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Guide to Wildlife Tree Management in New England Northern Hardwoods

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Abstract

Presents information on the culture and management of trees that have value as components of wildlife habitat in the northern hardwood and associated types in New England. Background information is provided for choosing the most suitable trees for wildlife habitats and for estimating the impact on timber production. Suggestions are made for choosing the numbers of trees for a variety of common situations and for cultural procedures to enhance the value of trees as wildlife habitat. Hard and soft mast production is discussed, and guides for culture and management of mast are presented. Simplified habitat objectives and a key are provided for choosing and culturing wildlife trees in common forestry situations.

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COVER PHOTO.—Brown creeper (*Certhia familiaris*). Photographed by Mike Hopiak for the Cornell Laboratory of Ornithology.

Guide to Wildlife Tree Management in New England Northern Hardwoods

Contents

Introduction

Intended for use in New England by foresters and wildlife managers, this publication includes forestry and wildlife information needed to provide individual tree habitat for a diverse wildlife community in northern hardwood and related cover types that will also be managed for timber production. Although knowledge of wildlife ecology is not essential, familiarity with the habitat needs of individual species will help the reader apply the principles presented. The habitat requirements of the region's wildlife are provided in *New England Wildlife: habitat, natural history and distribution* (DeGraaf and Rudis 1986). The development of natural cavities and decay patterns that produce conditions suitable for cavity excavation are provided in *Managing cavity trees for wildlife in the Northeast* (DeGraaf and Shigo 1985).

Our goal is to aid planning and decisionmaking in the silviculture and management of individual trees, especially in devising silvicultural techniques and prescriptions for specific stand conditions.

More than a hundred wildlife species utilize standing trees in different ways during different seasons. Dozens of tree species grow in northern hardwood stands on a wide variety of sites; tree species are grouped in a number of cover types that represent different sites and stages of plant succession. Also, trees are grown for a variety of timber uses as well as for the conservation of soil and water and for recreational uses. These factors render it impractical to make specific recommendations for each possibility. Instead, the information presented here is intended to provide general principles and information for use in identifying areas that will become deficient in some aspect of wildlife tree habitat. The guide presents silvicultural information and techniques for overcoming deficits as well as for tending the major tree species of the northern hardwood type for wildlife purposes. Recommendations for planning and practices are made for common situations and illustrate the uses of the information in the guide.

On large tracts of public and industrial forest land, this guide is intended to supplement the timber marking guidelines of existing management plans to help foresters achieve wildlife habitat objectives and goals as other cultural activites are conducted within individual stands. On small properties consisting of one or several stands, this guide can also be used to identify and tend trees with high wildlife habitat value.

Although most timber guides for managing northern hardwood forests recognize forest stands as wildlife habitat, they usually emphasize the production of high-quality hardwood stems, free of rot and other stem and branching defects. However, wildlife need seeds, buds, twigs and foliage of trees, decayed tree stems and limbs, undergrowth, and litter in various combinations. This guide emphasizes the identification and management of individual trees with good potential for producing these habitat features.

Background

The information in this guide applies to hardwood stands in New England where some combination of sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*) and yellow birch (*Betula alleghaniensis*) is characteristic of the site. Quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), paper birch (*Betula papyrifera*), gray birch (*B. populifolia*), and black cherry (*Prunus serotina*) are pioneer species in these forest types, usually developing in mixtures after major disturbances such as fire or clearcutting. Over time they are usually replaced by more shade tolerant northern hardwoods. Other important associates in northern hardwood communities are red maple (*Acer rubrum*), hemlock (*Tsuga canadensis*), white ash (*Fraxinus americana*), basswood (*Tilia americana*), sweet birch (*B. lenta*), northern red oak (*Quercus rubra*), white pine (*Pinus strobus*), balsam fir (*Abies balsamea*), American elm (*Ulmus americana*), red spruce (*Picea rubens*), and eastern hophornbeam (*Ostrya virginiana*). Thus the following forest cover types are also included: sugar maple-beech-yellow birch, sugar maple, beech-sugar maple, aspen, and paper birch (Eyre 1980).

Elements of Wildlife Habitat

Although the term wildlife habitat is used often in a general way, habitat requirements only can be defined precisely in reference to individual species. Northern hardwood forests provide habitat for several hundred wildlife species. Dealing with habitat on a species-by-species basis is beyond the scope of this paper and probably beyond the interests of most managers and landowners. We will consider the needs of groups of species with similar requirements, and discuss easily recognized elements of a stand that influence use by wildlife.

Woody plant species account for the bulk of the vegetation in northern hardwood stands, and the woody parts of trees account for most of the living biomass (Bormann and Likens 1979, Whittaker et al. 1974). The understory plants and wildlife account for a small fraction, usually less than 1 percent, of the total living biomass in northern hardwood stands. Individual trees used for food and cover are a small but important component of the northern hardwood ecosystem.

Tree Cavities. Tree cavities provide shelter, dens, and nest sites for many wildlife species. Intensive timber management seeks to eliminate trees with cavities; but opportunities exist to increase the availability of cavities and other wildlife habitat elements with timber/vegetation management. In general, seedlings and sapling stands produce abundant herbage (grasses and nonwoody plants), browse (buds, twigs, shoots and leaves of wood plants) and cover (high woody stem density—brush—and conifer crowns); while older stands produce more cavities and mast. It is important to note that stands seldom produce high levels of all five habitat elements at the same time.

Mast. Mast refers to the fruits and seeds of trees and other woody shrubs and is an important wildlife food source for migrating and resident birds and for mammals. Both birds and mammals are important disseminators of those seeds. Hard mast (tree nuts) is an important fall and winter diet component for white-tailed deer, black bear, turkey, and grey squirrel. Beech is a major source of mast in northern hardwoods, but red oak, the cherries, eastern hophornbeam, and other associates can add greatly to the diversity and abundance of mast.

Cavity Dwellers

In New England northern hardwood forests, 41 species of birds and mammals either nest, den, roost, or forage for insects and other invertebrates found in standing trees with decay present (Table 1). When decay occurs extensively in live tree boles, timber managers refer to it as rotten cull. Cull trees have minimal market value, and usually one of the first steps in managing timber stands is to eliminate them. The amount of rotten cull in unmanaged stands is variable, with estimates ranging from 10 to 65 percent of total volume (Trimble 1963; Zillgitt and Gevorkiantz 1946). The distribution of rotten cull shifts from large butt logs to the larger branches of the crown and upper stem under increasingly intensive timber management (Cooley 1964, Filip 1978). Cull formation is generally a slow process, and timber management over a 10- to 20-year period can reduce the amount of cull to very low levels (Trimble 1963, Tubbs 1977). Many cavity-nesting birds forage over the boles and limbs of sound trees regardless of size, but must nest in relatively large trees with suitable decay. For woodpeckers, excavation of the nest is vital to pair-bonding at the onset of the breeding season. Mammals need secure dens, especially in winter and when they bear young. Habitat needs during the breeding/young rearing period is the key to maintaining populations of these species over time.

Choosing the Number of Cavity Trees

The number of cavity trees to be retained in a given area will depend on (1) habitat requirements of cavity-dwelling species, (2) site capability to produce cavity trees, (3) current stand composition, structure, and tree condition, (4) rotation and cutting-cycle length (5) stand size, and (6) landowner objectives.

Cavity-Tree Habitat Requirements. Current estimates of large-diameter (18 inches d.b.h.) cavity/den tree density required to provide breeding and roosting or denning sites for populations of larger bodied, cavity-dwelling wildlife species such as raccoon, fisher, and pileated woodpecker range from 0.1 to 1.0 tree per acre (Table 2). Additional foraging sites and small diameter nesting/roosting sites can be expected regularly in the upper portions of tree crowns and from natural mortality in northern hardwood stands at the present time (Fig. 1). Smaller bodied species such as downy and hairy woodpeckers, nuthatches, and flying squirrels can use decayed upper portions of larger live stems in addition to smaller diameter dead/dying stems.

Site Capability. Ecosystem classifications based on landform, soils, and vegetation relationships can be used to evaluate a site's wildlife habitat potential on the basis of its capability to produce habitat elements. Examples of useful classifications are presented by Leak (1976, 1978, 1979, and 1982), Jordan (1982), and Barnes et al. (1982). Such estimates of total site quality will help in applying these guides because the capacity to produce wildlife habitat elements and cavity trees, in particular, varies among northern hardwood stands. For example, only 2 of 14 soil-site habitats defined by Leak (1979) are capable of producing a substantial proportion of very large-diameter (>24 inches d.b.h.) stems[1]. Very good hardwood sites are frequently deficient in conifer species and in hard mast species such as beech and oak.

[1] Leak, W. B. 1985. Effects of habitat on stand structure in old-growth hardwoods and mixed wood. Final report. Unpublished report on file at USDA Forest Service, Northeastern Forest Experiment Station, Durham, NH 03824.

Table 1.—Types of trees and cavities used by birds and mammals in northern hardwood forests (adapted from DeGraaf 1984)

	Use[a]					Tree type[b] and d.b.h. class (inches)						
Wildlife species	P	F	N	R	D	DS < 8	DH 6–12	DH 12–18	LCD 8–12	LBTL 12–18	LBTL > 18	Hollow > 24
Wood duck (*Aix sponsa*)			N								2[c]	
Common goldeneye (*Bucephala clangula*)			N								2	
Hooded merganser (*Lophodytes cucullatus*)			N								2	
Common merganser (*Mergus merganser*)			N								2	
Turkey vulture (*Cathartes aura*)	P		N								2	
E. screech owl (*Otus asio*)	P		N	R				2				
Barred owl (*Strix varia*)	P		N								2	
N. saw-whet owl (*Aegolius acadicus*)	P		N	R			2	1		2		
N. flicker (*Colaptes auratus*)	P	F	N	R				1		1	1	
Pileated woodpecker (*Drycocopus pileatus*)	P	F	N	R				1 (>18)				
Yellow-bellied sapsucker (*Sphyrapicus varius*)	P	F	N	R					1	1	1	
Hairy woodpecker (*Picoides villosus*)	P	F	N	R			1	1	1	1	1	
Downy woodpecker (*Picoides pubescens*)	P	F	N	R		1	1		1	1	1	
Great crested flycatcher (*Myiarchus crinitus*)			N							2	2	
Black-capped chickadee (*Parus atricapillus*)			N	R		1						
Boreal chickadee (*Parus hudsonicus*)			N	R		1						
Tufted titmouse (*Parus bicolor*)			N	R		1					2	
Red-breasted nuthatch (*Sitta canadensis*)		F	N	R					2	2	2	
White-breasted nuthatch (*Sitta carolinensis*)		F	N	R					2	2	2	
Brown creeper (*Certhia americana*)		F	N	R			2	2	2	2	2	
House wren (*Troglodytes aedon*)		F	N	R		2			2	2		
Winter wren (*Troglodytes troglodytes*)			N			2						
E. bluebird (*Sialia sialis*)		F	N	R		2	2	2				

Continued

Table 1.—Continued

Wildlife species	Use[a] P	F	N	R	D	Tree type[b] and d.b.h. class (inches) DS < 8	DH 6–12	DH 12–18	LCD 8–12	LBTL 12–18	LBTL > 18	Hollow > 24
European starling (*Sturnus vulgaris*)			N	R			2	2			2	
Little brown myotis (*Myotis lucifugus*)				R								2
Keen's myotis (*Myotis keenii*)				R				2			2	
Indiana myotis (*Myotis sodalis*)				R				2				2
Silver-haired bat (*Lasionycteris noctivagans*)				R							2	2
Big brown bat (*Eptesicus fuscus*)				R								2
Gray squirrel (*Sciurus carolinensis*)					D						2	2
Red squirrel (*Tamiasciurus hudsonicus*)					D						2	2
Southern flying squirrel (*Glaucomys volans*)					D		2		2	2	2	2
Northern flying squirrel (*Glaucomys sabrinus*)					D		2		2	2	2	2
Porcupine (*Erethizon dorsatum*)					D						2	2
Gray fox (*Urocyon cinereoargenteus*)					D							2
Black bear (*Ursus americanus*)					D							2
Raccoon (*Procyon lotor*)					D							2
Marten (*Martes americana*)					D						2	2
Fisher (*Martes pennanti*)					D						2	2
Ermine (*Mustela erminea*)					D		2		2	2	2	2
Long-tailed weasel (*Mustela frenata*)					D						2	2

[a] P—perching
F—foraging
N—nesting
R—roosting
D—denning

[b] DS—Dead, soft
DH—Dead, hard
LCD—Live, central decay
LBTL—Live, broken tops and limbs

[c] 1 = primary cavity excavators
2 = secondary cavity user

Table 2.—Estimates of large-diameter cavity/den tree densities per acre required to provide cavity/den sites[a] for viable populations of cavity-dwelling wildlife species

Author	Geographic area	Minimum stem size (d.b.h.)	No. stems per acre	Basal area[b]
		Inches		*ft²/acre*
DeGraaf (1984)[c]	Northeast	≥24	0.02	0.099
		18–24	0.2	0.486
			0.22	0.585
Evans and Conner (1979)[c]	Northeast	≥18	0.24	0.584
Conner et al. (1983)[c]	Texas	≥18	0.5	1.216
Thomas et al. (1979)[c]	Northwest	≥20	0.14	0.34
Titus (1983)[d]	Missouri	>19	1.0	2.432
Range			0.14–1.0	0.34–2.432

[a] Foraging needs of cavity-dwelling species will be incomplete with these density estimates.
[b] Calculations assume an average of 2.432 ft^2/acre for the 18–24″ d.b.h. range and 4.948 ft^2/acre for the 26–34″ d.b.h. range.
[c] Large-diameter estimates for woodpeckers only.
[d] Large-diameter estimates for cavity-dwelling birds and mammals in forested situations.

Rotation Length and Cutting Cycle. The time between harvests (rotations or cutting cycles) affects the size of trees in stands, tree species composition, and seed-bearing potential. The availability of large-diameter trees is especially affected by rotation length and cutting-cycle length. These factors can combine to reduce the availability of cavities, foraging sites, and mast production under current management conditions. Short rotations (<60 years) under normal management produce few large-diameter cavity trees. Rotations of 65 to 100 years could be expected to produce some smaller diameter cavity trees and probably would support populations of most cavity-dwelling species, but not the largest cavity dwellers. Rotations longer than 110 years can be expected to produce sufficient amounts of this habitat element and support populations of large cavity- or den-dwelling species, though not necessarily at maximum population levels.

Longer cutting cycles or periods between subsequent stand entries (>15 years) increase the availability of cavities and foraging habitat (Fig. 2) in managed stands (Crow et al. 1981). Short cutting cycles (5 to 10 years) minimize growth loss from mortality.

Stand Area. Opportunities to juxtapose cavity sites and foraging habitat adjacent to proposed final harvest areas decrease with shorter rotation lengths and increasing stand area (Fig. 3). Small stands (<30 acres) present more opportunities to intersperse habitat in desired patterns and combinations across a management area than large areas. The size and configuration of ecological sites, timber values, rotation lengths, and cutting cycles, govern the size of the cutting area.

Tree Condition Requirements. Tree species' longevity, rates and characteristics of rot, growing space requirements, and lumber value influence the suitability and length of time that trees will be available as a wildlife habitat element.

Obviously, the inherent longevity of tree species influences the length of time that tree habitat can be maintained. Other things being equal, a defective eastern hemlock will exist for many decades while a defective black cherry will be present for only a short time. However, a black cherry left for mast after thinning a sapling northern hardwood stand will be of value through the pole stage of the stand while an eastern hemlock left as cover, for nesting sites or potential cavities can live for several centuries if needed. Where choices are available and length of time of existence is important, eastern hemlock is the most long-lived associated species followed by red spruce, sugar maple, yellow birch, beech, white ash, red oak, red maple, white birch, aspen, and black cherry.

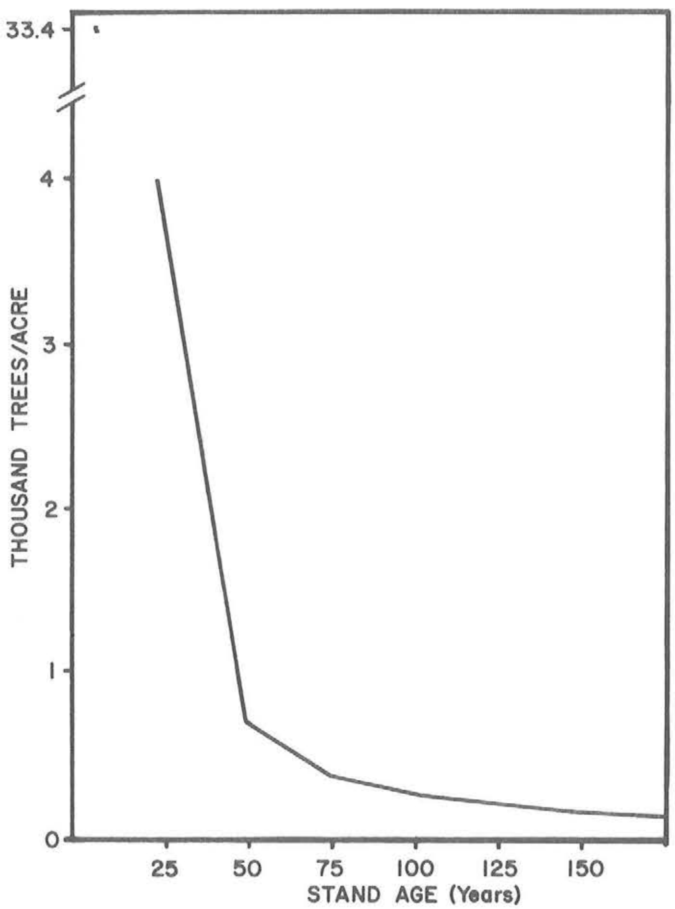

Figure 1.—Mortality over time in unmanaged even-aged northern hardwood stands (from Marquis 1967 and Leak et al. 1969).

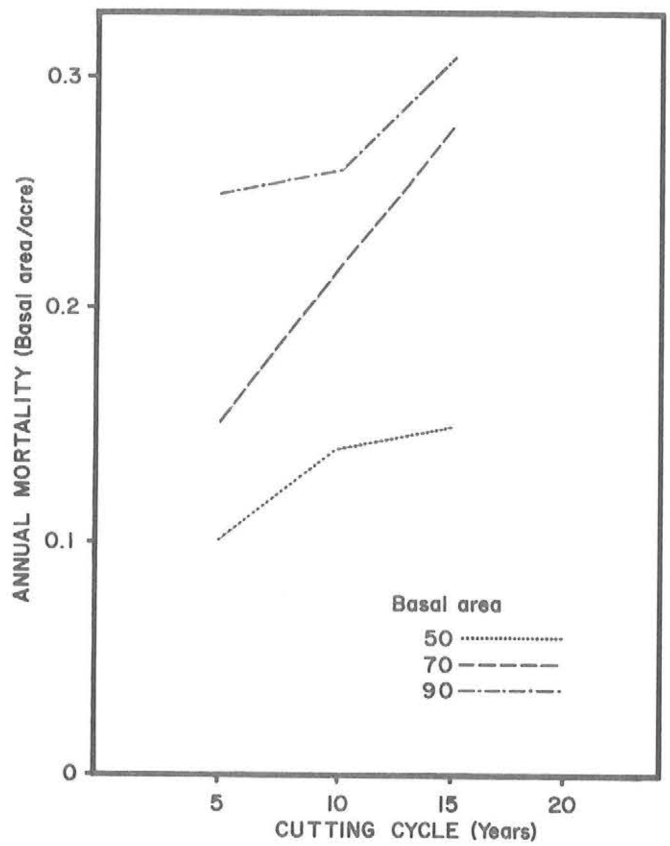

Figure 2.—Average annual mortality (square feet per acre) by cutting cycle length at 50, 70, and 90 square feet per acre residual stocking levels (from Crow et al. 1981).

Assessing the potential for both live sound trees and standing dead trees for cavities, and the length of time the trees will be suitable for cavity dwellers requires an estimate of the tree species rotting characteristics. Scattered sound aspen and paper birch left after a clearcut will ordinarily become highly defective before the surrounding stand reaches pole size while a sugar maple left in similar circumstances will not become more defective than its present condition would dictate in the same time period. On the other hand, defective aspen will rot quickly and the forest manager can expect that such trees will lose present characteristics quickly. Rot in conifers (except for balsam fir) is less prevalent than in hardwoods, so leaving red maple in mixed conifer-hardwood stands will provide potential cavity sites because even sound red maple in such situations frequently will become defective before reaching sawlog size. The following list should be useful in identifying opportunities and evaluating alternatives for cavity sites.

Red maple rots faster than paper birch, yellow birch, basswood, white ash, beech, black cherry, elm, sugar maple, oaks. The aspens probably rot more rapidly than any hardwood species growing on northern hardwood sites. Among conifers encountered in hardwood areas, balsam fir rots faster than spruce, white pine, and eastern hemlock.

Windfirmness is another important characteristic of individual trees to be a part of the landscape for long periods especially those left after heavy cutting. Windfirmness is determined by site and tree characteristics. Conifers are shallow-rooted and, except for white pine, windthrow easily when exposed. Hardwoods windthrow most easily on shallow sites; tap rooted species such as beech, the oaks, red

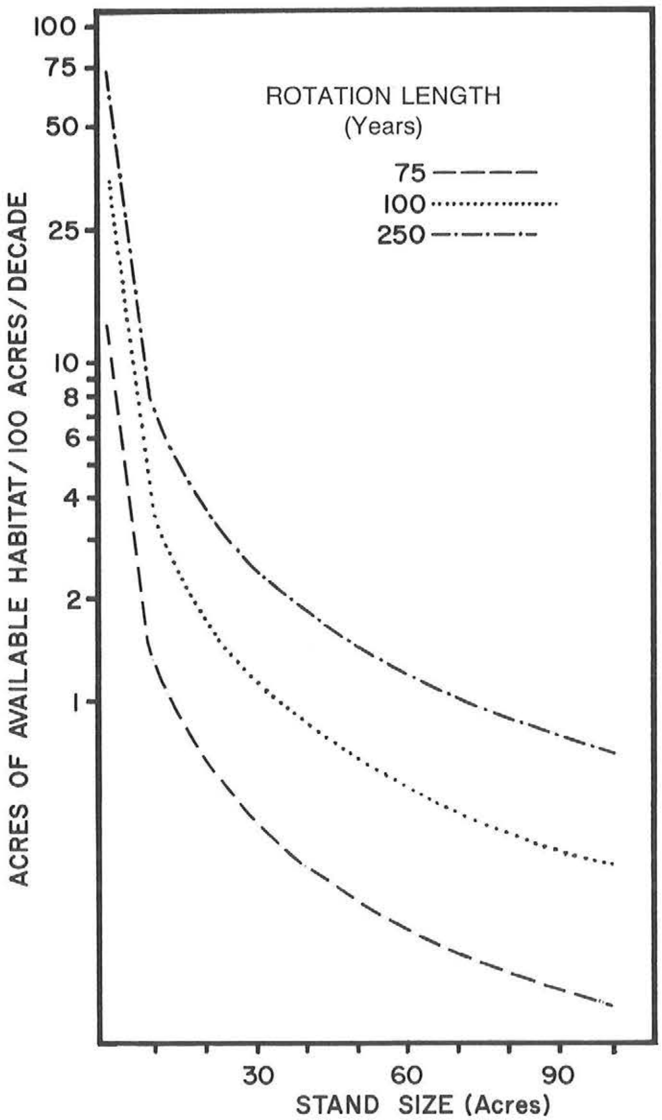

Figure 3.—Relationship between average stand size and percentage of area in suitable habitat conditions for selected rotation lengths of 75, 100, and 250 years.

maple (on deep soils), and aspens usually break off rather than windthrow. Loss of live trees can be minimized by leaving trees with greater than average stem taper, a characteristic that reflects good root systems. Consider the following conditions to identify sites and trees that are windfirm.

- In rough terrain, accelerated winds funnel through saddles, over ridges, and along stand borders that parallel storm directions. Wind damage is frequently greatest on the leeward side of clearcuts where the wind has the greatest force and turbulence.
- Trees on soils that promote shallow rooting are susceptible to windthrow (this includes soils shallow to bedrock, soils with high water tables, and soils with fragipans and hardpans near the soil surface).
- Shallow-rooted tree species are most susceptible to windthrow.
- Individual trees with butt rot and shallow root systems characterized by smaller than normal crowns are susceptible to windthrow.
- The most windfirm trees are young with well-developed crowns showing signs of free-to-grow conditions (long crowns and sharply tapering stems).
- Site is the more important characteristic, so choose windfirm sites first, then windfirm trees.

Using Cull Classes to Choose Potential Cavity Trees

Cull-class estimation can characterize both the wildlife habitat potential of cavity trees and the wood volume lost to cavity habitat production. Estimating cull volume affords the landowner or manager a choice of possible least-cost alternatives for providing cavities in northern hardwood stands.

Major visible defects such as butt rot, large holes, cracks, rotten burls, broken and dead limbs, and broken or dead tops are important indicators of potential cavity and foraging sites. More hardwood stems are rotten cull than are softwood stems of similar size (Fig. 4), and the frequency of rotten cull stems increases with stem diameter for both hardwoods and softwoods, though at different rates (Kingsley 1976).

The cull class estimation procedures of Zillgitt and Gevorkiantz (1946) can be modified to meet the present needs of wildlife biologists and foresters who need to identify and subsequently provide suitable and sufficient cavity-dwelling habitat in northern hardwood stands (Appendix I). Cull classes 3 and 4 sawlog-size trees can provide potential cavity sites in managed stands. For example, hardwood trees with two major defects (cull class 3) left in clearcuts and shelterwood cuts can provide cavities and foraging substrates for species that nest and feed in the open while a new stand is developing. If left when the residual overstory is removed, trees of longer lived species with slow rot development could continue to grow and provide suitable sites until the first thinning and still have some lumber value. Hardwood trees with three or more major

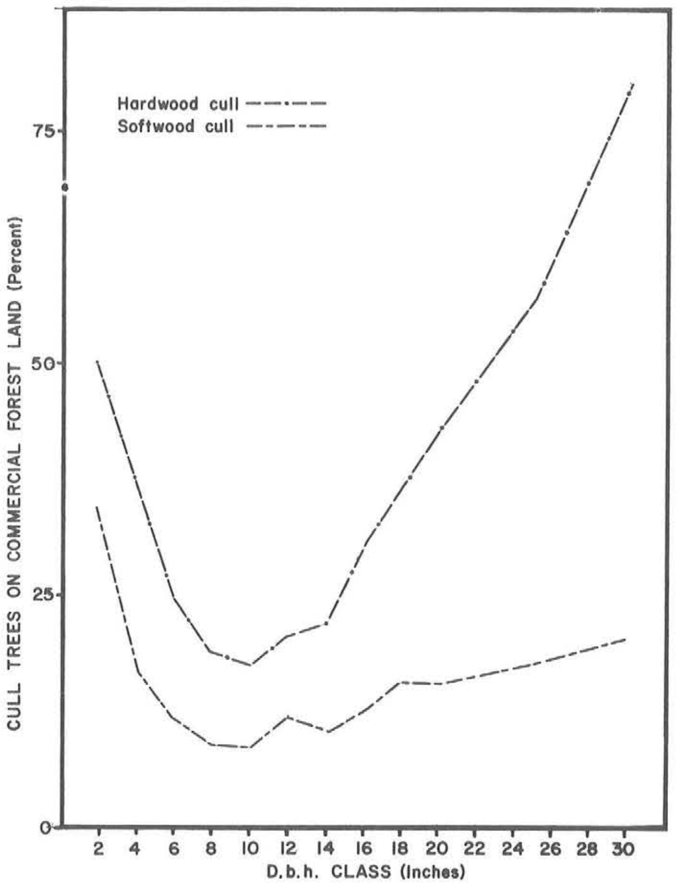

Figure 4.—Percentage of trees classified as rough and rotten (> 50 percent rotten cull of noncommercial species) on commercial forest land, New Hampshire (from Kingsley 1976).

defects (cull class 4) provide the highest probability of cavity use in live trees, but have limited lumber value. If left following an overstory removal, such large-diameter trees would have little effect on stand regeneration until the pole stage, if they have a high crown base.

The cull classification system was developed for sugar maple but can be used for other hardwood species. This method was developed for cruising sawlog stands and is most accurate in estimating cull volumes when 40 or 50 trees are averaged together. Sound cull factors (sweep and crook) should be disregarded when choosing wildlife cavity trees. Rot in such wildlife trees will be underestimated because this technique only estimates rot in bole sections suitable for sawlogs and cordwood. However, markers of wildlife trees are interested primarily in the probability of both present and future wildlife tree use. The classification of defects, together with a marker's judgment, can allow a quick estimation of probable use, in addition to estimations of present and future value, as wildlife habitat and lumber.

For example, a large hole is associated with rot of at least one-third the log volume in which it occurs—a log 14 inches in diameter at the small end, with such a hole has about 7 cubic feet of rot, which is ample den or nest space for a variety of wildlife species. By comparison, a similar defect in a log 8 inches at the small end contain only 2 cubic feet of rot and a low probability of wildlife use. As the tree increases in size though, the probability of future wildlife use would increase.

Broken and dead tops are common in large hardwoods and, although the cull associated with them may have a minor effect on lumber value, the top can be used by cavity nesters or as a source of food for woodpeckers and other insectivorous birds. Dead limbs over 6 inches in diameter can be associated with as much as 20 percent rot and, in large logs, present a relatively large area for use by wildlife. Such a defect is associated with about 4 cubic feet of rot in a 14-inch log, and thus creates the potential for a cavity of that size. Multiple defects increase the amount of rot beyond that obtained by simply adding the defect volumes or percentages together—a large hole, broken top, and a large dead limb indicate about 60 percent of the tree volume is rotten and potentially suitable for wildlife.

How Much Will It Cost?

Foresters want to know how much it will cost and what the returns will be to include wildlife habitat management with timber management. The next sections present some simple methods and rules-of-thumb for assessing the impact of leaving individual wildlife trees. Tables 1 and 3 describe wildlife use of specific habitat conditions and permit a choice of the most effective means of maintaining or increasing wildlife habitat for the life of a forest management plan. In many instances, the cost of providing habitat is only the planning time, and the returns may include timber harvesting on hitherto unmanaged properties owned for recreation or wildlife.

Effect on Lumber Value. Cavities obviously represent a loss of timber volume when they occur in merchantable stems. The management goal is to provide trees suitable for wood products using silvicultural modifications to meet the needs of wildlife that utilize tree cavities.

Table 3.—New England wildlife species using flower buds, fruits and seeds and hard mast (adapted from DeGraaf and Rudis 1986)

Common Name	Flower buds	Fruits/Seeds	Hard mast
Wood duck			1
American black duck			1
Mallard			1
Ruffed grouse	1	1	1
Wild turkey		1	1
Mourning dove		1	
Black-billed cuckoo		1	
Yellow-billed cuckoo		1	
Red-headed woodpecker			1
Red-bellied woodpecker			1
Yellow-bellied sapsucker		1	
Hairy woodpecker		1	1
N. flicker		1	
E. phoebe		1	
E. kingbird		1	
Tree swallow		1	
Gray jay	1	1	
Blue jay		1	1
American crow		1	1
Black-capped chickadee		1	
Boreal chickadee		1	
Tufted titmouse		1	1
Red-breasted nuthatch		1	
White-breasted nuthatch		1	1
Brown creeper		1	1
Ruby-crowned kinglet		1	
E. bluebird		1	
Veery		1	
Gray-cheeked thrush		1	
Swainson's thrush		1	
Hermit thrush		1	
Wood thrush		1	
American robin		1	
Gray catbird		1	
N. mockingbird		1	
Brown thrasher		1	1
Bohemian waxwing		1	
Cedar waxwing		1	
European starling		1	
White-eyed vireo		1	
Solitary vireo		1	
Philadelphia vireo		1	
Blue-winged warbler	1		
Golden-winged warbler	1		
Tennessee warbler	1		
Northern parula	1		
Yellow warbler	1		
Chestnut-sided warbler	1		

Continued

Table 3.—Continued

Common Name	Flower buds	Fruits/Seeds	Hard mast
Magnolia warbler	1		
Black-throated blue warbler	1		
Yellow-rumped warbler	1	1	
Black-throated green warbler	1	1	
Prairie warbler			
Pine warbler	1	1	
Palm warbler	1		
Blackpoll warbler		1	
American redstart	1	1	
Wilson's warbler	1		
Yellow-breasted chat		1	
Scarlet tanager	1	1	
N. cardinal		1	
Rose-breasted grosbeak		1	
Rufous-sided towhee		1	1
American tree sparrow		1	
Chipping sparrow		1	
Fox sparrow		1	
Song sparrow		1	
White-throated sparrow		1	
Dark-eyed junco		1	
Common grackle		1	1
Orchard oriole	1	1	
N. oriole	1	1	
Pine grosbeak	1	1	
Purple finch		1	
Red crossbill	1	1	
White-winged crossbill		1	
Common redpoll		1	
Hoary redpoll		1	
Pine siskin	1	1	
America goldfinch		1	
Evening grosbeak	1	1	
Virginia opossum			1
E. chipmunk		1	1
Gray squirrel	1	1	1
Red squirrel	1	1	1
S. flying squirrel		1	1
N. flying squirrel	1	1	1
Deer mouse		1	1
White-footed mouse		1	1
S. red-backed vole		1	1
Woodland vole		1	1
Meadow jumping mouse		1	1
Woodland jumping mouse		1	
Porcupine		1	1
Coyote		1	1
Red fox		1	1
Gray fox		1	1
Black bear		1	1

Continued

Table 3.—Continued

Common Name	Flower buds	Fruits/Seeds	Hard mast
Raccoon	1	1	1
Fisher		1	
Striped skunk	1	1	1
White-tailed deer		1	1
Moose		1	

As an example of the timber value involved in leaving line trees with cull, assume that an 18-inch sugar maple in cull class 3 (two major defects) with a grade 3 butt log will be left for 20 years. The gross board-foot volume is 300, and the stumpage value is $50/M bf. The present value of the net volume (195 board feet) is $9.75. In 20 years, the tree will have grown 3.3 inches in diameter and the gross volume will be 471 board feet, the net volume will be 305 board feet, and its value at present prices will be $15.25. The net gain is $5.50, which equals an annual interest rate of 2 percent. Judgment is required in making estimates of value growth. Trees left in the open, as in a clearcut, will grow faster than those left in a stand. In stands, short cutting cycles improve diameter growth but residual-stocking density affects diameter growth as well. Changes in tree or log grades must also be taken into account.

Effects on the Surrounding Stand. The effects of live trees that are left depends on the type of tree. Wolf trees suppress reproduction in a circle around them with a radius of about 1 foot for each inch of diameter (approximately the crown-stem ratio for most sawlog-size hardwoods). Conifers and small-crowned hardwoods, such as ash and basswood, suppress reproduction over an area of 1/2 to 1/3 less than other hardwoods of equal d.b.h., while beech have wider than average crowns and the ratio of this species can be 1.3 feet per diameter inch. However, trees with main crowns 20 or more feet above the ground have little effect until regeneration is in the sapling stage. The average height of crown base in forest grown hardwoods is about 50 percent of the total height of the tree; so, the effect on regeneration can be minimized further by leaving tall trees. Hardwoods over 19 inches d.b.h. are usually 80 to 110 feet high; single trees of this size may begin to suppress height growth only after the new stand reaches pole size. Even so, the spacing after the first thinning in pole stands is not less than 15 feet so that the number of affected trees in the new stand will be small, and the effect on them also will be small.

The competitive effect of one tree on another in even-aged stands is generally in direct proportion to the ratio of the tree basal area to stand basal area. In uneven-aged stands, the relationship is more complex, but, in general, leaving trees in large size classes has the greatest effect. For example, a 5-inch d.b.h. tree represents less than 0.2 percent of a stand of 70 square feet per acre, and 10 trees of this size would represent about 1 percent of the basal area per acre so leaving them will have negligible effect on growth or yield. For this reason, in uneven-aged stands, trees less than 5 inches d.b.h. are generally disregarded. However, a single 20-inch tree represents about 3 percent of the basal area of an even-aged stand that is 70 square feet per acre. In a well managed uneven-aged stand, a single 20-inch tree may represent 10 percent of the next harvest; but adding two trees to the large sawlog class of uneven-aged stands will not measurably affect growth or yields in stands close to recommended stocking and cutting cycles. When trees approach 30 inches d.b.h., other factors become important. Such large trees may cause substantial logging damage to adjacent stems when they are removed or may degrade surrounding trees from excessive opening of the stand.

Generally, leaving trees that would increase the total residual stand by 10 to 15 square feet will not have a measurable effect on gross timber yields. In uneven-aged stands, leaving 20 percent more basal area in any one size class (poles, small, medium, and large sawlogs), so long as the total does not exceed 10 or 15 square feet per acre for the stand, also will not affect gross timber yields. Obviously, in any stand, a tree may adversely affect an adjacent stem of exceptional timber value, and this may outweigh the value of the wildlife tree. Equally obvious is that this number of trees cannot be added in each succeeding cutting or thinning cycle because the stand will eventually become unmanageable through the presence of excessive cull.

Biology of Seed Production

The object of seed production is to increase the variety and quantity of seeds and nuts eaten by over 90 wildlife species in the Northeast. Some of the species depend heavily on seed while others utilize seed as a nutritious addition to their diet.

In general, forest-grown hardwoods do not begin to produce seed until the trees are several decades old. However, it is possible to encourage seed production at early ages and to increase the total amounts of seed produced per tree and unit area.

Although specific information about seed production is lacking for many northern hardwood species, some general principles are available that are useful both for timber and wildlife management:

- Large trees produce more seed than small trees.

- Fully exposed tree crowns offer the potential for the greatest production (Matthews 1963). The most seed is produced on the exposed portion of the crown. Understory trees produce few flowers or seed, and in fully stocked even-aged stands, seed is only produced on the tops of tree crowns. Many confiers produce seed primarily in the upper portion of the crown regardless of exposure.

- Individual trees vary in their seed production potential. Species such as white ash and aspens are dioecious (that is, male flowers on one tree and female flowers on another) and only the females will produce seed. Monoecious species (those that have both male and female flowers on the same tree) have varying degrees of maleness and femaleness, for example, red and sugar maples. Within a stand, a few individual trees produce seed frequently while others produce only at lengthy intervals as a result of genetic control or location in the stand. Species vary in seed production potential. For example, the interval between good black ash (*Fraxinus nigra*) seed production may be as long as 8 years, while quaking aspen has good production nearly every year. Stands of trees of the same species vary in the amount of seed produced annually with variations in climatic conditions, species biology, and site.

- Northern hardwood species have the potential for seed bearing every year.

- Trees are most seed productive at mid-age. Balsam fir, aspen, and white birch are relatively short-lived species whose average maximum life span is less than 75 years on most forest sites. White pine, red spruce, eastern hemlock, sugar maple, beech, and yellow birch live for 200 to 300 years on the average and individuals may survive for much longer.

- A number of species produce male catkins that are sought by some wildlife species. White and yellow birches, aspens, hazels (*Corylus* spp.), and alders (*Alnus* spp.) are common catkin-producing species.

- In stands of northern hardwoods, seed production increases as average diameter and average basal area per acre increase. Dense stands of large trees can produce twice the number of seeds as stands whose largest trees are of moderate size (less than 20 inches d.b.h.) and stocking (less than 70 square feet per acre) (Eyre and Zillgitt 1953). Mortality of overstory trees may be excessive when stands are dense and maximum tree size is large. Beech mortality is great when d.b.h. is over 18 inches and stocking of sawlogs is over 60 square feet per acre but sugar maple stands may have in excess of 90 square feet per acre in sawlog-size trees before mortality becomes excessive.

Species Characteristics

American beech is the most common nut-bearing species in northern hardwoods. Forest-grown trees seldom begin to bear seed until 5 to 8 inches d.b.h. and large crops are borne by sawlog-size dominant trees. However, when exposed, large saplings (3 to 4 inches d.b.h.) bear some seed. In a good seed year, over half the beech will bear good crops, and most overstory trees (>80 percent) will bear some seed. Seed failures in stands are common, but failures over large areas are uncommon.

Forest-grown sugar maple begin bearing some seed in even-aged stands when 5 inches d.b.h., but the largest crops are borne by sawlog-size dominant trees. Fully exposed trees with full crowns produce seed prolifically and steadily. Red maple sprout growth can bear seed as early as 6 years of age. Failure to produce some seeds in stands is uncommon.

Yellow and white birch develop male catkins in the fall and are capable of producing viable seed in the seedling-sapling stage. Sapling-size (2 to 4 inches d.b.h.) birch, fully exposed, are capable of producing large crops of seed. Sawlog-size yellow birch produce high amounts of both catkins and seed. White birch is most productive of catkins and seed at large pole through small sawlog sizes on average or poorer sites.

Eastern hemlock and white cedar (*Thuja occidentalis*) are the most prolific seed producers among common conifers followed by balsam fir, the spruces, and white pine, which is the most sporadic producer. Conifers with exposed crowns bear seed at early ages and small sizes.

The small trees—ironwood (*Ostrya virginiana*), pin cherry (*Prunus pensylvanica*), chokecherry (*P. virginiana*), and striped maple (*Acer pensylvanicum*)—bear good seed crops when sapling size or smaller if exposed to direct sunlight, as do shrubs such as hobblebush (*Viburnum alnifolium*), and beaked hazel (*Corylus cornuta*). Raspberry and blackberry (*Rubus* spp.) bushes bear small crops under closed overstories and large crops in full sunlight. The effect of overstory density may be decreased when overstories are composed of species with thin foliaged crowns such as the aspens, birches, and ashes.

Red maple and elm (*Ulmus* spp.) seed ripens in the spring, and the seed of these species usually germinates soon after falling. Most other species produce seed that ripens in the fall and lies over winter before germinating in the spring. Yellow birch, basswood, and hemlock retain some seed in the crown over the winter months. Ash, basswood, and cherry seeds will remain for 2 years (ash and basswood) to many years (cherries) in the duff.

Identification of Individual Trees With Steady Seed-Production Potential

The literature suggests that individual hardwood trees with relatively steady production will have rounded crowns. This should be especially true of sugar and striped maple, each of whose reproductive biology and branch structure results in the forking of seed-bearing branches. A number of environmental factors can influence crown shape, however, so the first criteria are large size and moderate age, followed by crown condition; that is, trees with full, rounded crowns are likely to be the best; trees with extremely spreading crowns or trees with shorter than average crowns may produce less seed. Trees with less desirable attributes can be improved by cultural practice when trees are of moderate or young age.

Choosing The Number of Trees

Trees isolated from their own species may not bear seed as steadily or prolifically as when growing in groups of the same species. Often, location of flowers and the timing of flowering in the crown reduces self-pollination and wind currents or insect activity may not be suitable for the transmission of pollen within a crown. Most pollen is deposited within 50 to 100 feet from a tree so that the chance of substantial amounts of pollination among trees beyond this distance is slim. Variations in the maleness or femaleness of trees and the location of trees with respect to microclimatic factors such as spring frost frequency also lead to variable seed production.

Trees to be released for seed production should be in stands containing several individuals of the same species. Trees spaced at more than 150 feet apart in forest stands have little probability of pollination and good seed production. There should be more than three regularly spaced trees per acre to ensure seed production. On the other hand, having the same number of trees in a group will increase the chance of good seed production. Groups of individuals of the same species are common because species occurrence is often related to soil conditions or patterns of disturbance. For example, spruces, firs, or hemlocks may line a water course through a stand of hardwoods, or hardwoods may be numerous on the better drained portion of a spruce-fir area; beech or red oaks may occupy warm, dry exposures or inclusions of coarse soil.

Because years with good seed production by all species are uncommon, mixtures of species should increase the probability of some seed production every year. For example, mixtures of red and white oaks and beech should result in nut production nearly every year.

Increasing Seed Production of Individual Trees and Small Groups of Trees. The goal is to promote maximum crown development and maintain full light in the upper half of the crown. Trees should be crown-thinned so that the tree is free to grow vertically, and the crown can expand horizontally and receive full light in at least the upper portion of the crown. Crown-thinning that removes trees whose crowns are overtopping or within a foot or so of the crowns of the hardwood tree to be released will provide growing space for a substantial time, perhaps 20 years for sawlog-sized trees. Conifers need much less space because the crowns are narrower and, except for eastern hemlock, produce most seed in the crown top regardless of degree of exposure to the rest of the crown. Thinning to release conifer crowns in hardwood stands should remove overtopping trees and/or the two or three most severely competing trees. Conifers in conifer stands or stands of narrow-crowned hardwood such as basswood or ash can be crown-thinned. Groups of two to four trees can be considered as a single tree if all crowns would benefit by thinning trees of other species around the group. If a tree's crown cannot be expanded on at least three sides, however, it may not contribute much seed and may reduce the productivity of other trees through shading or crowding.

Long-lived species such as eastern hemlock, red spruce, white pine, sugar maple, yellow birch, and beech continue to bear appreciable amounts of seed until the trees are several hundred years old. On the other hand, seed production of shorter lived species such as red oak, balsam fir, white birch, and the aspens drops off quickly at young ages and smaller sizes. In some areas, red oak seed production declines in trees larger than 20 inches d.b.h. Other oak species continue to increase seed production with increasing tree size up to 25 inches d.b.h. at least. Judgment is required in thinning because of the endless variation in stocking, species frequency, size classes, and thinning schedules.

The following suggestions will help in treating trees for mast production:

- Release codominant or smaller hardwood stems by crown-thinning on at least three sides.
- Do not, unless special circumstances[2] warrant, treat beech over 18 inches d.b.h. in the beech-*Nectria* zone, or red oak over 20 inches d.b.h., or shorter lived species such as white birch or balsam fir over 10 inches. Such trees may be retained for other wildlife values (cavities) or timber uses. Release conifers by removing the two or three most severe competitors.
- Release small trees and shrubs, such as hawthorn, alder, hazel, elderberry, striped and mountain maple, eastern hophornbeam, juneberry, and flowering dogwood by removing overtopping trees and those trees that will overtop before the next thinning cycle.

Heavy thinning increases the total amount of seed produced per tree. However, loss of quality in oak species especially and in surrounding trees is a result of heavy crown-thinning. Removing overtopping trees and one or two of the most severe competing trees will allow crown development, good growth, maintenance of the species in the stand, and reduce quality loss. Heavy thinning is more appropriate for the less tolerant species though very open birch may be seriously damaged by sapsuckers and be subject to insect attack.

Epicormic sprouting after heavy thinning in sawlog stands is greatest on oaks and birches. Reduce epicormic sprouting by heavily thinning only those trees with well-developed crowns. Sawlog-size sugar maple usually sprouts only in the crown; so, heavy or frequent thinning in sawlog stands has little effect on present quality. Crowns will be set, however, and further increases in merchantable length will be slow or will cease. Severe damage to crowns results in epicormic sprouting of all species.

Quality and merchantability loss following heavy thinning will be greater in the tolerant hardwoods, sugar maple and beech, than in other northern hardwood species. Heavy sapling thinning will have more effect on merchantability than will heavy thinning in poles. Avoid thinning in sapling stands of tolerant hardwoods to reduce adverse impact on timber quality, but consider thinning along permanent openings; that is, roads, streams, marsh edges, and log landings.

[2] Special circumstances that may occur include the use of the tree for purposes other than seed production; that is, den or nesting tree, shelter, or esthetic purposes.

Lengthening the time that a tree or group of trees remain in the stand will increase seed production and the size and quality of trees harvested, but net volumes will be reduced. On the other hand, gains in diameter growth from early and frequent thinning will tend to reduce rotation lengths. Some increase in the development of a tolerant understory will occur with frequent or heavy thinning.

Yellow birch, a species of intermediate tolerance, is somewhat adversely affected by heavy thinning throughout a rotation. Heavy thinning in the sapling stage produces misshapen trees and high mortality on some sites. Heavy thinning in pole and sawlog stands produces epicormic sprouts a few feet below the crown, reducing upper log quality and merchantability to a degree, but value reduction is slight.

Timber quality of white birch and aspen are least affected by heavy thinning at any size class.

Silviculture

Northern hardwood forests are managed for timber products under either even-age or uneven-age silvicultural systems. The availability of wildlife trees in managed forests is restrained by: the type of management or silvicultural system, which affects species composition and the distribution of tree sizes; the intensity of management, which affects the number of trees, logs, and slash suitable for wildlife; the stage of development of stands, which affects the size of trees available; the site, which affects tree and shrub species composition, and, as discussed previously, timber goals that influence the size of harvested area and final size of tree.

Providing wildlife trees in common timber management situations requires a knowledge of the consequences of management as well as planning ahead. Wildlife tree management can also include the use of silvicultural techniques to enhance and maintain desirable wildlife qualities of trees and to increase the time of their usefulness. It is well to note that on larger properties, both even-age and uneven-age silviculture will be needed to achieve or maintain the full range of community diversity.

Regenerating Even-aged Stands

Clearcutting. Clearcutting in northern hardwoods in the Northeast provides a mixture of long-lived tolerant and shorter lived intolerant tree species. The relative proportions of species change with clearcut size; clearcuts of 20 acres or more produce conditions for large proportions of intolerants while patches or narrow strips produce more moderately tolerant and tolerant species than intolerant tree species. All trees over 1 or 2 inches d.b.h. are removed or killed in clearcutting in intensive management.

Regenerating stands by clearcutting is an important aspect of wildlife habitat management in New England. Clearcutting alters the mix of habitat elements. Cavity trees and overstory mast production are eliminated. But, as clearcuts grow through the seedling stage, they provide the highest levels of forage, understory mast, and woody stem density in the northern hardwood forests. The forage and woody cover provided in regenerating stands are essential to maintain populations of ruffed grouse, snowshoe hare, and New England cottontail. Small mammals are more abundant in seedling stands than in other northern hardwoods, and part of the bird community occurs only in regenerating stands. Clearcutting is also important for the long-term production of share intolerant trees such as aspen, pin cherry, black cherry, and red oak, which are heavily used by wildlife. So, clearcutting is an important tool for maintaining plant and animal diversity in northern hardwoods.

More wildlife species can be attracted to clearcuts by leaving a few trees for cavities, mast, and perches. Assessing the probability of mortality is necessary when deciding which trees to leave for wildlife in clearcuts.

Conifers, in general, present a large surface for wind pressure all year long in contrast to hardwoods that are less subject to windthrow after leaf fall. In addition, eastern hemlock is especially sensitive to high soil temperatures and exposure. Consequently, individual conifers to be left should be windfirm. While small-crowned conifers may present less surface than those with large crowns, the latter trees have better root systems. Several stems left in a group will help ensure survival; root grafting is common, and although not predictable, leaving a group may add to the probability of windfirmness. The space occupied by two or three conifers is roughly equal to that of a hardwood of equal diameter (Appendix II). Dead snags of white pine remain standing for decades, but other conifer snags are relatively short-lived.

Balsam fir and large eastern hemlock often die after exposure; pole-size and larger hemlock and spruce should have well-developed crowns and no indications of advanced age.

Leaving trees on the windward side of clearcuts away from shallow soils, ridges, and saddles will help avoid windthrow. Leaving trees with open-grown characteristics on deep soils will also add to windfirmness. Because it will not be possible to fulfill all these requirements, compromises should favor windfirm topographical positions and then windfirm tree characteristics.

Hardwood saplings or poles left in clearcuts usually develop into wolf trees—the crown area tables (Appendix II) aid in calculating the area in which reproduction will be suppressed. The small trees, striped maple, mountain maple (*Acer spicatum*), and ironwood, generally live until the small sawlog stage. Sapling and pole-size beech and sugar maple survive clearcutting well. Sapling and pole-size trees of less tolerant species that have developed in mature stands may die or fail to develop after clearcutting. Red oak, paper birch, and yellow birch fall into this category.

Birches, when left exposed as sawlog-size trees, usually die within a few years, especially on poorer sites: shallow, wet, or coarse-textured soils. Sawlog-size beech will have a short existence if infected by *Nectria*-scale. Sawlog-size sugar maple survives well if windfirm and if the defects are not conducive to breakage by wind: sugar maple borer galleries, *Utipella* canker, root rot, and V-shaped forks. Oak species are generally windfirm. Snags of yellow birch and sugar maple last for several decades.

Some timber advantage may be gained by leaving windfirm sugar maples or well-formed vigorous red maple and smaller ash until the first commerical thinning in poles because such trees will produce sawlog material that may make sales more attractive.

Leaving aspen stems of any size will reduce root suckering. Aspen stems left after cutting normally deteriorate quickly, but remain alive for fairly long periods unless diseased. Whether the value to wildlife would be enhanced more by leaving aspen stubs or by increasing the amount of aspen reproduction by cutting all aspen stems during clearcutting depends on the wildlife goals for the area and local situation. For example, clearcutting a mature beech-red maple stand on a coarse-textured soil would result in a small aspen component in the regeneration stand; other tree species could provide foraging, perching, cavities, and so on. On the other hand, when clearcutting stands containing substantial numbers of aspens, it may be desirable to leave a few live ones to fulfill wildlife tree-habitat requirements.

Shelterwood. Shelterwood harvests commonly leave 30 to 50 percent crown cover over areas to be reproduced with white or yellow birch; 50 percent crown cover over advanced tolerant regeneration; or 70 percent crown cover over areas to be regenerated to tolerant species in stands that have inadequate advanced regeneration. Generally, the first two crown-cover levels are associated with two-cut shelterwoods whose overstories will be removed in 10 years or less. The latter crown cover—70 percent—usually is used as the first step in three-cut shelterwoods.

Many opportunities exist within this system to provide trees for wildlife purposes. Trees may remain for up to 20 years without altering the even-aged character of the next stand. The timber management functions of the shelterwood overstory are to provide uniform high shade and seed. Consequently, the trees in the overstory are chosen on the basis of spacing and height rather than timber characteristics. Although the cutting is generally from below, normal timber practice leaves thickets of saplings or poles where they are extensive enough to form a stand.

Wildlife trees left in the overstory after the first cut are constrained only by spacing and cover requirements for the regeneration objective; numbers and characteristics of wildlife trees left after the removal cut should follow the recommendations for clearcutting.

Except for shallow or wet sites, windfirmness is less of a consideration in the heavier shelterwood overstories than in clearcuts because extremes in wind, soil temperatures, and moisture are moderated. However, the same characteristics for leaving conifers should be considered in this practice as in clearcuts. Leaving saplings and small poles of tree species in the understory of a shelterwood has the same influence on reproduction as when they are left in clearcuts. Small trees (striped maple, ironwood) and tolerant shrubs (hobblebush, elderberry) compete well with tree species under the lighter shelterwood overstories.

The final removal cut can leave live trees for the period ranging from reproduction to the first commercial thinning in pole stands. The species most likely to survive for this relatively long time are sugar maple, the oaks, and white pine. Larger trees with considerable clear length (high crown bases) will have the least influence on the surrounding stand.

Tending Stands. Tending even-aged stands includes thinning and timber stand improvement practices, which are done at 10- to 20- year intervals beginning with precommercial practices in sapling stands. These practices have potential for regulating stand structure and tree species composition to produce timber, cavities, and mast. Thinning usually has only a modest and transitory effect on forage, browse, and understory cover because openings in the overstory canopy last 10 years or less. There are fewer restrictions on leaving trees during thinnings than on leaving trees in regeneration cuts. Wildlife trees that do not compete with timber crop trees have no effect on timber yield; mast producers are usually also potential timber crop trees.

The availability of standing dead and live defective trees varies by stand size class. Substantial numbers of dead and dying saplings result from competition in unthinned sapling stands. Typically, 1,000 saplings per acre are reduced to 500 or 600 small poles (5 to 9 inches d.b.h.); mortality in pole stands reduces the number of trees to 200 small sawlogs (> 11 inches d.b.h.) (Fig. 1).

Thinning in pole stands reduces but does not eliminate mortality, which may average two or three trees per acre over a 10- to 15-year period in stands of tolerant species; and perhaps a few more in intolerant species. Rotten cull in individual trees is low in pole stands.

Normal thinning practices can reduce the mortality and cull in the lower bole in sawtimber size stands. Natural mortality is usually the result of windthrow that may have other underlying causes but does not leave standing dead trees.

Proportions of conifers in hardwood stands are frequently reduced by management activity. Adding to the conifer component of a hardwood stand apparently simply adds to the stocking and yield of the stand, so leaving conifers may increase the total yield. Scattered conifers other than white pine should be crown-thinned to promote growth and survival among the faster growing hardwoods. White pine can be released by removing the most severe competitor. Small-crowned conifer stems and those with substantial rot normally will die during the rotation and add to the snag component without affecting timber management.

Den trees, can be tended by removing one or two of the most severe competitors to keep the tree vigorous but not injurious to neighboring timber trees. So long as the tree is not overtopping other trees, its effect on stand growth and yield will be proportional to its basal area and amount of usable wood it contains.

Regeneration of Uneven-Aged Stands

Management practices involving continual partial cutting are variously termed all-age, uneven-age, or selection management. These practices promote tolerant species and produce sawlogs and pulp in varying proportions. On the best sites, large sawlogs can be grown; high residual sawlog basal areas are possible, leading to a higher proportion of sawlog production. Variations in the structure are feasible, and products from small logs and pulp also can be substantial. On poorer sites, residual sawlog basal areas are lower; such areas commonly produce a high proportion of poles and small sawlog-size trees. Tolerant conifers are common on the poorer hardwood sites, which are typically sandy, wet or shallow. Tolerant shrubs and small trees are common to all sites.

Uneven-aged stands contain a variety of size classes on 1 acre, and the number of dead and and cull trees in one size class is less than in even-aged stands though the variety of sizes on an acre is increased in comparison to even-aged stands. Desirable subdominant trees can be selectively thinned for growth and survival; or crown-thinned if mast is the objective. Oaks and intolerant species such as aspen have to be regenerated in groups or patches and then thinned to reduce competition from tolerant species.

Dead snags of sawlog-size yellow birch, sugar maple, elm, the oaks, and white pine commonly remain standing for decades. After death, small twigs and branches fall first followed by the larger branches and the tops. Double chainsaw girdling can be used to produce snags of these species. Beech, white birch, and red maple stand dead for shorter periods. Basswood and ash are intermediate. Trees left standing dead in permanently flooded areas last for a longtime, probably because roots deteriorate slowly in such an environment.

Although down logs and slash are critical habitat for only a few wildlife species, such habitat is used by large numbers of animals. Few down logs accumulate under either even-age or all-age management in northern hardwood stands. Leaving marginal logs—those whose timber value equals or is close to production costs—and unlopped slash will increase wildlife habitat quality at small cost or a savings.

When choices of logs and slash disposal methods are available, consider the tree species and site to provide the most long-lasting habitat. Down logs of eastern hemlock last for decades. Logs of all species last longer on drier and colder sites. Large sawlog material lasts longer than smaller logs. Slash of eastern hemlock and other conifers remains after 15 years while hardwood slash will decompose in 5 to 8 years (Eyre and Zillgitt 1953). Slash decomposes fastest when in contact with the ground so that lopped and scattered slash rots faster.

Regeneration of Difficult Species

Aspen. Aspen is a common associate in northern hardwoods, but natural processes will eliminate it in both managed and unmanaged stands. Regenerating aspen stands provide cover for many species, and aspen is an important food source of deer, moose, hare, and beaver. Older aspen tree provide soft snags and cavities, and the buds (especially of male flowers) are important in the winter diet of ruffed grouse. In addition to its value to wildlife, aspen is important in northern hardwood ecosystems because of its ability to colonize sites rapidly after catastrophic disturbance.

Aspen stems left in otherwise clearcut northern hardwood stands deteriorate rapidly. Aspen often regenerates by root suckering which is suppressed by the main stem. Cutting the main stem stimulates root suckering which is most prolific within 20 feet of the stem but which may extend out for 40 to 50 feet. Aspens are short-lived on the best northern hardwood sites where they die from competition with other species by the end of the pole stage. Sites that are well to excessively well drained and would be considered red maple—beech sites (Leak 1978) usually maintain a small aspen component if harvested on a 100-year rotation or less. Shorter rotations (about 70 years) are likely to maintain some aspen on any site with more aspen occurring on the drier exposed sites. To maintain well stocked stands of aspen, rotations must be about 40 years, especially on better sites.

Aspen reproduction is inhibited by overhead shade and the species are relatively short-lived on any site. Maintaining aspen on the better northern hardwood sites will require cutting aspen at less than 50 years in relatively large patches. The first commerical thinning in even-aged northern hardwoods usually occurs when stands are between 40 and 50 years so that special treatments for aspen can be combined with normal timber operations. Pole-size northern hardwoods normally are about 50 feet in height when first thinned, so stimulating aspen root suckers requires cutting a rather large group around aspen stems. If the shade cast by trees is assumed to equal their height, to fully expose suckers in a 20-foot radius requires a 70-foot radius group or roughly one-third of an acre. Because this may not be a viable option for some owners, an alternate practice would be to prolong the existence of aspen stems by crown-thinning and removing all other species of crown competitors.

Red oak. It is difficult to regenerate red oak in northern hardwood stands, and there is no silvicultural techniques that will guarantee success (Arend and Scholz 1969). If mast is the primary objective, stems should be cut when 12 to 16 inches in diameter or less in groups or patches large enough so that the coppice will grow well. In intensively managed areas, thinning oak coppice should be a part of the area marking guide.

Thinning oak sprout clumps should be done by 5 to 10 years of age to prevent rot and promote growth. Thinning that leaves one sprout per stump results in maximum growth, although two or three sprouts per stump are also satisfactory.

Planting 1/0 or 2/0 red oak stock on cut-over areas on medium to good sites can also be successful, but cleaning and weeding will be necessary because the early height growth of planted red oak is slow (Arend and Scholz 1969).

Apple. Wild apple trees or abandoned orchards are important food plants and nest-sites for wildlife in New England. Game animals—white-tailed deer and ruffed grouse—readily feed on apples; snowshore hare and cottontails browse on the twigs. Wild apple trees also provide nest sites for eastern bluebirds, robins, northern orioles, and great crested flycatchers, and food for wintering yellow-bellied sapsuckers.

Most apple trees growing wild lack vigor because of crowding or overtopping trees. Those invading edges of old fields or openings decline in vigor in the shade of overtopping trees. They can be released to increase vigor, productivity, and longevity.

Release requires cutting all trees and shrubs back to the drip line of the apple tree, and the removal of large overtopping trees on at least three sides, especially toward the south side of the tree. Pruning, liming, and fertilizing improve apple trees.

Carefully examine the tree, noting dead branches and the presence of more than one stem. If there is more than one stem, select the largest and most vigorous and remove the others by cutting them off as close to the ground as possible. If the largest stem is weak or broken, select the next largest, most vigorous stem for improvement.

Remove all dead branches except large, hollow, fairly horizontal main branch stubs. These stubs are nest sites for great crested flycatchers if the tree is in the woods, or bluebirds if it is in the open or on the edge of an opening.

Remove about one-third of the live growth, attempting to open up thick clusters of branches. Prune 1 or 2 feet from each of the side branches or vertical suckers. Do not remove the short spur branches that grow on the sides of the larger branches because these are bearing fruit. The top of young saplings with few side branches may be cut off to encourage branching.

Management Implications

Providing large-diameter trees for cavities and foraging sites in managed northern hardwood stands greatly concerns managers. Environmental factors such as tree competition, wind, ice, sunscald, and logging damage will continue to provide a steady supply of small-diameter trees (<18 inches d.b.h.) in stands devoted to the production of large-diameter sawtimber. Large branches in residual tree crowns are routinely broken and rot develops, creating cavity-dwelling/foraging sites with small-diameter trees for smaller birds.

Providing large-diameter wildlife trees must involve intentional management because selective cutting can remove much of the large-diameter butt-log decay present over time (Cooley 1964, Filip 1978). Logging injury is unavoidable in managed stands; however, this creates a continuous source of potential large-diameter cavity trees. Nyland and Gabriel (1971) reported that 12 percent of the residual stems greater than 12 inches d.b.h. were damaged in managed stands.

Minimum estimates of basal area of cavity and den trees >18 inches d.b.h. range from 0.34 to 2.43 square feet per acre (Table 2). Such small additions to the stocking of northern hardwoods will have no measurable effect on volume growth and yield. The theoretical effect can be estimated by calculating the ratio of tree basal area to stand basal area.

Marking guides in uneven-aged northern hardwoods normally suggest 20 to 24 inches d.b.h. for maximum tree size on good sites, but several large (>24 inches d.b.h.) defective stems per 10 acres could be allowed. As an alternative to leaving single large trees, areas could be left without treatment at regular intervals and be easily identified and managed in ways to provide this type of habitat component and distribution. In New England northern hardwoods, an uncut area of 1/4 to 1/3 of an acre per 10 to 15 acres could provide the recommended level of large wildlife trees on many soil site units.

For subsequent thinnings and timber stand improvement operations, managers need to recognize and maintain quality and density standards to perpetuate cavities and foraging sites. Dead stems that are not cut for safety or visual management remain as foraging sites at no cost to stand growth and development.

Short-rotation (<60 years), even-age management strategies could designate a recognizable inclusion (1/4 to 1/3 acre in size) per 10 to 15 acres of final harvest to remain uncut for 2 to 3 times the rotation length. Such small inclusions would not be subject to final harvest for one or two subsequent rotations for that area. Maximum usefulness of these small inclusions could be gained by careful selection for species longevity and site suitability. For example, a 1/3-acre inclusion of tolerant long-lived species per 10 acres of final harvest on short rotation could be expected to have 6 to 10 large-diameter defective hardwood stems per 10 acres if left untreated for several subsequent rotations of the surrounding stand, using stocking-level estimates (Leak et al. 1969) and assuming the current proportions of rot found in northern hardwoods in New Hampshire. Experience indicates that increased value of large-diameter and high grades of sound trees in these inclusions will balance the loss of net volume under most conditions. This type of area control and distribution is useful to consider where large contiguous areas (>50 acres) are treated at the same time, and in intensively managed areas on short cutting cycles, regardless of rotation length.

Site-specific opportunities—such as water influence zones or landscapes, survey and boundary trees, areas inaccessible to equipment, and minimum vegetation management areas—are possible in all management strategies if cultural treatments to remove stand mortality are kept to a minimum. Cultural treatments such as girdling and boring cavity holes in live stems have limited use on large tracts of public and private lands at the present time, but landowners may find such techniques effective and applicable on small woodlots.

Northern hardwood forests offer resource managers many opportunities to manipulate managed stands and areas to produce a sufficient and continuous supply of cavities and foraging habitat for the 41 wildlife species dependent on such habitat in New England, and to produce fruit and mast for many others. Wildlife habitat requirements, soil-site relationships, tree species characteristics, silvicultural techniques, and various vegetative management practices must be considered when providing wildlife trees.

Key to Common Stand Conditions and Management Recommendations

The general principle that underlies this key is that common forest management provides incomplete wildlife tree habitat because of management procedures or site and forest type-site interactions. Consequently, a manager who wishes to provide trees for wildlife would focus on growing them on sites where "normal timber management" would not generally produce the desired numbers and conditions of wildlife trees. For example, short rotation or small maximum tree diameter objectives on larger areas reduce the possibility of large trees and/or tolerant long-lived trees. Intensive timber management may develop one tree type (hardwoods or conifers), or in some instances, one species. Long rotations, long cutting cycles, and large maximum tree size objectives produce many of the wildlife trees needed but may reduce or eliminate some tree species.

The higher quality northern hardwood sites tend to have a lower probability of either conifer or mast tree occurrence. Mixedwood and poorer quality hardwood sites may have abundant conifers and defective hardwood stems, yet few hardwood stems grow larger than 24 inches in diameter. On these sites, conifers may be relatively abundant and capable of growing to large sizes, but defect develops more slowly.

Tables 4 and 5 present, in condensed form, vegetation objectives for broad stand sizes and regeneration activity for three northern hardwood cover types. Table 4 shows typical canopy closures for the three general regeneration methods, the ground vegetation that is desirable, and the distribution of both dead and live tree boles that are desirable habitat for wildlife. The objectives reflect the capabilities of the cover types to provide certain kinds of habitat; for example, northern hardwoods with high percentages of white ash and sugar maple usually have few conifers, but sites that are presently populated with high proportions of beech and red maple cannot produce large diameter trees of those species.

Table 5 provides the same objectives for intermediate treatments in pole and sawlog stands. Two management intensities are included, one which emphasizes timber products with wildlife as a secondary objective and the other emphasizes wildlife with timber products as a secondary but necessary objective. The objectives within cover types also take into account the wildlife habitat limitations of the type and reflect the desirability of the type for timber or wildlife. For example, the white ash-sugar maple type is very desirable for timber products, and wildlife management activities are restricted to large defective trees, which are the most widely used individual tree habitat component.

The characteristics of living trees left for wildlife habitat have been chosen to help ensure the presence of suitable habitat over long periods of time. Eight-inch d.b.h. trees with small holes are quite likely to develop into large hollow trees in time. Small and medium sawlog-sized trees with external indicators of internal rot are likely to be excavated by woodpeckers and then provide habitat for secondary users in time. If not excavated, they will at least provide foraging, roosting, or perching sites for a variety of wildlife.

Ground cover objectives include herbaceous plants. There is very little information for use in controlling this type of vegetation so when herbaceous material occurs in situations where it is desirable, the recommendation is to avoid destroying it.

Table 4.—Three regeneration alternatives to retain wildlife trees and related conditions in northern hardwoods: sugar maple-ash (SA), beech-birch-maple (NH), and beech-red maple (BR)

Component	Clearcutting			Shelterwood			Selection		
	SA	NH	BR	SA	NH	BR	SA	NH	BR
Canopy closure (%)									
≤15	X		X						
16–30		X							
31–70				X	X	X			
≥70							X	X	X
Ground vegetation:									
Composition									
herb*	X	X	X	X	X	X			
woody				X	X	X	X	X	X
Cover (%)									
<30				X	X	X	X	X	X
>30	X	X	X						
Tree boles:									
Dead									
<6″							X	X	X
6–12″		X	X				X	X	X
12–18″	X	X	X	X	X	X	X	X	X
Live									
8–12″ (hole)		X	X	X	X	X	X	X	X
12–18″ (broken limb)	X	X	X			X	X	X	X
>18″ (broken limb)	X	X	X	X	X	X	X	X	X
>24″ (hollow)	X	X		X	X		X	X	
Down material	X	X	X	X	X	X	X	X	X
Softwood inclusion		X	X		X	X		X	X
Slash pile	X	X	X	X	X	X	only if group selection		
Mast and fruit					X	X		X	X

* Temporary herb cover for 2–3 years.

Table 1 shows the wildlife associated with various kinds of wildlife trees and indicates the type of habitat that several types of trees represent. With this information, it is possible to estimate the number of species that will use the habitat provided and how it will be developed and used. For example, woodpeckers will be primary excavators of trees larger than 18 inches d.b.h. that exhibit external indicators of internal rot (broken tops or limbs); such trees along water courses may be subsequently used by wood ducks for nesting. The tables on pages 24 and 25 show how to calculate the number of trees to be kept along water courses to maintain this kind of habitat over long time periods.

The birds and mammals that utilize flowers and seed as a food source are listed in Table 3. The list should assist in estimating the number of species affected by increases in tree or shrub seed production.

Table 5.—Wildlife trees and related conditions under management for timber products and wildlife (T–W) and under management to favor wildlife (W–T) in northern hardwood types: sugar maple-white ash (SA), beech-birch-maple (NH), and beech-red maple (BR)

	Poletimber						Sawtimber					
	T–W			W–T			T–W			W–T		
Component	SA	NH	BR	SA	NH	BR	SA	NH	BR	SA	NH	BR
Canopy closure (%)												
≤15												
16–30												
31–70				X	X	X				X	X	X
≥70	X	X	X				X	X	X			
Ground cover:												
Composition												
herb				X	X	X				X	X	X
woody	X	X	X	X	X	X	X	X	X	X	X	X
Cover (%)												
<30	X	X	X				X	X	X			
>30				X	X	X				X	X	X
Tree boles:												
Dead												
<6″		X	X		X	X		X	X		X	X
6–12″			X			X			X		X	X
12–18″									X		X	X
Live												
8–12″ (hole)		X	X		X	X		X	X		X	X
12–18″ (broken limb)								X	X		X	X
>18″ (broken top)								X	X		X	X
<24″ (hollow)								X		X	X	
Down material				X	X	X	X	X	X	X	X	X
Softwood inclusion					X	X					X	X
Slash pile												
Mast and fruit					X	X	X	X	X	X	X	X

A large number of wildlife species is associated with trees 18 inches d.b.h. with internal rot, and Table 2 and the preceding text suggest the numbers of such trees to leave to provide adequate habitat under a variety of forest conditions. Crown cover tables (Appendix II) are useful in apportioning the number of trees among size classes to leave in clearcuts and shelterwoods especially where recommendations are in terms of canopy closure.

The following key characterizes the most common northern hardwood stand conditions and lists wildlife tree recommendations (see page 23). Because of the large number of alternatives, the suggestions are generally illustrative, and the Appendix tables and text also should be consulted before prescriptions are made.

Stand Conditions	*Wildlife Tree Recommendations*
SEEDLING STANDS, WELL STOCKED <1 INCH D.B.H.	
1. Stands without overstories The common recommendation for timber production is to review in 10 years	1, 2, 3
2. Stands with overstories of <40 ft^2/acre BA The common timber production recommendation removes the overstory when the reproduction conditions are suitable (see Leak et al. 1969 and Tubbs 1977)	4, 5, 6
SAPLING STANDS (1.5 to 4.5 INCHES D.B.H.)	9
1. Without overstories The common timber production recommendation maintains species composition by thinning birch series and sprouting stumps (basswood, oak, and red maple) or do nothing and review when stands are pole size (especially tolerant sapling stands)	7
a. With abundant white pine	8
b. With scattered white pine	8
2. With scattered overstories of <30 ft^2/acre BA The common timber production recommendation removes the overstory	4, 5, 6
POLE STANDS (4.5 to 9.5 INCHES D.B.H.)	8
(9.5 inches d.b.h. is the largest size hardwood stem that will not convert to lumber with the average utilization processes).	
1. Stocking less than B-line (even-age objective) or less than 100 ft^2/acre (all-age objective). The common timber production recommendation waits until stands are well enough stocked to provide economic harvests. Residual stand recommendations vary from 50 to 70+ ft^2/acre depending on species and average stand diameter	6, 8, 10
2. Stocking more than B-line (even-age objective) or 100 ft^2/acre or more (all-age) sawlog objective.	
a. Stands with scattered (<25 ft^2/acre) sawlog overstories	11, 13
1) Even-age objective The usual timber production recommendation removes and/or kills the overstory and thins the pole stand	4, 5, 6
2) All-age objective The usual timber production recommendation retains merchantable sawlog material and selectively thins the pole stand	12, 13
b. Pole stands under short rotation (i.e. aspen-northern hardwoods, aspen-birch, tolerant hardwoods, and birch forest types). The usual timber management objective emphasizes fiber production. Clean clearcutting occurs at 40- to 60-year intervals with average stand diameters less than 10 inches d.b.h.	14, 15
SAWLOG STANDS (>9.5 INCHES D.B.H.)	
1. Better hardwood sites (sugar maple and white ash present; moderately well-drained to well-drained soils of a sandy loam or finer texture).	
a. Even-age sawlog objective (<120 years). Common timber recommendation regenerates the stand at 100 years with a shelterwood cut or clearcut.	16, 17
b. Even-age sawlog objective (>120 years).	
1) Stand diameter is less than harvest size. Common timber recommendations include thinning and Timber Stand Improvement practices	17
2) Stand diameter equals harvest size. Common timber recommendation regenerates the stand	16

Stand Conditions	Wildlife Tree Recommendations
3) Medium and poor sites (sugar maple/white ash absent or rare; shallow soils depth; somewhat poorly to poorly drained soils of a coarse texture). Even-age sawlog rotation objective is <100 years.	18
SELECTION STANDS	
1. Common timber recommendations develop stands with large d.b.h. (up to 24 inches) and high residual sawlog class stocking on sites with substantial sugar maple/white ash stocking. Lower sawlog stocking and smaller maximum tree d.b.h. (<18 inches) are common recommendations on other sites. Cutting cycles are longer on these sites than on the better hardwood sites.	
a. Good sites	19
b. Medium and poor sites	20
2. Mixedwood stands Common timber recommendations include short rotations or long cutting cycles; low residual basal area stocking; and small maximum tree d.b.h. objectives	21
3. Streamside, water influence zones, roadside stands, and so on	22

Wildlife Tree Recommendations

1. Consider clearing scattered trees in patches of raspberries and similar fruit-bearing shrubs or grassy areas to prolong the existence of the patches.

2. Consider cleaning and weeding of seedling mast-bearing species (oaks, beech) and conifers.

3. Do nothing, review when stands are sapling size.

4. Leave a minimum of one large (18 to 24 inches d.b.h.) live defective tree per 10 acres or a maximum of one tree per acre. The tree should be capable of surviving for 40 years.

   Leave any standing dead trees. To maximize individual tree habitat, leave live trees of a variety of size classes (one per 6-inch d.b.h. class) from 6 inches d.b.h. to 24+ inches d.b.h. The smaller trees are especially suitable if they have minor defects and the larger trees should have defects such as broken tops and limbs; and when large hollow trees are present, these larger trees will provide habitat for the greatest number of wildlife species (Table 1). Favor hard-mast producers (beech and oak) and conifers when wildlife is a primary goal. Canopy closure should be 15 percent or less of the area to minimize impacts on the reproduction but provide adequate wildlife tree habitat requirements. Appendix II can be used to estimate crown cover to be left.

5. Where the overstory is patchy, consider leaving trees in groups up to one-third of an acre in area per 10 to 15 acres, especially where rotations (<100 years) or cutting cycles (<15 years) are short.

6. Where wildlife is the primary objective, thin to not less than 50 square feet per acre 5+ inches d.b.h.; favor mast trees and conifers. When wildlife is a secondary objective, thin to recommended levels if economic harvest is possible. The open overstory and resultant understory development will promote additional wildlife species habitat; the more open overstories will provide additional habitat for the longest period of time.

7. To promote plant species diversity and stimulate early flowering and fruiting, thin sprouting stumps to 1 or 2 sprouts per stump and thin individual saplings heavily. Favor catkin-bearing hardwoods (birch family) and conifers.

8. Partially release white pine where weeviling is prevalent and where pine is common; release heavily where pine is scattered and/or weeviling is not common. Release other conifers heavily.

9. Decisionmaking in seedling and sapling stands. Practices in these stands are out-of-pocket costs, and many wildlife practices are similar to those commonly used in timber production. Precommercial thinning for timber production is usually done on the best sites with desirable species composition. Wildlife objectives might be to add to the total area treated or add to the number of species treated; current precommercial practices treat the most desirable species at regular spacing which might be modified to include mast-bearing species and conifers at the same intervals; or to include all mast-bearing and conifer species on each line or specified area (streamsides, lake edges, saddles, etc.); heavier thinnings would result in fuller crown development and earlier seed production.

10. Do nothing now—review in 10 years.

11. Retain live sawlog trees not to exceed 10 square feet per acre, favoring species and size that will produce trees 24 inches d.b.h. Favor conifers and mast-bearing species in thinning activities.

12. Leave live, sawlog-size defective trees in amounts up to 10 square feet per acre and increase residual stocking by 10 square feet per acre. (Any number of dead trees can be left). Favor tolerant conifers and mast-bearing species in thinning activities.

13. Scattered aspen may be cut to provide patches of reproduction.

14. At harvest, leave the most tolerant and/or long-lived species in numbers specified in recommendations 4, 5 and 6; or leave patches of 1/4 to 1/3 of an acre per 10 to 15 acres. Aspen, aspen-birch, and birch mixtures may be partially cut to encourage tolerant species in these patches and the overstory left to deteriorate naturally.

15. Unlopped slash and cull logs can be left when they do not constitute a hazard or encumbrance to logging or site preparation. Piled or windrowed slash is also acceptable. Combinations of piled and scattered slash lead to the most varied habitat. Burning slash is least desirable. When cull sawlogs are to be converted to fiber products, consider leaving those logs which are at the break-even value on the ground.

16. Wildlife trees can grow over 24 inches d.b.h. on these sites. Leave a distribution of windfirm, long-lived tolerant species as Table 2 suggests. Individual trees that remain should be able to survive at least to the pole stage of the next rotation (that is, 40 to 50 years). Leaving small 1/4- to 1/3-acre patches per 10 to 15 acres is also suitable. Mast trees (beech and oak) and long-lived conifers will ordinarily be rare on these sites. Cull logs, tops, and slash can also be left.

17. Maintain den trees and cull class 4 trees in the densities recommended in Table 2 during stand improvement and thinning activities.

18. Favor conifers in hardwood stands but include long-lived tolerant hardwoods of less than cull class 4 or cull stems of species of intermediate tolerance. Favor hardwoods in mixedwood stands but include conifers. Leave culls and cull class 4 hardwoods after harvest suggested in recommendation 4 and Table 2. In small sawlog stands, selectively thin suitable tolerant conifers and larger size tolerant hardwoods. Hardwoods are likely to be defective on these sites, so size should be a major criterion.

19. Favor long-lived tolerant hardwoods; cut or kill when d.b.h. approaches 30 inches if wildlife tree will adversely affect the surrounding stand. Occasional conifers should be left without adjusting residual stand basal areas (up to a maximum of 15 square feet per acre of conifers).

20. Favor long-lived tolerant conifers and hardwoods of larger sizes other than beech which deteriorates rapidly. Conifers may attain the largest sizes on these sites.

21. Hardwoods are often defective; focus should be on conifers for large-size wildlife trees. Windthrow is often a problem in such stands and more attention to that factor is required. Other factors affect wildlife-tree selection the same as in hardwood stands.

22. Perpetuation of higher densities of large-diameter cavity and den trees in water influence landscapes/riparian zones requires periodic treatment. Where sufficient water influence landscape/riparian zone widths exist, all-age selection systems using low q-values could ensure a continual supply of large-diameter trees with cavity/den tree habitat potential. The following table (from Smith and Lamson 1982) provides a comparison of density estimates of trees 18 to 30 inches d.b.h. per acre based on q-values in riparian corridors larger than 200 feet (1/2 width):

Selected Q-values	Residual basal area (ft^2/ac) 70	80	90	100
	(Number of large trees/acre)			
1.7	5.7	6.5	7.3	8.1
1.5	9.0	10.3	11.6	12.9
1.3	13.4	15.3	17.2	19.1

If the wildlife objective is to carry a higher density of cavity and den trees in these corridor situations, then cultural activities need to focus on growing large-diameter trees with a high potential for cavity- and den-tree habitat. Even with large q-values of 1.7 and residual basal areas of 70 sqare feet per acre, there are sufficient numbers of large ($\geq$18 inches d.b.h.) stems with which to work. Favor conifers where possible.

In those riparian corridors less than 200 feet (1/2 width), it is easier to think of densities of large ($>$18 inches d.b.h.) defective stems per 200 feet of corridor. If for purposes of this exercise we use square acres (208.7 ft. on a side), then the following table describes possible distance options between large cavity/den trees:

Selected densities using the concept of a square acre (approximately 200 feet per side)	Variable spacing (ft) between large trees on riparian corridors less than 200 feet 1000′ 100′ 50′ 20′
0.2 trees/acre	1000
0.5 trees/acre	400
1.0 tree/acre	200
2.0 trees/acre	100
3.0 trees/acre	67
4.0 trees/acre	50
5.0 trees/acre	40
10.0 trees/acre	20

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Appendix I.—Two Methods for Estimating Cull in Northern-Hardwood Stands

Method One (from Zillgitt and Gevorkiantz 1946)

The method outlined below is for estimating cull in stands but also can be used for a quick, rough estimate of cull in individual trees.

For northern-hardwood sawtimber, a fair approximation of cull percentage can be obtained by the following method:

1. Record the cull class for each tree on the basis of visible effects.

   Class 1—Trees with no major defect,[3] minor defect[4] permitted.

   Class 2—Trees with one major defect.

   Class 3—Trees with two major defects.

   Class 4—Trees with three or more major defects.

2. Determine gross volume of each sample tree.
3. Compute the cull volume of each tree by applying the following percentage deductions to gross volumes: Class 1—5; class 2—15; class 3—35; class 4—60.

[3] Major visible defects: Butt rot, conk, canker, large or spiral seam, large crack, large scar, large hole, large rotten burl, large broken or dead limb or fork, broken or dead top, serious crook or sweep, abnormally short merchantable length.

[4] Minor defects: Ingrown bark, sterile conk, small seam, small crack, small scar, small hole, small rotten burl, small broken or dead limb, slight crook or sweep.

4. Determine gross volume and cull volume.
5. Divide the cull volume by the gross volume to determine the cull.

To increase the accuracy of the appraisal:

a. Consider a single defect culling the first 16-foot log as two defects.

b. Consider a single defect extending into two 16-foot logs as two defects; if into three logs, count as three defects.

c. Any defect in the top log should be considered minor for trees 15 inches d.b.h. and larger, unless it completely culls the section.

d. Where two or more defects will cut out together, consider as one defect.

e. Minor defects so numerous or extensive as to equal a major defect in loss of scale should be considered as one major defect.

f. Always place borderline cases into the higher class to compensate for hidden defect.

The cull percentage obtained by this method is most accurate for trees averaging 2-1/2 logs. Increase the percentage by one-third for 1-log trees, by 10 percent for 2-log trees; decrease it by 10 percent for 3-log trees, and by one-fourth for 4-log trees.

Method Two (from Zillgitt 1946)

The "defects and cull percentages" table indicates the approximate amount of cull caused by a specific type of defect; this may be useful when conisdering the need of a specific cavity-using animal or bird.

Defect	Position within merchantable length of tree	Condition or degree	Class	Cull percent[a] 2-log tree	2-log tree	2½-log tree	3-log tree	4-log tree
Broken or dead limb								
(At least 6 inches in diameter)	Anywhere	Large	3	20	17	14	13	11
(Less than 6 inches in diameter)	Anywhere	Small	1	5	4	4	3	4
Broken or dead top (Broken or rotten close enough to top limit of merchantability to indicate loss in scale.)			3	20	17	14	13	11
Butt rot (At least 1/3 of log lost. If not visible, detectable by blow.)	First log	Advanced	5	39	35	28	25	22
Canker	First log	Advanced	6	56	50	41	36	32
	Above first log	Advanced	4	26	24	20	17	15
Hidden rot (Cannot be detected in standing tree.)	Anywhere		2	9	8	6	6	5
Conk	First log	Active	5	39	35	28	25	22
	Above first log	Active	4	26	24	20	17	15
	Anywhere	Sterile	1	5	4	4	3	3
Crack								
(Open. At least 1/3 of log lost.)	First log	Large	5	39	35	28	25	22
(Open. At least 1/3 of log lost.)	Above first log	Large	3	20	17	14	13	11
(Open. Less than 1/3 of log lost.)	Anywhere	Small	2	9	8	6	6	5
Crook or sweep								
(More than 2/3 volume lost.)	First log	Excessive	5	39	35	28	25	22
(1/3 to and including 2/3 volume lost.)	First log	Moderate	4	26	24	20	17	15
(Less than 1/3 volume lost.)	First log	Slight	2	9	8	6	6	5
(More than 2/3 volume lost.)	Intermediate log	Excessive	4	26	24	20	17	15
(To and including 2/3 volume lost.)	Intermediate log	Slight to moderate	2	9	8	6	6	5
(More than 2/3 volume lost.)	Top log	Excessive	3	20	17	14	13	11
(To and including 2/3 volume lost.)	Top log	Slight to moderate	2	9	8	6	6	5
Bole								
(Cavity. At least 1/3 of log lost.)	First log	Large	5	39	35	28	28	22
(Cavity. At least 1/3 of log lost.)	Above first log	Large	4	26	24	20	17	15
(Cavity. Less than 1/3 of log lost.)	Anywhere	Small	2	9	8	6	6	5
Ingrown bark								
(Bark folded into right cylinder.)	First log		1	5	4	4	3	3

Continued

Method Two—Continued

Defect	Position within merchantable length of tree	Condition or degree	Class	Cull percent[a] 2-log tree	2-log tree	2½-log tree	3-log tree	4-log tree
Rotten burl								
(At least 1/4 of log affected.)	Anywhere	Large	4	26	24	20	17	15
(Less than 1/4 of log affected.)	Anywhere	Small	1	5	4	4	3	3
Scar								
(At least 1/4 of log affected.)	Anywhere	Large	4	26	24	20	17	15
(Less than 1/4 of log affected.)	Anywhere	Small	2	9	8	6	6	5
Seam (Open or tight.)	Anywhere	Spiral	6	56	50	41	36	32
(Tight. At least 6 feet long.)	Anywhere	Large, straight	3	20	17	14	13	11
(Tight. Less than 6 feet long.)	Anywhere	Small, straight	2	9	8	6	6	5

[a] Class averages.

Appendix II.—Crown cover percentage tables for three species-form groups (from Leak and Tubbs 1983)

Cumulative percentage crown cover for white ash, white pine, red spruce, balsam fir, and hemlock, 10-factor prism.

D.b.h. (inches)	Tree count 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	32	64	95	127														
4	15	30	45	60	74	89	104											
6	11	21	32	43	54	64	75	86	96	107								
8	9	18	27	36	44	53	62	71	80	89	98	107						
10	8	16	24	32	40	47	55	63	71	79	87	95	103					
12	8	15	22	30	38	45	52	60	68	75	82	90	98	105				
14	7	14	20	27	34	41	48	54	61	68	75	82	88	95	102			
16	6	13	20	26	32	39	46	52	58	65	72	78	84	91	98	104		
18	6	13	19	25	32	38	44	50	57	63	69	76	82	88	94	101	107	
20	6	12	18	24	30	37	43	49	55	61	67	73	79	85	92	98	104	110
22	6	12	18	24	30	35	41	47	53	59	64	71	77	83	88	94	100	106
24	6	12	17	23	39	35	41	46	52	58	64	70	75	81	87	93	100	104
26	6	11	17	23	28	34	40	46	51	57	63	68	74	80	86	91	97	104

Continued

Appendix II. (Cont'd).

Cumulative percentage crown cover for beech, 10-factor prism.

D.b.h. (inches)	Tree count 1	2	3	4	5	6	7
2	52	105					
4	30	59	89	118			
6	23	47	70	93	117		
8	21	41	62	82	103		
10	19	38	57	76	95	114	
12	18	36	54	72	90	107	
14	17	34	51	69	86	103	
16	17	33	50	67	83	100	
18	16	33	49	65	81	98	114
20	16	32	48	64	80	95	111
22	16	31	47	63	78	94	110
24	15	31	46	62	77	93	108
26	15	30	46	61	76	91	107

Cumulative percentage crown cover for sugar and red maples, yellow and paper birches, 10-factor prism.

D.b.h. (inches)	Tree count 1	2	3	4	5	6	7	8	9	10	11	12
2	59	119										
4	28	57	85	114								
6	21	41	62	82	103							
8	17	34	51	68	84	101						
10	15	30	44	59	74	89	103					
12	13	27	40	53	67	80	93	106				
14	12	24	37	49	61	73	86	98	110			
16	11	23	34	45	57	68	80	91	102			
18	11	21	32	43	54	64	75	86	96	107		
20	10	20	30	40	50	60	70	80	91	101		
22	10	19	29	38	48	57	67	76	86	96	105	
24	9	18	27	36	45	54	64	73	82	91	100	109
26	9	17	26	35	43	52	61	69	78	87	95	104

*U.S. G.P.O. 1987-748-076:40037

Tubbs, Carl H.; DeGraaf, Richard M.; Yamasaki, Mariko; Healy, William M. 1987. **Guide to wildlife tree management in New England northern hardwoods.** Gen. Tech. Rep. NE–118. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 30 p.

Presents information on the culture and management of trees that have value as components of wildlife habitat in the northern hardwood and associated types in New England. Background information is provided for choosing the most suitable trees for wildlife habitats and for estimating the impact of timber production. Suggestions are made for choosing the numbers of trees for a variety of common situations and for cultural procedures to enhance the value of trees as wildlife habitat. Hard and soft mast production is discussed, and guides for culture and management of mast are presented. Simplified habitat objectives and a key are provided for choosing and culturing wildlife trees in common forestry situations.

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

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- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
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- Parsons, West Virginia.
- Princeton, West Virginia.
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