access to recreational and development opportunities, including shoreline development. Most of these private roads are in unorganized townships and plantations in the northern and eastern regions of Maine, areas with abundant recreational opportunities.

Excessive public access to private lands may result in a number of undesirable outcomes including: unsustainable hunting, fishing, and trapping pressures (Brocke et al. 1988, Hodgman et al. 1994); adverse effects on natural resources from overuse, littering, and illegal dumping; increased potential for shoreline development on remote, undeveloped lakes; introduction of exotic flora and fauna; and negative effects on water quality.

There are currently several formal landowner-sponsored, public-access programs underway in Maine, including Project Landshare, the Landowner-Sportsman Alliance, and the North Maine Woods. Other examples of successful, informal interactions between landowners and outdoor recreationists include local snowmobile clubs and the numerous state boat launch facilities on private lands.

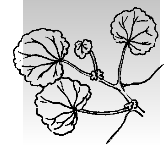
Road Effects

Roads are a type of managed disturbance in the forest with direct and indirect effects on organisms and habitats. At least three acres of forest are directly converted for every mile of 24-foot wide roadway that typically includes a 14- to 18-foot travel surface and cleared right-of-way. Roads create permanent forest openings and “edge” habitat, providing benefits to some wildlife and plant species, while having negative effects on species that may be more sensitive to disturbance or predator pressures. Roadways can serve as travel lanes for some wildlife species (e.g., moose, fox, coyote, bats), but can also create filters and barriers for species that require vegetative cover for protection from exposure or predation.

Roads can also be a barrier to colonization by some plant species, especially those that reproduce primarily by runners and root sprouts rather than seed, as well as a corridor for invasion by non-native species. Roads may also contribute to forest fragmentation by isolating individuals, species, and populations that formerly inhabited contiguous forest and work as a barrier to maintaining genetic diversity. Salamanders and frogs are particularly susceptible because of their seasonal migration to and from wetlands and vernal pools (deMaynadier 1996).

Gravel roads that are improperly constructed or poorly maintained can cause sedimentation and siltation of streams and other water bodies, adversely affecting fish and aquatic organisms. Properly located roads frequently pose little concern for water quality. Road construction and maintenance issues involving improperly constructed older road systems, as well as inadequate diversion of water from roads and trails, culvert maintenance, and ditch stabilization have been identified as specific threats to water quality (Briggs et. al. 1996, Cormier 1996). Although water-quality effects from forest harvesting have been regarded as temporary, effects from improperly constructed or maintained forest roads can pose a major, long-term problem (Kahl 1996).

Roads can also affect local wildlife populations by contributing to roadkill, particularly where



roads cross important wildlife dispersal and migration routes (e.g., those for amphibians and turtles during breeding and egg-laying seasons) (Fahrig et. al. 1995, deMaynadier 1996).

The number of miles of forest-management roads in Maine has increased dramatically since the early 1970s, when the use of rivers for log driving was banned, and has shifted from mainly temporary to more-permanent roads. It is estimated that in 1996 there were over 25000 miles of privately owned forest roads in Maine (not including skid trails), surpassing in length the state's existing public highway system. In addition, between 500 and 1000 miles of forest-management roads are built annually, creating a means for the public to readily access areas that were previously accessible only by foot, canoe, or float plane (LURC 1997). This increase in road development has increased the consumptive and non-consumptive use of natural resources (e.g., hunting, trapping, fishing, bird watching, disturbance), and can result in the overuse of previously unexploited resources (e.g., over-fishing a small pond or over-harvesting furbearers in remote areas).

CONSIDERATIONS

- The process of building and maintaining private forest-management roads remains a major investment for private landowners. For many, a large network of roads is essential for harvesting, thinning, and planting activities, and for accessing and controlling forest fires. Permanent roads are especially important where frequent access is required, as is the case with managing small stands and using selection harvests and other uneven-aged management techniques. Consequently, private landowner interest in permanent, long-term access is great.
- There is a long-standing tradition of open access to private land in Maine.
- The construction of new roads near previously inaccessible lakeshore areas has allowed the development of new camp subdivisions. This is considered a threat to the ecological integrity of Maine's remote lakes and ponds, as well as to exploitable wildlife populations and wildlife species sensitive to disturbance.
- Access to previously remote ponds and lakes threatens the ecological integrity of native fish populations because of increased fishing pressure, as well as accidental and intentional introduction of exotic fish by anglers.
- Because of the need to manage the increasing public use of their lands, some private landowners are reconsidering their policies on access. Some have installed gates to limit access and to collect user fees. The fees have been used to offset the costs of increased road maintenance, and to provide funds to develop and manage recreational facilities such as campsites and boat launches. Most private forest-management roads are currently open to the public, but in some instances landowners are restricting access and posting their land.
- Gating or blocking roads is not always successful in controlling access.

RECOMMENDED PRACTICES

Public Access

- Landowners, public agencies, environmental organizations, and recreational and sporting groups should work together to devise solutions to the challenges associated with public access to private forestlands, while recognizing the ultimate responsibility of the landowners.

- Consider public-access issues in planning new roads, particularly in areas that contain fragile resources that are likely to be at risk from public access. Identifying and protecting unique and high-value resources is an important aspect of the planning process.

- Upgrade existing roads rather than build new roads, and plan the efficient lay out of new roads to minimize the total area of land converted to road networks.

- Adopt a policy of limiting permanent road construction to the lowest density possible. For example, Woodley and Forbes (1997) currently recommend a maximum of one mile of permanent road per square mile to help maintain biodiversity of forest ecosystems in the Fundy Model Forest. Although this type of example may work well in relatively level terrain, up to 1.84 miles of road per square mile may be required in more hilly or mountainous regions of the state (S. Balch, pers. com.). For these high-density road systems, adherence to proper road and crossing construction, maintenance, and closure is critical to maintaining water quality.

- Limiting access by gating or closing roads when they are no longer required or when public access can cause harm is a viable way of protecting fragile or over-used resources and restoring a degree of remoteness within managed forests. Limiting public access during wet seasons will also help to reduce road rutting and erosion problems.

- Road closures should be coordinated among landowners to create large blocks that are located away from primary travel routes.

- Road networks should avoid loop roads and promote cul-de-sac roads.

- Stands under even-aged management, with few anticipated intermediate treatments, should be accessed by temporary roads only.

- On gated or blocked roads, post signs with a positive stewardship message.

Roads

Road Planning and Design

- Minimize adverse effects on streams, wetlands, and special ecosystems (e.g., vernal pools) by surveying the landscape ahead of time, and carefully locating new roads where they will not cause a permanent loss or alteration of these features or adjacent buffers.

- Roads should not be built in the riparian management zone except where unavoidable.

- Keep the width of the cleared right-of-way to the minimum necessary to meet basic construction, maintenance, and traffic requirements.

- Trees harvested using whole-tree methods and then piled along roads for long distances can increase the effective width of the right-of-way. Minimize whenever possible by using short-wood systems and more-frequent delivery.

- One-lane roads with occasional turnouts are preferable to two-lane roads for all but major, continuously used, haul roads.

- Design roads and water crossings to withstand heavy rainfall and normal floodwaters without the need for continual maintenance and rebuilding. Follow recommendations provided by the Maine Forest Service Field Handbook of

Best Management Practices (July 1995) when constructing new roads or upgrading existing roads. The Land Use Regulation Commission (LURC) also regulates road construction and maintenance through use of Standards and Guidelines (Land Use Districts & Standards Chapter 10.17A 4 & 5) and provides relevant information through the Maine Erosion and Sediment Control Handbook for Construction: Best Management Practices.

During Road Construction

- Use appropriate erosion control measures during construction to keep sediment from washing into wetlands, streams, and other water bodies. Maintain erosion control measures until disturbed soils in the right-of-way have become vegetated. Divert runoff from roads into vegetated buffer strips rather than directly into streams.
- Slash from roads and trails should not be disposed of in vernal pools and other wetlands.
- When opening a borrow pit, stockpile topsoil for later use in rehabilitating the closed pit.

After Road Construction

- All ditches should drain thoroughly.
- Limit access to roads when the ground is saturated (i.e., spring and fall rainy seasons), particularly on roads that have not been designed and constructed to handle year-round traffic.
- Follow Maine's Best Management Practices for Erosion and Sedimentation Control (Smith 1991) and LURC Standards and Guidelines to ensure that approaches to water crossings are stabilized and ditches are diverted so that sedimentation does not occur.
- Restore borrow pits when no longer being used. Re-contour the steep faces of the pit, spread topsoil, and seed or plant the pit to encourage vegetation.
- If use of the road is temporarily discontinued, install a gate or block access with boulders or other obstacles to prohibit vehicular traffic. Contact state forestry officials regarding the need to keep access open for fire-fighting equipment. Be sure all water crossings on the discontinued road have been "put to bed" to withstand flooding and heavy rain events. If appropriate, post signs that send a positive stewardship message regarding the reasons for restricting access.

CROSS REFERENCES

General Principles; Special Habitats and Ecosystems; Riparian and Stream Ecosystems; Habitat Patch Size; Habitat Connectivity; Conversion to Non-Forest Use

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Land-Use Issues:

Conversion to Non-Forest Use

By Gro Flatebo

DEFINITION

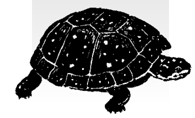
Conversion to non-forest use refers to long-term or nearly permanent change in the ecology of an area to uses that will not support a forest ecosystem. For biodiversity to be affected, the change must normally be of sufficient size and duration that it creates a significant non-forested area. Non-forest uses include recreational and commercial development, roads and parking lots, agriculture, reservoirs, and gravel pits.

IMPORTANCE FOR BIODIVERSITY

Conversion to non-forest uses can directly affect biodiversity by eliminating important ecosystems, isolating plant and animal populations, restricting breeding opportunities, disrupting wildlife travel corridors, and introducing predators and pests along the edges of converted areas. The greatest effects on biodiversity usually occur when small specialized ecosystems are eliminated, or domestic and wild animals (e.g., domestic cats, raccoons) prey upon forest species. Breeding populations may be fragmented or isolated as a consequence of land conversion, but it is hard to quantify the extent of this problem in Maine. Conversion can introduce invasive exotic plant species that may out-compete native species.

GOAL

Prevent the elimination of any significant forest ecosystems through conversion to non-forest conditions. Weigh the anticipated negative effects of any new conversion on forest biodiversity and reduce them where appropriate.



BACKGROUND AND RATIONALE

Today, almost 90 percent of Maine is covered in forest, 96 percent of which is productive timberland (Griffith and Alerich 1996, Appendix O). Maine has more forest cover than during the late 1800s and early 1900s, when a third to a half of the state (predominantly southern and central Maine) was cleared for agricultural fields, pastures, and homes (Figure 19) (Irland 1998). Today, only about 7 percent of Maine land is used for agriculture. However, land subdivision and development, especially in central and southern Maine, have increased dramatically (Hasbrouck 1994).

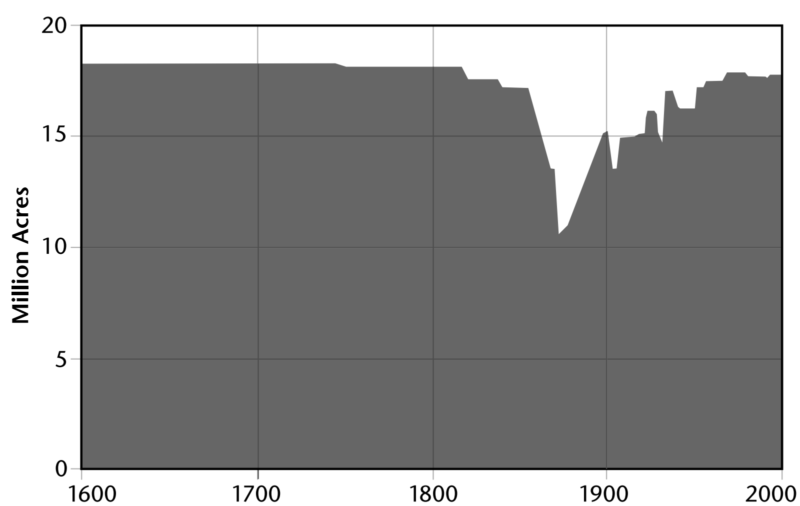


Figure 19.

Estimates of area of forestland in Maine, 1600 to 1995. (Adapted from Irland 1998.)

Although forests can take over abandoned agricultural land, conversion of forests to residential or commercial development, roads, or parking lots is a more-permanent ecological change. Conversion of unusual ecosystems such as pine barrens is more of a problem than conversion of more-common ecosystems.

Conversion is usually most problematic along streams and on shorelands. Forestland conversion affects aquatic ecosystems primarily by interrupting groundwater movement, by siltation and run-off from lawns, roads, and parking lots, and by fragmenting riparian travel corridors. Small wetlands are lost and the quality of larger wetlands along the shore is compromised. Maine has regulated shoreland development since the 1970s, requiring setbacks, vegetative buffers, and minimum lot sizes to lessen the effect of conversion on lake and stream shorelands, wetlands, and coastal areas. However, shoreland zoning does not address the cumulative effects of development, and enforcement has been uneven.

Acreage converted to non-forest use is not extensive in Maine. According to Maine Forest Service (MFS) data, an average of about 2400 acres of Maine's 17.7 million acres of forestland are converted each year — a total of about 17000 acres or 0.1 percent of Maine's forestland base in the seven years these figures have been reported (MFS 1997). However, these figures mask the fact that people are drawn to special areas, primarily shoreland areas. The Maine Land Use Regulation Commission (LURC) reports that 43 percent of all building permits for new residences in the unorganized territory and 66 percent of seasonal residences were located on water bodies, mostly lakes. Fifty-three percent of these new lakeside residences were located on lakes with very high resource values (LURC 1997). Thus, it is not the quantity of forestland conversion that is the issue for Maine's managed forest but rather that the conversion is happening in special areas that may put native biodiversity at risk.

Quantifying the effects of forest conversion is difficult because changes in distribution and abundance of plant and animal species are difficult to assess. Twenty percent of Maine's rare plant species are found in southern Maine (York and Cumberland counties), an area that has experienced the greatest development pressure and subsequent habitat alteration. Some southern plants are no longer found zin Maine, including the lance-leaved bluet, rue-anemone, butterfly weed, and stiff gentian. Others have had their numbers and extent reduced (e.g., variable sedge) (Gawler et al. 1996).

Fifteen percent of Maine's rare plant species are found in northern Maine. Information on rare plants in northern Maine is not comprehensive, however, more is known about certain unusual areas (Gawler et al. 1996). The sporadic inventory efforts to date indicate that most of northern Maine does not contain rare flora but little information is available on the distribution of rare or unusual flora of northern Maine away from river shores and certain wetlands.

The animal species most at risk from forest conversion in Maine are habitat specialists. Amphibians and reptiles are at risk from wetland loss or degradation. Mammals have suffered some local losses and severe reductions of species in southern Maine, with more significant negative effects expected if land use changes permanently.

CONSIDERATIONS

- Conversion of forestland to non-forest uses, particularly development, often generates the greatest income from forestland.

- Voluntarily limiting conversion of forestland or altering development plans may mean lost income potential to the landowner. However, landowners can sell or generate income or estate tax benefits through voluntary conservation easements that restrict land development. A bargain sale, or selling land to a nonprofit organization, also generates income or estate tax benefits.
- Maine's Tree Growth Tax Program works to keep land forested. Landowners are taxed on a forested property's current use rather than on its development potential. There are substantial penalties for withdrawing land from this program.
- Studies commissioned by Maine Coast Heritage Trust have shown that land development may result in a net revenue loss to towns as increased demand for services more than offsets increased revenues from property taxes based on development (Ad Hoc Associates 1997).

RECOMMENDED PRACTICES

- Landowners converting their forestlands should be aware of the existence and significance of natural areas on their properties. Avoid converting unique or unusual ecosystems or natural communities, or areas where unusual ecosystems or natural communities have already been extensively converted to non-forest. Contact the local conservation commission or planning board, the Maine Natural Areas Program (MNAP), or the Maine Department of Inland Fisheries and Wildlife (MDIFW) for this information. In unorganized areas, LURC or the MNAP may assist in identifying these areas.
- If converting forestland to non-forest, minimize the effect of development on biodiversity by (Arendt 1996):
  - Utilizing limited development design that involves dividing the land into a smaller number of higher-priced lots, typically much larger than the standard development lot, with permanent conservation restrictions in areas outside designated "building envelopes." The approach is best used in very special areas with high landscape value, attractive views, or access to water.
  - Using conservation subdivision design, where overall building density remains the same as conventional development but significant undeveloped open space is permanently set aside to maintain biodiversity and provide other values. Planners will usually use the technique of "cluster housing" as the approach to maintain wildlife habitat and environmentally unique areas (Preece 1986). LURC (1992) has developed several conservation subdivision design concepts that are adaptable to different site conditions.
- Focus conservation efforts on forest-cover types or age-class conditions that are under-represented in the area. In most regions, this will include mature forest stands.
- Design conservation areas to minimize fragmentation and incorporate connectivity and corridors, so stands are not isolated. Whenever possible, connect stands with existing or potential conservation areas on adjoining property.
- Avoid landscaping with non-native shrub or tree species, particularly if they are known to be invasive species or aggressive colonizers.
- Minimize clearing on individual house sites.

CROSS REFERENCES

General Principles; Habitat Patch Size

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Appendices

Appendix A

Agencies and organizations in Maine that offer landowner information or assistance

A selection of agencies and organizations in Maine that offer advice or assistance related to forest management and the maintenance of forest biodiversity.

MAINE DEPARTMENT OF INLAND FISHERIES AND WILDLIFE

284 State St., State House Station #41
Augusta, ME 04333
207-287-5252

REGIONAL OFFICES

Region A
RR 1 Box 328, Shaker Rd.
Gray, ME 04039
207-657-3258

Region B
270 Lyons Rd.
Sidney, ME 04330
207-547-5318

Region C
68 Water St.
Machias, ME 04654
207-255-4715

Region D
RR 1 Box 264
Strong, ME 04983-9419
207-778-3324

Region E
PO Box 551
Greenville, ME 04433
207-695-3756

Region F
HCR 67 Box 1066
Enfield, ME 04433
207-732-4131

Region G
PO Box 416
Ashland, ME 04732-0416
207-435-3231

MAINE FOREST SERVICE

State House Station #22
Augusta, ME 04333
207-287-2791

REGIONAL OFFICES

Downeast District Headquarters
PO Box 130
Jonesboro, ME 04648
207-434-2621

Central Region Headquarters
Box 415, Airport Rd.
Old Town, ME 04468
207-827-6191

Northern Region Headquarters
RR 1 Box 16DC
Ashland, ME 04732-9722
207-435-7963

MAINE FOREST SERVICE, continued

Southern Region Headquarters
RR 1 Box 650
Augusta, ME 04330
207-287-2275

SMALL WOODLAND OWNERS ASSOCIATION OF MAINE

PO Box 836, 153 Hospital St.
Augusta, ME 04332-0836
207-626-0005

CHAPTERS

Southern Maine
Dennis Brennan
14 Freemont St.
Sanford, ME 04073
207-324-7000

MidCoast
Paul Dumdey
RR 1 Box 340
Woolwich, ME 04579
207-443-3479

Down East
Vacant

Penobscot Valley
Ervin Tower
PO Box 299
Patten, ME 04765

Northern Maine
Rene Violette
594 Grivois Rd.
Lille, ME 04746
207-528-2710

Western Maine
Stuart Cooper
74 Greenwoods Rd.
Sumner, ME 04292
207-388-2539

Upper Kennebec Valley
Jack Frost
PO Box 62
Anson, ME 04911
207-696-9206

Forest Product Marketing
and Management Association
Vacant

St. Croix
Dale Covey
RR 1 Box 41AB
Princeton, ME 04668-9801
207-427-4051

UNIVERSITY OF MAINE

College of Natural Sciences,
Forestry, and Agriculture
University of Maine
5782 Winslow, Room 105
Orono, ME 04469-5782
207-581-3202

Cooperative Forestry Research Unit
University of Maine
5755 Nutting Hall, Room 229
Orono, ME 04469-5755
207-581-2893

Cooperative Fish and Wildlife
Research Unit
University of Maine
5755 Nutting, Room 258
Orono, ME 04469-5755
207-581-2870

UNIVERSITY OF MAINE COOPERATIVE EXTENSION

Administrative Offices
5741 Libby Hall, Room 102
Orono, ME 04469-5741
207-581-3188
TDD (for hearing impaired): 207-581-2832 or 800-287-8957
800-287-0274 (in Maine)

Forestry and Wildlife Office
5755 Nutting Hall, Room 105
Orono, ME 04469-5755
207-581-2892

COUNTY OFFICES

Androscoggin and Sagadahoc Counties
133 Western Ave.
Auburn, ME 04210-4927
207-786-0376
1-800-287-1458 (in Maine)

Aroostook County

13 Hall St.
Fort Kent, ME 04743-1126
207-834-3905
1-800-287-1421 (in Maine)

Houlton Road
PO Box 727
Presque Isle, ME 04769-0727
207-764-3361
1-800-287-1462 (in Maine)

Central Building
PO Box 8
Houlton, ME 04730-0008
207-532-6548
1-800-287-1469 (in Maine)

Cumberland County
PO Box 9300
15 Chamberlain Ave.
Portland, ME 04104-9300
207-780-4205
1-800-287-1471 (in Maine)

Franklin County
145A Main St.
Farmington, ME 04938-1729
207-778-4650
1-800-287-1478 (in Maine)

Hancock County
63 Boggy Brook Rd.
Ellsworth, ME 04605-9540
207-667-8212
1-800-287-1479 (in Maine)

Kennebec County
125 State St., 3rd Floor
Augusta, ME 04330-5692
207-622-7546
1-800-287-1481 (in Maine)

Knox and Lincoln Counties
235 Jefferson St.
PO Box 309
Waldoboro, ME 04572-0309
207-832-0343
1-800-244-2104 (in Maine)

Oxford County
9 Olson Rd.
South Paris, ME 04281-6402
207-743-6329
1-800-287-1482 (in Maine)

Penobscot County
307 Maine Ave.
Bangor, ME 04401-4331
207-942-7396
1-800-287-1485 (in Maine)

UNIVERSITY OF MAINE COOPERATIVE EXTENSION, continued

Piscataquis County
59 E. Main St.
Dover-Foxcroft, ME 04426-1396
207-564-3301
1-800-287-1491 (in Maine)

Somerset County
Norridgewock Ave.
RR1, Box 4734
Skowhegan, ME 04976-9734
207-474-9622
1-800-287-1495 (in Maine)

Waldo County
RR 4, Box 4645
Belfast, ME 04915-9627
207-342-5971
1-800-287-1426 (in Maine)

Washington County
11 Water St.
Machias, ME 04654-1017
207-255-3345
1-800-287-1542 (in Maine)

York County
RR 2 Box 1678
Sanford, ME 04073-9502
207-324-2814
1-800-287-1535 (in Maine)

OTHER AGENCIES AND ORGANIZATIONS

Forest Society of Maine
PO Box 775
Bangor, ME 04402
207-945-9200

Maine Audubon Society
PO Box 6009
Falmouth, ME 04105
207-781-2330

Maine Low Impact Forestry Project
Hancock County Planning Commission
RFD Box 22
Ellsworth, ME 04605
207-667-7131

Maine Natural Areas Program
State House Station #93
Augusta, ME 04333
207-287-8043

Maine TREE Foundation
RR 4 Box 2770
Winslow, ME 04901
207-877-7123

The Nature Conservancy
14 Maine St., Suite 401
Brunswick, ME 04011
207-729-5181

USDA Forest Service –
State and Private Forestry
271 Mast Rd
Durham, NH 03824
603-868-7600

Appendix B

Relative abundance and distribution of tree species in Maine

Compiled from Maine Forest Service 1995, Gawler et al. 1996.

Common Name	Scientific Name	Abundance	Distribution
Eastern white pine	*Pinus strobus*	Abundant	Widespread
Red pine	*Pinus resinosa*	Common	Local
Pitch pine	*Pinus rigida*	Common	Local
Jack pine	*Pinus banksiana*	Uncommon	Local
Tamarack	*Larix laricina*	Abundant	Widespread
Black spruce	*Picea mariana*	Common	Widespread
Red spruce	*Picea rubens*	Abundant	Widespread
White spruce	*Picea glauca*	Common	Widespread
Eastern hemlock	*Tsuga canadensis*	Common	Widespread
Balsam fir	*Abies balsamea*	Abundant	Widespread
Atlantic white cedar	*Chamaecyparis thyoides*	Very rare	Southern
Northern white cedar	*Thuja occidentalis*	Common	Widespread
Eastern red cedar	*Juniperus virginiana*	Uncommon	Local
Black willow	*Salix nigra*	Uncommon	Widespread
Trembling aspen	*Populus tremuloides*	Abundant	Widespread
Bigtooth aspen	*Populus grandidentata*	Abundant	Widespread
Balsam poplar	*Populus balsamifera*	Common	Widespread
Butternut	*Juglans cinerea*	Uncommon	Widespread
Shagbark hickory	*Carya ovata*	Uncommon	Central, southern
Bitternut hickory	*Carya cordiformis*	Very rare	Southwestern
Eastern hop hornbeam	*Ostrya virginiana*	Common	Widespread
American hornbeam	*Carpinus caroliniana*	Uncommon	Central, southern
Black birch	*Betula lenta*	Uncommon	Southern
Yellow birch	*Betula allegheniensis*	Abundant	Widespread
Gray birch	*Betula populifolia*	Abundant	Central, southern
Paper birch	*Betula papyrifera*	Abundant	Widespread
Heart-leaved paper birch	*Betula cordifolia*	Uncommon	Local
Swamp birch	*Betula pumila*	Uncommon	Central, northern

Common Name	Scientific Name	Abundance	Distribution
Speckled alder	*Alnus rugosa*	Abundant	Widespread
American beech	*Fagus grandifolia*	Abundant	Widespread
American chestnut	*Castanea dentata*	Very rare	Southern
Northern red oak	*Quercus rubra*	Abundant	Widespread
Scarlet oak	*Quercus coccinea*	Very rare	Southern
Scrub oak	*Quercus ilicifolia*	Uncommon	Coastal, southern
Black oak	*Quercus velutina*	Common	Southern
White oak	*Quercus alba*	Common	Southern
Bur oak	*Quercus macrocarpa*	Uncommon	Central, southern
Chestnut oak	*Quercus prinus*	Very rare	Southwestern
Swamp white oak	*Quercus bicolor*	Very rare	Local
American elm	*Ulmus americana*	Uncommon	Widespread
Slippery elm	*Ulmus rubra*	Very rare	Local
Sassafras	*Sassafras albidum*	Very rare	Southern
American mountain ash	*Sorbus americana*	Common	Local
Showy mountain ash	*Sorbus decora*	Uncommon	Northern
Allegheny serviceberry	*Amelanchier laevis*	Common	Widespread
Downy serviceberry	*Amelanchier arborea*	Uncommon	Widespread
Pin cherry	*Prunus pennsylvanica*	Common	Widespread
Black cherry	*Prunus serotina*	Common	Widespread
Common chokecherry	*Prunus virginiana*	Common	Widespread
Canada plum	*Prunus nigra*	Common	Widespread
Sugar maple	*Acer saccharum*	Abundant	Widespread
Silver maple	*Acer saccharinum*	Common	Widespread
Red maple	*Acer rubrum*	Abundant	Widespread
Striped maple	*Acer pennsylvanicum*	Abundant	Widespread
Mountain maple	*Acer spicatum*	Abundant	Northern
American basswood	*Tilia americana*	Uncommon	Widespread, except north
Flowering dogwood	*Cornus florida*	Very rare	Southern
Alternate-leaf dogwood	*Cornus alternifolia*	Common	Widespread
Black gum	*Nyssa sylvatica*	Uncommon	Central, southern
Black ash	*Fraxinus nigra*	Common	Widespread
White ash	*Fraxinus americana*	Abundant	Widespread
Green ash	*Fraxinus pennsylvanica*	Common	Widespread

Appendix C

Birds, mammals, amphibians, and reptiles that use downed woody material, snags, and cavity trees in Maine

Compiled from Elliott 1988.

Species	Use			
	Shelter or Resting	Nesting or Denning	Foraging Perch	Displaying or Basking
Birds				
Wood duck[1]		X		
Common goldeneye[1]		X		
Hooded merganser[1]		X		
Common merganser[1]		X		
Ruffed grouse		X		X
American kestrel[1]		X	X	
Barred owl[1]	X	X		
Saw-whet owl[1]	X	X		
Pileated woodpecker[2]	X	X	X	
Hairy woodpecker[2]	X	X	X	
Downy woodpecker[2]	X	X	X	
Black-backed woodpecker[2]	X	X	X	
Three-toed woodpecker[2]	X	X	X	
Northern flicker[2]	X	X	X	
Yellow-bellied sapsucker[2]	X	X	X	
Chimney swift[1]		X		
Great crested flycatcher[1]		X	X	
Tree swallow[1]		X		
Purple martin[1]		X	X	
Black-capped chickadee[2]	X	X	X	
Boreal chickadee[2]	X	X	X	
Red-breasted nuthatch[2]		X	X	
White-breasted nuthatch[1]		X	X	
Brown creeper[1]		X	X	
House wren[1]		X		

Species	Use			
	Shelter or Resting	Nesting or Denning	Foraging Perch	Displaying or Basking
Winter wren[1]		X	X	
Eastern bluebird[1]		X	X	
Ovenbird			X	X
Common yellowthroat		X	X	X
Rufous-sided towhee		X	X	X
Starling[1]		X		
White-throated sparrow			X	X
Lincoln's sparrow		X	X	X
Song sparrow		X	X	X
House sparrow[1]		X	X	X
Mammals				
Masked shrew	X	X	X	
Pygmy shrew	X		X	
Little brown bat[1]	X	X		
Keen's bat[1]	X	X		
Silver-haired bat[1]	X	X		
Big brown bat[1]	X	X		
Deer mouse	X	X	X	
Red-backed vole	X	X	X	
Woodland jumping mouse	X	X	X	
Red squirrel[1]	X	X	X	
Northern flying squirrel[1]	X	X	X	
Eastern chipmunk	X		X	
Porcupine[1]	X	X		
Cottontail rabbit	X			
Snowshoe hare	X			
Short-tailed weasel[1]		X	X	
Long-tailed weasel[1]		X	X	
Mink		X	X	
Pine marten[1]	X	X	X	
Fisher[1]	X	X	X	

Species	Use			
	Shelter or Resting	Nesting or Denning	Foraging Perch	Displaying or Basking
Striped skunk	X	X	X	
Raccoon	X	X	X	
Coyote		X	X	
Red fox		X	X	
Grey fox		X	X	
Lynx		X	X	
Bobcat		X	X	
Black bear		X	X	
Reptiles				
Northern brown snake	X		X	
Northern redbelly snake	X		X	
Eastern garter snake	X		X	
Northern ringneck snake	X		X	
Eastern milk snake	X		X	
Northern water snake				X
Spotted turtle				X
Eastern painted turtle				X
Amphibians				
Trembaly's salamander	X		X	
Blue-spotted salamander			X	
Spotted salamander	X		X	
Red-backed salamander	X		X	
Four-toed salamander	X		X	
Red eft (juvenile Eastern newt)	X		X	
Grey treefrog	X		X	
Spring peeper	X		X	
Bullfrog	X		X	X
Wood frog	X			

[1] Secondary cavity users [2] Primary cavity excavators

Appendix D

Snag requirements of primary cavity excavators in Maine

Adapted from Elliott 1988.

The data presented in this table allow the calculation of the number of snags required to provide for the needs of each of nine primary cavity excavators in Maine; the result is presented in the last column as snags required per 10 acres. Based on these calculations, meeting the needs of all nine species requires that for every 10 acres 2 snags >22” dbh, 62 snags >12” dbh, 40 snags >8” dbh, and 17 snags >4” dbh are available.

It is more likely that any particular area will not have all nine species of primary excavators present. For example, if it is determined that yellow-bellied sapsuckers, hairy woodpeckers, downy woodpeckers, and black-capped chickadees were present, 34 snags >12” dbh, 40 snags >8” dbh, and 10 snags >4” dbh would be required, for a total of 84 snags per 10 acres. Knowing that larger trees can be substituted for smaller ones, and that more than one species may use the same tree (but only one pair of a particular species), the total number of snags needed can be reduced. Providing 34 snags >12” dbh will also provide for 34 of the 40 snags >8” dbh; providing an additional 6 snags >8” dbh will also provide for 6 of the 10 snags >4” dbh; leaving 4 snags >4” dbh to be provided. The total number of snags needed is now 44 per 10 acres.

Species	Minimum snag diameter (inches)	Average territory size (acres)	Territories per 10 acres	Cavities excavated per year per pair	Snags required per 10 acres[1]
Pileated woodpecker	22	150	0.067	3	2
Common flicker	12	5	2	1	20
Yellow-bellied sapsucker	12	7.5	1.33	1	14
Hairy woodpecker	12	15	0.67	3	20
Three-toed woodpecker	12	75	0.133	3	4
Black-backed woodpecker	12	75	0.133	3	4
Downy woodpecker	8	5	2	2	40
Black-capped chickadee	4	10	1	1	10
Boreal chickadee	41	15	0.66	1	7

[1] Rounded up to the nearest snag. Snags required per 10 acres = (Territories per 10 acres) x (Cavities excavated per year per pair) x (Allowance for unsuitable and unused trees). From information in the literature, an allowance of 10 unused trees per excavated tree was determined and used in this calculation.

Appendix E

Trees and shrubs that bear nuts, fruits, and berries in Maine

Compiled from Mathews 1915, DeGraaf and Witman 1979, Krochmal and Krochmal 1982, Burns and Honkala 1990.

Common Name	Scientific Name	Fruiting Period[1]
Nut-bearing species		
Butternut	*Juglans cinerea*	September-December
Shagbark hickory	*Carya ovata*	September-December
Bitternut hickory	*Carya cordiformis*	September-October
Eastern hop hornbeam	*Ostrya virginiana*	August-December
American hornbeam	*Carpinus caroliniana*	August-October
American hazelnut	*Corylus americana*	July-February
Beaked hazelnut	*Corylus cornuta*	July-February
American beech	*Fagus grandifolia*	September-November
Northern red oak	*Quercus rubra*	September-December
Scarlet oak	*Quercus coccinea*	September-November
Black oak	*Quercus velutina*	September-December
Scrub oak	*Quercus ilicifolia*	October-November
White oak	*Quercus alba*	September-November
Bur oak	*Quercus macrocarpa*	August-November
Chestnut oak	*Quercus prinus*	September-October
Swamp white oak	*Quercus bicolor*	October
Fruit or berry-bearing species		
Eastern red cedar	*Juniperus virginiana*	September-March
Common juniper	*Juniperus communis*	September-August
Canada yew	*Taxus canadensis*	July-September
Greenbrier	*Smilax rotundifolia*	September-March
White mulberry	*Morus alba*	July-August
Sassafras	*Sassafras albidum*	August-October
Spicebush	*Lindera benzoin*	July-October
Currants, gooseberries	*Ribes spp.*	July-September

Common Name	Scientific Name	Fruiting Period[1]
Crab apple	*Malus spp.*	August-April
Common apple	*Malus pumilla*	September-November
Chokeberries	*Pyrus spp.*	August-February
American mountain ash	*Sorbus americana*	August-March
Hawthorns	*Crataegus spp.*	August-February
Serviceberries	*Amelanchier spp.*	June-August
Wild roses	*Rosa spp.*	July-December
Pin cherry	*Prunus pennsylvanica*	July-December
Black cherry	*Prunus serotina*	June-October
Common chokecherry	*Prunus virginiana*	July-October
Sumacs	*Rhus spp.*	August-March
Poison ivy	*Toxicodendron radicans*	August-February
Winterberries	*Ilex verticillata*	August-March
Mountain holly	*Nemopanthus mucronata*	August-September
Climbing bittersweet	*Celastrus scandens*	August-December
Alder-leaved buckthorn	*Rhamnus alnifolia*	August-October
Virginia creeper	*Parthenocissus inserta*	August-February
Grapes	*Vitis spp.*	August-October
Dogwoods	*Cornus spp.*	July to December
Black gum	*Nyssa sylvatica*	August-October
Huckleberries	*Galussacia spp.*	June-August
Blueberries	*Vaccinium spp.*	June-September
Honeysuckles	*Lonicera spp.*	June-September
Hobblebush	*Viburnum alnifolium*	July-October
Witherod	*Viburnum cassinoides*	September-January
Nannyberry	*Viburnum lentago*	July-September
Arrow-wood	*Viburnum recognitum*	August-November
Maple-leaved viburnum	*Viburnum acerifolium*	July-January
Highbush cranberry	*Viburnum trilobum*	August-April
Elderberry	*Sambucus canadensis*	July-September
Red-berried elder	*Sambucus pubens*	June-September

Appendix F

Nutritional value of selected hard mast (per 100-gram edible portion)

Compiled from Krochmal and Krochmal 1982.

Nut	Protein (gr)	Fat (gr)	Calories
Acorns (mixed species)	3.5	2.5	260
Beechnuts	19.4	50.5	568
Butternuts	23.7	61.2	629
Chestnuts	2.9	1.5	194
Hazelnuts	12.6	66.9	634
Hickory nuts	13.2	68.7	673

Appendix G

Amphibians and reptiles of vernal pools in Maine

Compiled from Maine Audubon Society 1997.

Common Name	Scientific Name	Use
Blue-spotted salamander*	*Ambystoma laterale*	Breed
Spotted salamander*	*Ambystoma maculatum*	Breed
Four-toed salamander	*Hemidactylium scutatum*	Breed
Eastern newt	*Notophthalmus viridescens*	Breed
American toad	*Bufo americanus*	Breed
Gray tree frog	*Hyla versicolor*	Breed
Spring peeper	*Pseudacris crucifer*	Breed
Bullfrog	*Rana catesbeiana*	Feed
Green frog	*Rana clamitans*	Breed
Wood frog*	*Rana sylvatica*	Breed
Snapping turtle	*Chelydra serpentina*	Feed
Painted turtle	*Chrysemys picta*	Feed
Spotted turtle	*Clemmys guttata*	Feed, breed
Blanding's turtle	*Clemmys blandingii*	Feed, hibernate
Wood turtle	*Clemmys insculpta*	Feed

* Indicator species

Appendix H

Pathological and maximum ages of late-successional forest trees in Maine

Compiled from Burns and Honkala 1990, Hunter 1990.

Common Name	Mean Pathological Age[1] (Years)	Maximum Known Age (Years)
Eastern hemlock	400	988
White spruce	160 (250-300?)	637
Red spruce	170	426
Black spruce	200	504
Tamarack	150-180	335
Eastern white pine	160-170	461
Red pine	150?	360
Northern white cedar	400	1550
Yellow birch	170	380
American beech	250?	412
American chestnut	310	??
White oak	??	400
Red oak	??	300
Red maple	150	287
Sugar maple	250	440
Black gum	??	562
White ash	70?	141

[1] Average age at which trees begin to suffer serious decay.
Question marks indicate unknown or uncertain ages.

Appendix I

Rare animal species of Maine forests

Compiled from Maine Department Inland Fisheries and Wildlife data.

Common Name	Scientific Name	Status[1]	Habitat[2]	Area[3]
Mammals				
Gray wolf	*Canis lupus*	FE	X	*
Cougar	*Felis concolor*	FE	X	*
Northern bog lemming	*Synaptomys borealis*	T	BG,MX	N
Lynx	*Lynx canadensis*	SC	X	N,W
Long-tailed shrew	*Sorex dispar*	SC	SF	N,W
Yellow-nosed vole	*Microtus chrotorrhinus*	SC	SF	N,W
Southern flying squirrel	*Glaucomys volans*	SC	DF,MX	S
New England cottontail	*Sylvilagus transitionalis*	SC	E	SW
Little brown bat	*Myotis lucifugus*	SC	V	T
Eastern small-footed myotis	*Myotis leibii*	SC	SF,V	S
Northern long-eared bat	*Myotis septentrionalis*	SC	V	T
Silver-haired bat	*Lasionycteris noctivagans*	SC	R,V	T
Eastern pipistrelle	*Pipistrellus subflavus*	SC	R,V	W
Big brown bat	*Eptesicus fuscus*	SC	V	T
Red bat	*Lasiurus borealis*	SC	DF,V	T
Hoary bat	*Lasiurus cinereus*	SC	V	T
Birds				
Golden eagle	*Aquila chrysaetos*	E	X	W,N
Peregrine falcon	*Falco peregrinus*	E	V	W,N
Bald eagle	*Haliaeetus leucocephalus*	T	R	T
Black-crowned night-heron	*Nycticorax nycticorax*	SC	R	T

See page 156 for key to last three columns.

Common Name	Scientific Name	Status[1]	Habitat[2]	Area[3]
Cooper's hawk	*Accipiter cooperii*	SC	R,MX	T
Northern goshawk	*Accipiter gentilis*	SC	MX	T
Eastern screech owl	*Otus asio*	SC	D	S
Three-toed woodpecker	*Picoides tridactylus*	SC	SF	N,W
Olive-sided flycatcher	*Contopus borealis*	SC	R,E	T
Bicknell's thrush	*Catharus bicknellii*	SC	SF	N,W
Rusty blackbird	*Euphagus carolinus*	SC	SF,R	N,W
Reptiles				
Blanding's turtle	*Emydoidea blandingii*	E	R,S	SW
Box turtle	*Terrapene carolina*	E	V	S
Black racer	*Coluber constrictor*	E	V	SW
Spotted turtle	*Clemmys guttata*	T	R,W,S,P	S
Wood turtle	*Clemmys insculpta*	SC	R,S	T
Stinkpot	*Sternotherus odoratus*	SC	P,S,W	S
Ribbon snake	*Thamnophis sauritus*	SC	R,W	SW
Brown snake	*Storeria dekayi*	SC	V	SW,M
Amphibians				
Northern leopard frog	*Rana pipiens*	SC	W,P,S	T
Spring salamander	*Gyrinophilus porphyriticus*	SC	S	C,W
Four-toed salamander	*Hemidactylium scutatum*	SC	BG, W	T
Fish				
Swamp darter	*Etheostoma fusiforme*	T	P,S	S
Creek chubsucker	*Erimyzon oblongus*	SC	P	C
Bridle shiner	*Notropis bifrenatus*	SC	P	T
Grass pickerel	*Esox americanus vermiculatus*	SC	S	M
Landlocked arctic char	*Alvelinus alpinus oquassa*	SC	L	N

See page 156 for key to last three columns.

Common Name	Scientific Name	Status[1]	Habitat[2]	Area[3]
Mollusks				
Tidewater mucket	*Leptodea ochracea*	T	P,S	C
Yellow lampmussel	*Lampsilis cariosa*	T	S,P	C
Brook floater	*Alasmidonta varicosa*	SC	S	C,E
Triangle floater	*Alasmidonta undulata*	SC	S	T
Squawfoot	*Strophitus undulatus*	SC	S	T
Mystery vertigo	*Vertigo paradoxa*	SC	DF	NE
Mayflies				
A flat-headed mayfly	*Epeorus frisoni*	E	S	L
Tomah mayfly	*Siphlonisca aerodromia*	T	R	T
A cleft-footed minnow mayfly	*Metretopus borealis*	SC	S	N
An armored mayfly	*Baetisca berneri*	SC	S	L
An armored mayfly	*Baetisca carolina*	SC	S	L
A flat-headed mayfly	*Rhithrogena brunneotincta*	SC	S	C,NE
Damselfies and Dragonflies				
Ringed boghaunter	*Williamsonia lintneri*	E	BG, W	SW
Pygmy snaketail	*Ophiogomphus howei*	T	S	T
Harpoon clubtail	*Gomphus descriptus*	SC	S	L
Extra-striped snaketail	*Ophiogomphus anomalus*	SC	S	C,N,E
Zigzag darner	*Aeshna stichensis*	SC	BG	L
Muskeg darner	*Aeshna subarctica*	SC	BG	L
Ocellated darner	*Boyeria grafiana*	SC	L,S	N,C
Ebony boghaunter	*Williamsonia fletcheri*	SC	BG, W	L
Delicate emerald	*Somatochlora franklini*	SC	BG	L
Warpaint emerald	*Somatochlora incurvata*	SC	BG	L
Black meadowfly	*Sympetrum danae*	SC	W, BG	L
Superb jewelwing	*Calopteryx amata*	SC	S	L

See page 156 for key to last three columns.

Common Name	Scientific Name	Status[1]	Habitat[2]	Area[3]
Subarctic bluet	*Coenagrion interrogatum*	SC	BG	L
New England bluet	*Enallagma laterale*	SC	L, P	C
Beetles				
American burying beetle	*Nicrophorus americanus*	FE	V	*
Butterflies and Moths				
Clayton's copper	*Lycaena dorcas claytoni*	E	W	N
Edward's hairstreak	*Satyrium edwardsii*	E	BN	SW
Hessel's hairstreak	*Mitoura hesseli*	E	AC	S
Karner blue	*Lycaeides melissa samuelis*	FE	BN	*
Twilight moth	*Lycia rachelae*	T	BN	SW
Pine barrens zanclognatha	*Zanclognatha martha*	T	BN	SW
Spicebush swallowtail	*Papilio troilus*	SC	DF	*
Bog elfin	*Incisalia lanoraieensis*	SC	BG,BN	T
Western banded elfin	*Incisalia eryphon ssp. 1*	SC	BG	L
Olive hairstreak	*Hitoura grynea*	SC	V	SW
Bog fritillary	*Boloria eunomia dawsoni*	SC	BG	L
Tawny crescent	*Phyciodes batesii*	SC	V	W
Pine sphinx moth	*Lapara coniferarum*	SC	BN	SW
Huckleberry sphinx moth	*Paonias astylus*	SC	BN	C,N
Pine-devil moth	*Citheronia sepulcralis*	SC	BN	*
Inland barrens buck moth	*Hemileuca maia ssp. 3*	SC	BN	*
Pine pinion	*Lithophane lepida lepida*	SC	BN	W,C,N
Acadian swordgrass moth	*Xylena thoracica*	SC	BN	SW, W,N
Thaxter's pinion moth	*Lithophane thaxteri*	SC	BG,BN	SW,C
Ceromatic noctuid moth	*Pyreferra ceromatica*	SC	MX	*
Red-winged sallow	*Xystopeplus rufago*	SC	BN	SW
A noctuid moth	*Chaetaglaea cerata*	SC	BN	C
Trembling sallow	*Chaetaglaea tremula*	SC	BN	SW,MC

See page 156 for key to last three columns.

Common Name	Scientific Name	Status[1]	Habitat[2]	Area[3]
Broad sallow	*Xylotype capax*	SC	BN	SW
Oblique zale moth	*Zale obliqua*	SC	BN	SW
Pine barrens zale moth	*Zale sp. 1*	SC	BN	SW
Similar underwing moth	*Catocala similis*	SC	BN	SW
Precious underwing moth	*Catocala pretiosa pretiosa*	SC	W	SW
Pine barrens itame moth	*Itame sp. 1*	SC	BN	W

[1] E: State endangered
FE: Federally endangered
T: State threatened
SC: State special concern

[2] AC: Atlantic white cedar swamps
BG: sphagnum bogs
BN: oak-pine or pine barrens
DF: deciduous forest
E: early-successional forest
L: cold-water lakes
MX: mixed forest
P: warm-water lakes and ponds
R: riparian areas and shores
S: streams or rivers
SF: spruce-fir forest
V: variable, including forests, wetlands, and openings
W: fens, marshy ponds, or swamps
X: extensive forest of various types

[3] N: Northern
NE: Northeastern
E: Eastern
S: Southern
SW: Southwestern
W: Western
C: Central
M: Midcoast
L: locally distributed in one or a few locations
T: widely scattered locations throughout state
*: current presence in Maine undocumented

Appendix J

Rare plant species of Maine forests

Compiled from Gawler et al. 1996.

Rare plant fact sheets are available on the web at:
http://www.state.me.us/doc/nrimc/mnap/factsheets/mnapfact.htm

Common Name	Scientific Name	Habitat[1]	S-Rank[2]	Status[3]
Allegheny vine	*Adlumia fungosa*	RTL	S1	E
Wild garlic	*Allium canadense*	DFW	S2	
Wild leek	*Allium tricoccum*	RMH	S2	
Small round-leaved orchis	*Amerorchis rotundifolia*	NWC	S1	T
Smooth rockcress	*Arabis laevigata*	RTL	S1	E
Missouri rockcress	*Arabis missouriensis*	RTL	S1	T
Branching needlegrass	*Aristida basiramea*	BDW	S1	
Wild ginger	*Asarum canadense*	RMH	S1/S2	T
Ebony spleenwort	*Asplenium platyneuron*	RTL	S1	T
Green spleenwort	*Asplenium trichomanes-ramosum*	RTL	S1	E
White wood aster	*Aster divaricatus*	BDW	S1	T
Fern-leaved false foxglove	*Aureolaria pedicularia*	BDW	S2	
Wild indigo	*Baptisia tinctoria*	BDW	S1	E
Hairy wood brome-grass	*Bromus pubescens*	RMF	S1	E
New England northern reed-grass	*Calamagrostis stricta var. inexpansa*	BDW	S1	T
Upright bindweed	*Calystegia spithamaea*	BDW	S1	T
Cut-leaved toothwort	*Cardamine concatenata*	RMH	S1	E
Large toothwort	*Cardamine maxima*	RMH	S1	
Sedge	*Carex adusta*	BDW	S1	E
Back's sedge	*Carex backii*	BDW	S1	
Spreading sedge	*Carex laxiculmis*	RLR	S1	
Muhlenberg sedge	*Carex muhlenbergii*	BDW	S?	
Variable sedge	*Carex polymorpha*	BDW	S1	T
Bur-reed sedge	*Carex sparganioides*	RMH	S1	E
Bitternut hickory	*Carya cordiformis*	BDW	S1	E

See page 159 for key to last three columns.

Common Name	Scientific Name	Habitat[1]	S-Rank[2]	Status[3]
American chestnut	*Castanea dentata*	BDW	S2	
New Jersey tea	*Ceanothus americanus*	BDW	S1	T
Atlantic white cedar	*Chamaecyparis thyoides*	CFW	S2	T
Spotted wintergreen	*Chimaphila maculata*	NFU	S2	
Purple clematis	*Clematis occidentalis*	RTL	S2	
Sweet pepper-bush	*Clethra alnifolia*	DFW	S2	T
Autumn coralroot	*Corallorhiza odontorhiza*	NFU	S1	E
Flowering dogwood	*Cornus florida*	DFU	S1	E
Slender cliffbrake	*Cryptogramma stelleri*	RTL	S1	
Ram's-head lady's-slipper	*Cypripedium arietinum*	CFW	S1	T
Squirrel-corn	*Dicentra canadensis*	RMH	S1	T
Male fern	*Dryopteris felix-mas*	RTL	S1	E
Goldie's wood-fern	*Dryopteris goldiana*	RMH	S2	
Eastern Joe-pye weed	*Eupatorium dubium*	DFW	S1	E
Showy orchis	*Galearis spectabilis*	RMH	S1	T
Northern commandra	*Geocaulon lividum*	CFW	S2	
Giant rattlesnake-plantain	*Goodyera oblongibolia*	NFU	S1/S2	E
Northern stickseed	*Hackelia deflexa*	RMH	S1	E
Poor robin's plantain	*Hieracium venosum*	BDW	S1	E
Ink-berry	*Ilex glabra*	DFW	S1	E
Pale jewelweed	*Impatiens pallida*	RMH	S2	T
Large whorled pogonia	*Isotria medeoloides*	NFU	S1	E
Northern blazing star	*Liatris scariosa*	BDW	S1	T
Mountain honeysuckle	*Lonicera dioica*	NFU	S1	E
Trumpet honeysuckle	*Lonicera sempervirens*	DFW	S1	
White adder's mouth	*Malaxis brachypoda*	NWC	S1	E
Cliff muhly	*Muhlenbergia sobolifera*	RMH	S1	E
Mountain sweet cicely	*Osmorhiza berteroi*	RMH	S2	T
American ginseng	*Panax quinquefolius*	RMH	S2	T
Furbish's lousewort	*Pedicularis furbishiae*	RLR	S2	E
Common butterwort	*Pinguicula vulgaris*	RTL	S1	E
Jacob's ladder	*Polemonium vanbruntiae*	DFW	S1	E

See page 159 for key to last three columns.

Common Name	Scientific Name	Habitat[1]	S-Rank[2]	Status[3]
Swamp white oak	*Quercus bicolor*	DFW	S1	
Scarlet oak	*Quercus coccinea*	BDW	S1	E
Chestnut oak	*Quercus prinus*	BDW	S1	E
Early crowfoot	*Ranunculus fascicularis*	RTL	S1	T
Lapland buttercup	*Ranunculus lapponicus*	NWC	S1S2	T
Great rhododendron	*Rhododendron maximum*	DFW	S1	T
Clammy azalea	*Rhododendron viscosum*	DFW	S1	T
Sassafras	*Sassafras albidum*	BDW	S2	
Swamp saxifrage	*Saxifraga pensylvanica*	DFW	S2	T
Broad beech fern	*Thelypteris hexagonoptera*	RMH	S2	
Wild coffee	*Triosteum aurantiacum*	RMH	S1	T
Nodding pogonia	*Triphora trianthophora*	RMH	S1/S2	T
Canada violet	*Viola canadensis*	RMH	S1	
Summer grape	*Vitis aestivalis*	BDW	S1	T
Barren strawberry	*Waldsteinia fragarioides*	BDW	S1	T
Blunt-lobed woodsia	*Woodsia obtusa*	RTL	S1	T
Netted chain fern	*Woodwardia areolata*	DFW	S1	E

[1] BDW: Barrens, dry woods, and/or clearings (typically species with more southern affinities)
CFW: Coniferous forest wetlands
DFU: Deciduous forest uplands
DFW: Deciduous forest swamps and lowlands
NFU: Non-specific forest uplands
NWC: Northern white cedar swamps and forests
RLR: Rivershore, lakeshore riparian
RMH: Rich, mesic hardwoods
RTL: Rocky outcrops, talus slopes, ledgy woods, often with calcareous influence

[2] S1: Critically imperiled
S2: Imperiled

[3] E: State endangered
T: State threatened

Appendix K
Rare forest-community types in Maine

Compiled from Gawler et al. 1996.

Closed-Canopy Upland Forest Types

Oak-hickory forest (4 occurrences): This very rare and highly imperiled community occurs in patches of 2.5 to 250 acres on well-drained soils in southern Maine. White oak species dominate the overstory that also includes shagbark hickory and often black birch and red oak. The understory is usually quite open, and sedge lawns form the predominant groundcover. This community type is a landscape dominant in Appalachian areas south of Maine.

Maple-basswood-ash forest (also referred to as cove forest or enriched sugar maple forest) (30 occurrences): This rare to imperiled community occurs in patches of 2.5 to 25 (and occasionally 250) acres on enriched mesic soils and sometimes on pockets of talus, primarily in western and northern Maine. Sugar maple strongly dominates the overstory that includes more basswood and ash than northern hardwood communities on less-fertile soils. A rich diversity of herbaceous plants comprise the groundcover that includes a number of rare and uncommon species.

Subalpine spruce-fir forest (20 occurrences): This moderately rare community occurs in patches of 25 to 7500 acres on exposed level ridges and steep rocky slopes, typically at elevations of 2900 feet or more in mountainous regions of the state. Balsam fir dominates the overstory that also includes red spruce, black spruce, mountain ash, and heart-leaved paper birch. This community differs from the more-common spruce slope forest in several ways: much of the balsam fir overstory typically consists of stunted trees; these forests often include patches of blowdowns with mountain ash and hobblebush; and they typically have lower basal area and volume. Many sub-alpine forests contain no merchantable timber.

White oak-red oak forest (5 occurrences): This moderately rare community occurs in patches of 2.5 to 250 acres on mesic to somewhat xeric soils in southern and midcoastal Maine. White and red oaks dominate the overstory, and few tall shrubs are present.

Partial-Canopy Upland Forest Types

Red pine woodland (12 occurrences): This rare community occurs in patches of 2.5 to 25 acres on eskers, rocky soils, and outcrops in northern and western Maine. The red pine-dominated overstory is usually semi-open, but may be closed, and often includes some white pine.

Pitch pine woodland (13 occurrences): This rare community occurs in patches of 2.5 to 250 acres on ledges and outcrops with a thin layer of dry, nutrient-poor soil along the Maine coast west of Mount Desert Island. Pitch pine dominates the semi-open overstory that also may include red oak. This type is not well documented at present.

Jack pine woodland (8 occurrences): This rare community occurs in patches of 2.5 to 250 acres on thin-soiled ledges and outcrops along the coast east of Mount Desert Island, and on some inland sand beaches in northern Maine. Stunted jack pine forms the scattered overstory.

Northern white cedar woodland (2 occurrences): This rare community occurs in patches of 2.5 to 250 acres in an upland setting on rocky hillslopes. Other conifers may be present, but nothern white cedar is dominant in this partial-canopy woodland. In Maine, this community is known from only the Mount Desert Island area, but there may be more examples throughout the state.

Pitch pine dune semi-forest (4 occurrences): This very rare and critically imperiled community occurs in patches of 2.5 to 25 (and occasionally 250) acres on stabilized dunes along the coast south and west of Portland. The stunted overstory of pitch pine occasionally includes red oak and maple.

Pitch pine-scrub oak barrens (12 occurrences): This very rare and critically imperiled, fire-dependent community occurs in patches of 250 to 2500 acres on well-drained sandy soils and glacial outwash in York and Cumberland counties. Dominant vegetation includes a patchy overstory of pitch pine and a scrub oak understory.

Pitch pine-heath barrens (3 occurrences): This very rare and critically imperiled community occurs in patches of 25 to 2500 acres in interior sections of southern and central Maine. Pitch pine dominates the canopy that may be closed in patches or consist of scattered trees. Scrub oak is rare or absent, and heath shrubs and grasses dominate the understory and groundcover.

Cold-air talus woodland (4 occurrences): This very rare and imperiled community occurs in patches of <25 acres on north-facing talus slopes. Labrador tea and stunted black spruce dominate the vegetation, growing in thick, peaty duff covered with fruticose lichens.

Closed-Canopy Wetland Forest Types

Perched hemlock-hardwood swamp (coastal plain pocket swamp) (8 occurrences): This very rare and imperiled community occurs in 2.5- to 25-acre basins with a perched water table scattered among low hills, primarily along the coastal plain of York and Cumberland counties. Black gum is a characteristic overstory species, with red maple and eastern hemlock dominating.

Atlantic white cedar swamp (8 occurrences): This very rare and imperiled community occurs in southern coastal Maine in patches of 2.5 to 2500 acres. Cedar may form pure stands or occur in combination with red maple. Highbush blueberry, winterberry, and other shrubs occupy openings in the canopy; sedges and sphagnum form the primary groundcover. Atlantic white cedar can be distinguished from northern white cedar by its foliage and fruits.

Northern white cedar seepage forest (13 occurrences): This moderately rare community occurs in patches of 2.5 to 250 acres on gentle slopes with hummocky surfaces and seeping groundwater in northern Maine. The cedar-dominated overstory also includes red spruce and balsam fir.

Hardwood seepage forest (1 occurrence): This rare community occurs in patches of 2.5 to 250 on gentle slopes with hardpans in the soil that divert water to seepage at the surface. Yellow birch, red maple and hemlock dominate the overstory, and mixed sedges occur with skunk cabbage as primary groundcover. This type needs further surveys and documentation.

Hardwood floodplain forest (27 occurrences): This moderately rare community occurs in patches of 25-2500 ha on flats along medium to large rivers throughout the state. Seasonally flooded, low floodplain forests have an overstory of silver maple, ash, and elm (where disease has not yet eliminated the species); red oak, ash, and sugar maple dominate higher floodplain terraces. A rich groundcover of herbaceous plants may be present briefly during the spring. Later in the season, sensitive and ostrich ferns dominate the groundcover of many floodplain sites.

Outwash seepage forest (6 occurrences): This rare to imperiled community occurs locally in patches of 2.5 to 250 acres on slopes of deep glacial deposits where groundwater seeps to the surface. Red spruce, balsam fir, and red maple dominate the overstory, and alder and viburnums are common understory shrubs.

Partial-Canopy Wetland Forest Types

Pitch pine bog (7 occurrences): This rare community occurs in patches of 2.5 to 50 acres. Characteristic of the coastal plain of mid-coast and southern Maine, these partly to sparsely forested peatlands have pitch pine as a common to dominant tree. Typical bog conditions predominate otherwise, with acidic conditions and abundant sphagnum in the ground layer. Huckleberry is a common shrub, along with other heath shrubs.

Appendix L

Forested natural communities in Maine

Compiled from Gawler et al. 1996.

Community	Status in Maine	Distribution
Spruce-fir flats forest	Abundant	Northern (sporadic elsewhere)
Mixed hardwood-conifer forest	Abundant	Central, western, northern
Birch-aspen forest	Abundant	Statewide
Beech-birch-maple forest	Abundant	Northern, western, central (mostly)
Red maple swamp	Abundant	Statewide
Pine-hemlock-spruce forest	Common	Statewide (less common north)
Hemlock slope forest	Common	Statewide (less common north, coastal)
Maritime spruce-fir forest	Common	Coastal
Spruce slope forest	Common	Northern (mostly)
Oak-pine forest	Common	South, central
Northern white cedar swamp	Common	Northern, western, central
Spruce-fir swamp	Common	Statewide
Forested bog	Common	Statewide
Oak-beech forest	Uncommon-common	Statewide
Sub-alpine spruce-fir forest	Uncommon	Montane
White oak-red oak forest	Uncommon	Southern, midcoastal
Hardwood floodplain forest	Uncommon	Statewide
Northern white cedar seepage forest	Uncommon	Northern
Maple-basswood-ash forest	Uncommon-rare	Western, northern (mostly)
Outwash seepage forest	Uncommon-rare	Sporadic
Oak-hickory forest	Rare	Southern
Perched hemlock-hardwood swamp	Rare	Southern
Atlantic white cedar swamp	Rare	Southern
Black willow-alder swamp	Uncertain	Southern, central
Hardwood seepage forest	Uncertain	Sporadic

Appendix M

Changes in age-class and size-class composition of forestland in Maine, pre-settlement to present

Compiled from Lorimer 1977, Seymour and Lemin 1987, Griffith and Alerick 1996.

Pre-settlement[1] **(Lorimer 1977)**	**1980 USFS Inventory Data[2]** **(Seymour and Lemin 1987)**	**1990 USFS Inventory Data[3]** **(Griffith and Alerich 1995)**	**Other Data**
2% recently burned land and large windfalls, to 10 years old		25% regenerating sapling-sized stands	Between 1990 and 1996, 2.4% of Maine's forestland base was clearcut and 3.3% was harvested in a shelterwood method[4]
14% birch-aspen forest and young regeneration on windfalls, to 75 years old	84% of forest in age classes less than 75 years old	41% pole-sized stands[5]	
25% young, late-successional forest, 75 to 150 years old	16% of forest greater than 75 years old	34% sawtimber-sized stands[6]	2.6% older forest[7]
32% older, late-successional forest, 150 to 300 years old			1% oldest forest[8]
27% over-mature forest, greater than 300 years old [9]			

1 Derived from land survey records in north-central Maine 1793-1827.
2 USDA Forest Service inventory records size classes rather than age. Seymour and Lemin used effective age versus chronological age in their predictions. Stands may be older, particularly tolerant species.
3 Based on size classes rather than age.
4 From Maine Forest Service 1996 Silvicultural Activities Report.
5 At least 50% of basal area in trees between 5" and 9 to 11" dbh, at least 10% full stocking.
6 At least 50% of basal area in trees > 9 to 11" dbh, at least 10% full stocking.
7 >100 sq. ft. ba/acre, 5+ trees/acres > 18 to 20" dbh, 5+ dead trees/acre >15" dbh (Allen and Plantiga 1999).
8 > 150 sq. ft. ba/acre, 5+ trees/acre > 20 to 24" dbh, 5+ dead trees/acre >15" dbh (Allen and Plantiga 1999).
9 Age is from last major disturbance, actual age is greater.

Appendix N

Important avian predators of spruce budworn

Compiled from Harrison 1975, Jennings et al. 1985, DeGraff and Rudis 1987.

Common Name	Budworm Life-Stage Eaten[1]	Breeding Habitat	
		Forest Type[2]	Nest Site[3]
Black-capped chickadee	L, P, A	NH, SF, MX	C
Red-breasted nuthatch	L, P	SF, MX	C
Golden-crowned kinglet	L, P, A	SF, MX	U, O
Swainson's thrush	L	NH, SF, MX	U
Solitary vireo	L, P	SF, MX	U
Tennessee warbler	L	AB	G
Nashville warbler	L, P	AB, SF	G
Blackburnian warbler	L, P	SF, MX	O
Cape May warbler	L, P, A	SF	O
Magnolia warbler	L, P	SF	U
Yellow-rumped warbler	L, P, A	SF, MX	U, O
Black-throated green warbler	L, P	SF, NH, MX	U, O
Bay-breasted warbler	L, P, A	SF	U, O
White-throated sparrow	L	SF, NH, MX	G
Red-winged blackbird	P	W	U
Common grackle	P	W	O
Evening grosbeak	P	SF	O
Pine grosbeak	P	SF	U

1 L: Larvae; P: Pupae; A: Adults

2 AB: Aspen-Birch
MX: Mixed hardwoods-softwoods
NH: Northern Hardwoods
SF: Spruce-Fir
W: Wetlands

3 G: Ground (<2 ft.); U: Understory (2-20 ft.); O: Overstory (>20 ft.)

Appendix O

Changes in area (thousands of acres) and proportion (%) of forest types in Maine, 1982 to 1995

Compiled from Griffith and Alerich 1996.

Forest Type	1982		1995		% Change	
	Area	Prop.	Area	Prop.	Area	Prop.
Mixed northern hardwoods	550.0	3.21	813.9	4.81	+47.98	+49.70
Northern red oak	115.2	0.67	164.4	0.97	+42.71	+44.36
Red maple-northern hardwoods	1220.8	7.12	1538.8	9.09	+26.05	+27.51
Northern white cedar	1061.7	6.20	1332.5	7.87	+25.51	+26.96
Paper birch	724.2	4.23	890.0	5.25	+22.89	+24.32
White pine	467.6	2.73	540.5	3.19	+15.59	+16.93
Sugar maple-beech-yellow birch	3474.8	20.28	3865.4	22.82	+11.24	+12.53
Aspen	1132.9	6.61	1211.3	7.15	+6.92	+8.16
White pine-hemlock	154.3	0.90	164.3	0.97	+6.48	+7.72
Mixed central hardwoods	213.8	1.25	213.0	1.26	-0.37	+0.78
Hemlock	516.3	3.01	509.0	3.01	-1.41	-0.27
Red spruce	1013.3	5.91	901.7	5.32	-11.01	-9.98
Black ash-American elm-red maple	180.5	1.05	160.2	0.95	-11.25	-10.22
Balsam fir	2233.5	13.04	1830.8	10.81	-18.03	-17.08
White pine-red oak-white ash	151.2	0.88	120.8	0.71	-20.11	-19.18
Gray birch	208.4	1.22	148.3	0.88	-28.84	-28.01
Black spruce	284.4	1.66	194.5	1.15	-31.61	-30.82
Pin cherry-reverting field	198.7	1.16	132.8	0.78	-33.17	-32.39
Red spruce-balsam fir	2764.7	16.14	1486.8	8.78	-46.22	-45.60
Total	16,666.3	97.27	16,219.0	95.77	-0.03	-0.02

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