New Hampshire's Forests 2007

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Abstract

The first full annual inventory of New Hampshire's forests reports nearly 4.8 million acres of forest land with an average volume of nearly 2,200 cubic feet per acre. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 53 percent of total forest land area. Fifty-seven percent of forest land consists of large-diameter trees, 32 percent contains medium-diameter trees, and 11 percent contains small-diameter trees. The volume of growing stock on timberland has been rising since the 1980s and currently totals nearly 9.5 billion cubic feet. The average annual net growth of growing stock on timberland from 1997 to 2007 is approximately 164 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, timber products, and forest health. Detailed information on forest inventory methods and data quality estimates is included in a DVD at the back of the report. Tables of population estimates and a glossary are also included.

Acknowledgments

The authors would like to thank New Hampshire's inventory crew members over the 2002-2007 inventory cycle: Aaron Clark, Robert Gregory, John Higham, Paul Kelley, Katherine Locke, Jason Morrison, Joyce Quinn, Ann Quinion, Keith Raymond, Jennifer Thompson, Bryan Tirrell, and Ashley Zickefoose. Thanks also to Ken Desmarais, George Frame, and Jonathan Horton for serving as reviewers and providing insightful, constructive comments.

Cover: The view westward from the Ashuelot River Headwaters Forest in Lempter, NH. Photo by Jerry and Marcy Monkman, EcoPhotography, courtesy of the Society for the Protection of New Hampshire Forests.

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Foreword

Our forests are one of our most precious assets. Today, forests dominate New Hampshire's landscape, covering over 80 percent of the State's land area. Our forested ecosystem provides the basis for biological diversity, natural communities, scenic landscapes, and recreational opportunities. As a natural resource, forests provide an important economic base supporting a diverse forest products industry, as well as a myriad of ecosystem services such as clean water, clean air, and carbon storage.

In New Hampshire, we recognize that sustainable forests begin with healthy forests. And we also recognize that managing forests sustainably involves the recognition of connections among ecological, social, and economic systems to maintain forest health while preserving options for future generations and meeting the needs for the present. However, this valuable resource is threatened by fragmentation and parcelization, invasive species, and conflicts among recreational users. These are among the many issues that challenge our collective ability to maximize the protection and sustainable management of New Hampshire's forests so that they can provide the full array of ecological, economic, and social benefits for current and future generations.

To make informed decisions about forest resources, it is important to have accurate and timely forest resource information. The Division of Forests and Lands is pleased to partner with the U.S. Forest Service in the Forest Inventory and Analysis (FIA) of New Hampshire. The more we know and understand of the wonderful resources of New Hampshire's forests, the better we can sustain our forests. Decisions and actions we make today will influence our forests for years to come. Livable communities, functioning natural systems, and our quality of life depend on healthy, sustainable forests. We must accept and embrace responsibility as stewards of this valuable resource.

Brad Simpkins

New Hampshire Interim State Forester

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Highlights

On the Plus Side

New Hampshire's forest land base has remained stable since 1997 at 81 percent of total land area, making it the second most forested state in the United States.

Timberland makes up 96 percent of New Hampshire's forest land.

Ninety-seven percent of New Hampshire's forest land is in patches greater than 100 acres, a size preferred by many wildlife species.

Only 10 percent of forest land in New Hampshire is near population centers that exceed 150 people per square mile, the density at which the probability of commercial forestry drops to zero.

The majority of New Hampshire's forest land is well stocked with trees of commercial importance. Changes in stand stocking indicate that forest management practices over the past three decades may have improved the general stocking condition across the State.

The quality of saw logs in New Hampshire has remained stable since the last inventory, but the value of sawtimber has increased based upon the increase in available board-foot volume.

Most of the wood-processing facilities in New Hampshire are sawmills processing primarily saw logs. These mills provide woodland owners with an outlet to sell timber and provide jobs in some of the rural area.

Lichen species richness scores fall into the medium and high categories across New Hampshire; this is likely to be related to levels of sulfate deposition.

In Vermont and New Hampshire, the presence of invasive plant species is relatively low compared to neighboring New England states.

Foliar injury from ozone has decreased as ozone exposure rates have decreased.

Areas of Concern

People at least 65 years old make up nearly 50 percent of New Hampshire's family forest owners and own 42 percent of family forest acreage. Because of the large change in ownership that is likely to occur in the next two decades, it will be important to watch how the new owners manage their lands.

Due to the continuing increases in volume, New Hampshire's timber resource is at record levels. However, this increase has leveled off and may continue to do so as the forest continues to mature, reducing future growth rates.

The mortality rate (1.0 percent) for 1997 to 2007 is the highest ever reported in an FIA inventory of New Hampshire, but this rate is comparable to those in surrounding states.

Fifteen percent of the red maple basal area had poor crowns.

A well-managed forest. Society for the Protection of New Hampshire Forests forest in Groton, NH. Photo by Jerry and Marcy Monkman, EcoPhotography, courtesy of the Society for the Protection of New Hampshire Forests.

Issues to Watch

Commercial and residential development of forest land in the southern part of the State may cause reductions in forest cover in future years.

The small parcels held by many landowners complicate the economics of forest management and the delivery of government programs. The trend toward more landowners with smaller parcels will only increase this problem.

Cumulative ecological impacts on forest land from roads should be a very real consideration.

A statistically significant decrease in area of medium-diameter stands and a statistically significant increase in area of large-diameter stands have both occurred over the past three decades. There needs to be continued monitoring as the forest matures and less area contains stands of small- and medium-diameter trees.

The 1983 to 1997 and 1997 to 2007 periods are the first time that the growth-to-removal ratio has dropped below 2.0:1.0 since the 1960s. Even with the slower growth rate, the current level of removals appears to be sustainable barring any increases in mortality.

New Hampshire's forests are continuing to accumulate biomass as the forests mature. Because most of the biomass is contained in the boles of growing-stock trees, and most of the gains in biomass stocks are found in the high value sawtimber-size trees, only a fraction of the accumulated material is available for use as fuel.

Changes in species composition point toward potential reductions in tree quality for sawtimber into the future. Two of the species with a high proportion of low grade volume, American beech and red maple, are showing large increases in numbers of trees (red maple) and saplings (American beech).

An important consideration for landowners actively managing their land is the ability of the primary wood-products industry to retain pulp mills, sawmills, and veneer mills. The number of wood-processing mills has been steadily declining across the region.

The scarcity of large coarse woody debris resources may indicate lower quality habitat for some wildlife species.

Invasive insect pests that may impact abundant tree species in New Hampshire in the future include the emerald ash borer and Asian longhorned beetle.

The presence of invasive plants may have caused a reduction in seedling cover based upon data collected in Vermont and New Hampshire.

Background

The view from the south peak of Double Head Mountain, NH. Photo by Jack Tracy.

Data Sources and Techniques

The forests of New Hampshire are one of the State's most valuable assets due to their importance to New Hampshire's economy and the quality of life for residents. Accurate and statistically defensible information is critical for understanding the current conditions, interpreting trends over time, and projecting future scenarios. In this report we highlight the current status and trends observed in New Hampshire's forests.

This report is the culmination of the first complete inventory of New Hampshire's forests using FIA's annualized forest inventory system. Previous forest inventories, completed in 1952 (USDA Forest Service 1954), 1960 (Ferguson and Jensen 1963), 1972 (Frieswyk and Malley 1985, Kingsley 1976), 1983 (Frieswyk and Malley 1985, Frieswyk and Widmann 2000), and 1997 (Frieswyk and Widmann 2000), were collected under a different inventory system where states were inventoried periodically with no measurements made between inventories. The annualized system was implemented to provide updated forest inventory information every year based on a 5-year cycle. The FIA program is the only source of data collected from a permanent network of ground plots from across the Nation that allows for comparisons to be made among states and regions.

The FIA sampling design is based on a tessellation of the United States into hexagons approximately 6,000 acres in size with at least one permanent plot established in each hexagon. In Phase 1 (P1), the population of interest is stratified and plots are assigned to strata to increase the precision of estimates. In Phase 2 (P2), tree and site attributes are measured for forested plots established in each hexagon. P2 plots consist of four 24-foot fixed-radius subplots on which standing trees are inventoried. During Phase 3 (P3) of FIA's multi-phase inventory, forest health indicators are measured on a 1/16th subset of the entire FIA ground plot network so that each plot represents approximately 96,000 acres. The forest health indicators are tree crown condition, lichen communities, forest soils, vegetation diversity, down woody material, and ozone injury.

A Beginners Guide to the FIA Forest Inventory

What is a tree?

The FIA program of the U.S. Forest Service defines a tree as a perennial woody plant species that can attain a height of at least 15 feet at maturity.

What is a forest?

A forest can come in many forms depending on climate, quality of soils, and the available gene pool for the dispersion of plant species. Forest stands can range from very tall, heavily dense, and multi-structured, to short, sparsely populated, and single layered. FIA defines forest land as land that is at least 10 percent stocked by trees of any size or formally having been stocked and not currently developed for nonforest use. The area with trees must be at least 1 acre in size and 120 feet wide.

What is the difference between timberland, reserved forest land, and other forest land?

From an FIA perspective, there are three types of forest land: timberland, reserved forest land, and other forest land. In New Hampshire, approximately 96 percent of all forest land is classified as unreserved and productive timberland, 2 percent is reserved and productive forest land, and the remaining 2 percent is unproductive reserved or unreserved forest land.

- Timberland is unreserved forest land that meets the minimum productivity requirement of 20 cubic feet per acre/year.

- Reserved forest land is land withdrawn from timber utilization through legislative regulation.

- Other forest land is commonly found on low-lying sites or high craggy areas with poor soils where the forest is incapable of producing 20 cubic feet per acre. In earlier inventories, FIA measured trees only on timberland plots and did not report volumes on all forest land. Since the implementation of the new annual inventory in New Hampshire in 2002, FIA has been reporting volume on all forest land.

- The second remeasurement is in its fourth field season, and by 2012, FIA will be able to compare two sets of growth, mortality, and removals data. Much of the trend reporting in this publication is focused on timberland, because comparing current data to older periodic inventories requires timberland estimates.

How many trees are in New Hampshire?

New Hampshire's forest land contains approximately 933 million live trees that are at least 5 inches in diameter at breast height (d.b.h., diameter of the tree at 4.5 feet above the ground). We do not know the exact number of trees because the estimate is based upon only a sample of the total population. The frequency estimates are calculated from field measurement of 800 forested plots classified by ownership. For information on sampling errors, see the Statistics and Quality Assurance DVD at the back of this report.

How do we estimate a tree's volume?

The volume for a specific tree species is usually determined by the use of volume equations developed specifically for a given species. Sample trees are felled and measured for length, diameter, and taper. Several volume equations have been developed at the Northern Research Station for each tree species found within the region. Models have been developed from regression analysis to predict volumes within a species group. We produce individual tree volumes based upon species, diameter, and merchantable height. Tree volumes are reported in cubic-foot and International ¼-inch rule board-foot scale.

How much does a tree weigh?

Specific gravity values for each tree species or group of species were developed at the U.S. Forest Service's Forest Products Laboratory and applied to FIA tree volume estimates for developing merchantable tree biomass (weight of tree bole). To calculate total live-tree biomass, we have to add the biomass for stumps (Raile 1982), limbs and tops (Hahn 1984), and belowground stump and coarse roots (Jenkins et al. 2004). We do not currently report live biomass for foliage. FIA inventories report biomass weights as oven-dry short tons. Oven-dry weight of a tree is the green weight minus the moisture content. Generally, 1 ton of oven-dry biomass is equal to 1.9 tons of green biomass.

How do we compare data from different inventories?

New inventories are commonly compared with older datasets to analyze trends or changes in forest growth, mortality, removals, and ownership acreage over time (Powell 1985). A pitfall occurs when the comparison involves data collected under different schemes or processed using different algorithms. Recently, significant changes were made to the methods for estimating tree-level volume and biomass (dry weight) for northeastern states, and the calculation of change components (net growth, removals, and mortality) was modified for national consistency. These changes have focused on improving the ability to report consistent estimates across time and space—a primary objective for FIA. Regression models were developed for tree height and percent cull to reduce random variability across datasets.

Before the Component Ratio Method (CRM) was implemented, volume and biomass were estimated using separate sets of equations (Heath et al. 2009). With the CRM, determining the biomass of individual trees and forests has become simply an extension of our FIA volume estimates. This allows us to obtain biomass estimates for growth, mortality, and removals of trees from our forest lands, not only for live trees, but also for their belowground coarse roots, standing deadwood, and down woody debris.

Another new method, termed the "midpoint method," has introduced some differences in methodology for determining growth, mortality, and removals to a specified sample of trees (Westfall et al. 2009). The new approach involves calculating tree size attributes at the midpoint of the inventory cycle (2.5 years for a 5-year cycle) to obtain a better estimate for ingrowth, mortality, and removals. Although the overall net change component is equivalent under the previous and new evaluations, estimates for individual components will be different. For ingrowth, the midpoint method can produce a smaller estimate because the volumes are calculated at the 5.0-inch threshold instead of using the actual diameter at time of measurement. The actual diameter could be larger than the 5.0-inch threshold. The estimate for accretion is higher because growth on ingrowth, mortality, and removal trees are included. As such, the removals and mortality estimates will also be higher than before (Bechtold and Patterson 2005).

A word of caution on suitability and availability

FIA does not attempt to identify which lands are suitable or available for timber harvesting especially because suitability and availability are subject to changing laws and ownership objectives. Simply because land is classified as timberland does not mean it is suitable or available for timber production. Forest inventory data alone are inadequate for determining the area of forest land available for timber harvesting because laws and regulations, voluntary guidelines, physical constraints, economics, proximity to people, and ownership objectives may prevent timberland from being available for production.

Forest Features

Sugar maples on the Washburn Family Forest in Clarksville, NH. Photo by Jerry and Marcy Monkman, EcoPhotography, courtesy of the Society for the Protection of New Hampshire Forests.

Dynamics of the Forest Land and Timberland Base

Background

New Hampshire hosts the transition of the maple/beech/birch forests of the northeastern United States to the spruce/fir forests of northern New England. Because forests are so important for wood products, tourism, clean water, wildlife habitat, and biomass energy, evaluating change in the status and condition of those forests is important. The amount of forest land and timberland are vital measures for assessing forest resources and making informed decisions about their management and future. Gains or losses in forest area are an indication of forest sustainability, ecosystem health, and land use practices, and they have a direct effect on the ability of forests to provide goods and services. Additionally, these measures are the basis for FIA's estimates of numbers of trees, wood volume, and biomass.

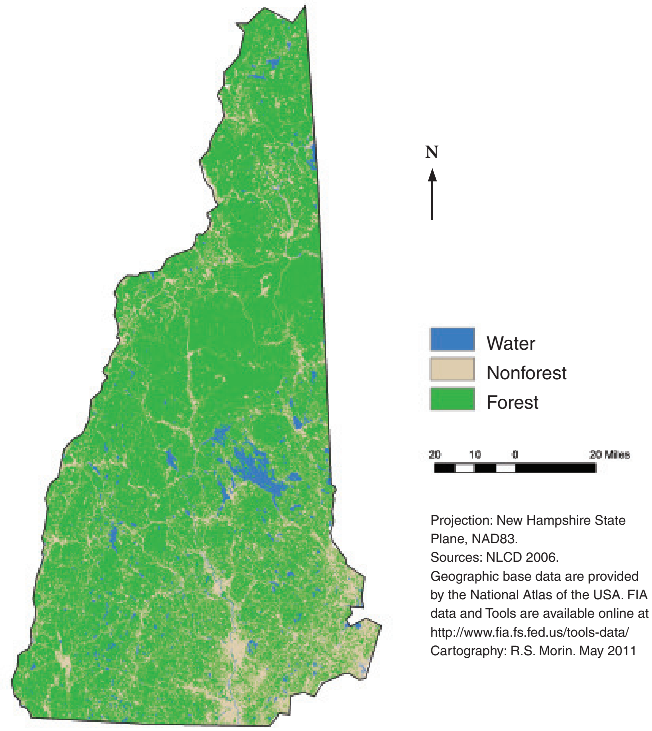


Figure 1.—Distribution of forest land in New Hampshire, 2006.

What we found

Forests are the dominant land cover across most of New Hampshire. The percentage of forest cover generally increases from south to north (Fig. 1), mostly due to more urbanization in the south. When FIA completed its first inventory (1948) in New Hampshire, 84 percent of the State's area was forested. The subsequent 1960 inventory showed a small increase in forest cover (87 percent of land area). New Hampshire's forested land base then decreased at a slow rate between the 1960s and 2000s (Fig. 2). Currently, forest covers 81 percent of New Hampshire's land base. Much of the nearly 230,000-acre decrease in forest land since 1960 is due to development to meet the needs of a growing population, particularly in the southeastern part of the State near Boston, MA. Since 1997 the amount of forest cover has remained relatively stable (Figs. 2, 3).

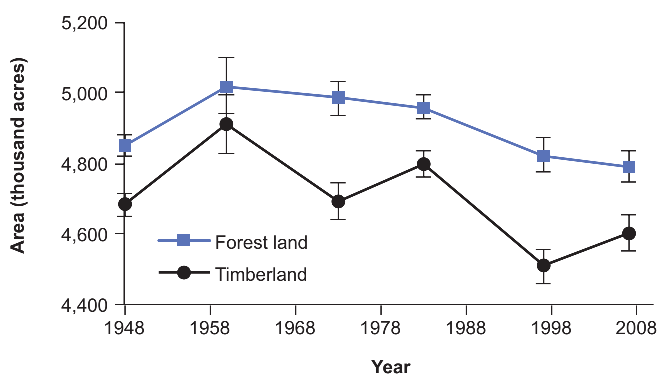
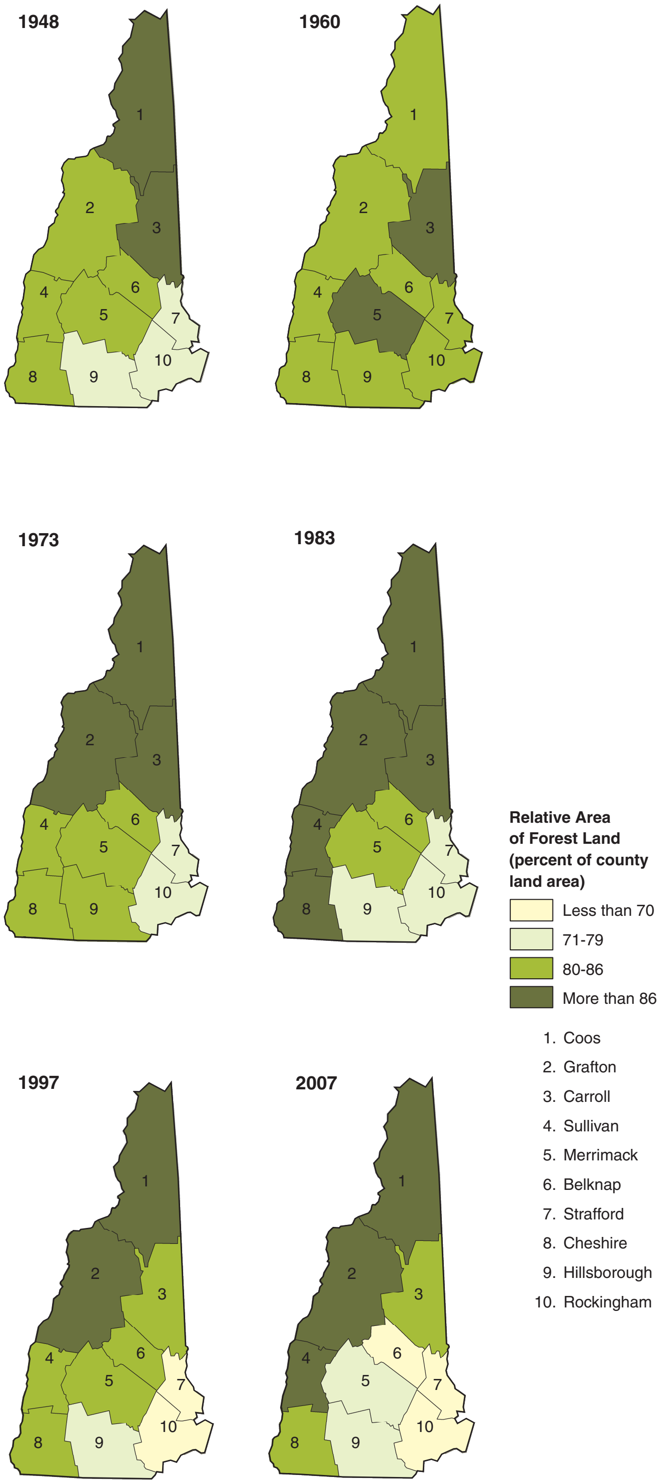


Figure 2.—Area of forest land and timberland, New Hampshire, 1948, 1960, 1973, 1983, 1997, and 2007. Error bars represent one sampling error (68%).

What this means

At 81 percent, New Hampshire is the second most forested state in the United States. The current statewide estimate of forest land has remained statistically unchanged since 1997 (Fig. 1). Future changes in New Hampshire's forest land base will depend on the pace of land development, particularly in the southern parts of the State.



Projection: New Hampshire State Plane, NAD83.
Sources: U.S. Forest Service, Forest Inventory and Analysis Program, 1948, 1960, 1973, 1983, 1997, and 2007 data.
Geographic base data are provided by the National Atlas of the USA. FIA data and Tools are available online at http://www.fia.fs.fed.us/tools-data/
Cartography: R.S. Morin. May 2011

Figure 3.—Distribution of relative area of forest land by county and inventory year, New Hampshire, 1948, 1960, 1973, 1983, 1997, and 2007.

Availability and Productivity of Forest Land

Background

FIA divides forest land into three categories—timberland, reserved forest land, and other forest land—to clarify the availability of forest resources and forest management planning. Two criteria are used to make this determination: reserved status (unreserved or reserved) and site productivity (productive or unproductive). Forest land that is capable of growing trees at a rate of at least 20 cubic feet per year and that is not legally restricted from being harvested is classified as timberland. If harvesting is restricted on forest land by statute or administrative decision, then it is designated as reserved regardless of its productivity class. The harvesting intentions of private forest land owners are not used to determine the reserved status. The other forest land category is made up of forest land that is unreserved and low in productivity.

What we found

Ninety-six percent of New Hampshire's forest land meets the definition of timberland (Figs. 1, 4). The current statewide estimate of timberland has remained statistically unchanged since 1997. The majority of the land in the reserved class is designated natural areas on the White Mountain National Forest. Other forest land (i.e., unreserved and unproductive) is rare in New Hampshire and accounts for only 1 percent of total land (Fig. 4).

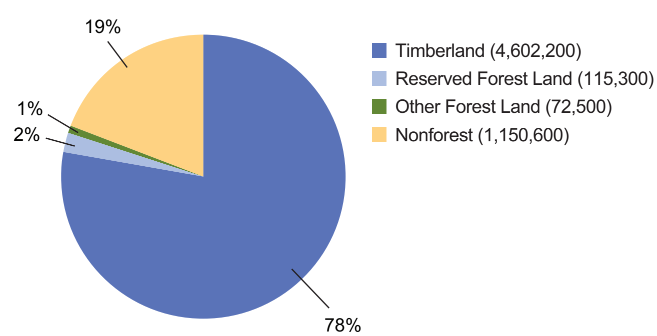


Figure 4.—Land area (acres) by major use, New Hampshire, 2007.

What this means

Because the vast majority of New Hampshire's forest land is classified as timberland, it is potentially available for harvesting timber or other forest products. It also means that trends observed on timberland are likely to apply to forest land as well. The demand for forest products will increase as the number of industries that utilize them expands. Therefore, the balance of supply and demand for these forest products needs to be closely monitored. Later sections in this report provide more details on how much forest land is actively managed for forest products and a more accurate estimate of how much timberland is truly available for harvesting.

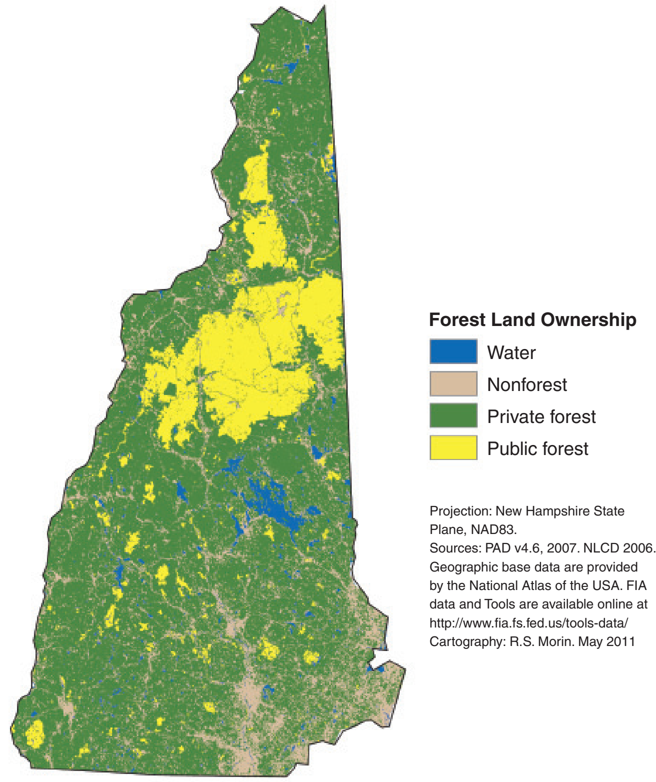


Figure 5.—Distribution of forest land by owner group, New Hampshire, 2007.

Ownership of Forest Land

Background

Forest land owners are a primary factor in determining how the distribution, composition, structure, and health of forest ecosystems will change into the future. Different types of owners (e.g., private, public) have varying objectives, opportunities, and constraints that govern decisions about forest management practices. FIA conducts the National Woodland Owner Survey (NWOS) to further our understanding of who owns forest land, why they own it, and what they intend to do with it. The NWOS collects data on forest holding characteristics, ownership histories, ownership objectives, forest uses, forest management practices, preferred methods for receiving information, concerns, future intentions, and demographics (see Butler 2008).

What we found

A relatively small proportion of New Hampshire's forest land is owned by the public (24 percent; Fig. 5). The Federal Government holds 774,000 acres (16 percent) of forest land of which the majority is administered by the White Mountain National Forest (740,600 acres of forest land). The State of New Hampshire holds 187,000 acres of forest land (4 percent) in various state agencies including state parks and forests, and local governments hold another 568,000 acres of forest land (12 percent; Fig. 6). Public land has remained stable since 1983 (Fig. 7).

New Hampshire's forest land is primarily held by private landowners (68 percent). Approximately 2.4 million acres, 49 percent, of forest land is owned by 124,000 families and individuals (Butler 2008). Other kinds of private owners (e.g., corporations, nonfamily partnerships, nongovernmental organizations, clubs, and other nonfamily private groups) hold another 900,000 acres of forest land (19 percent: Fig. 6).

The number of family or individual forest owners in New Hampshire increased by 41 percent over the past two decades from 88,000 to 124,000 (Birch 1989, Butler 2008) during which the average forest landholding size decreased from 47 acres (Birch 1989) to 19 acres (Butler 2008). The majority of family forest owners (66 percent)

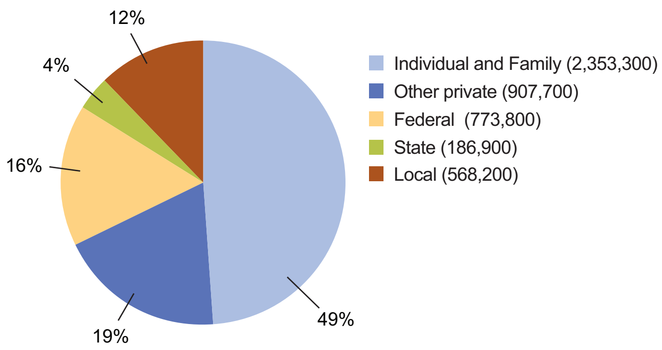


Figure 6.—Forest land area (acres) by major ownership category, New Hampshire, 2007.

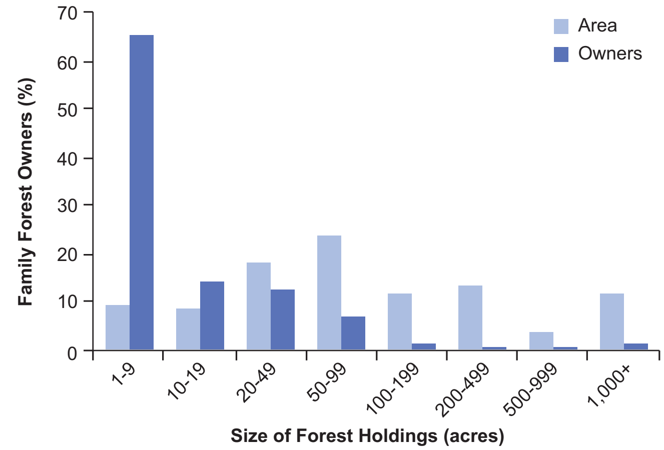


Figure 8.—Area of family or individual owned forests and number of individual or family forest owners by size of landholdings, New Hampshire, 2006.

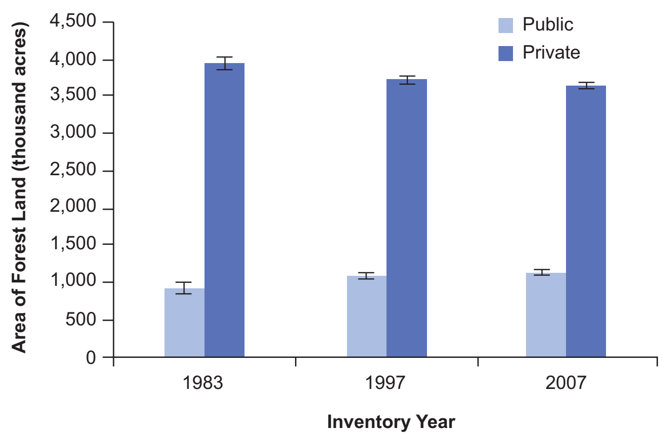


Figure 7.—Forest land area by major ownership category, New Hampshire, 1983, 1997, 2007. Error bars represent one sampling error (68%).

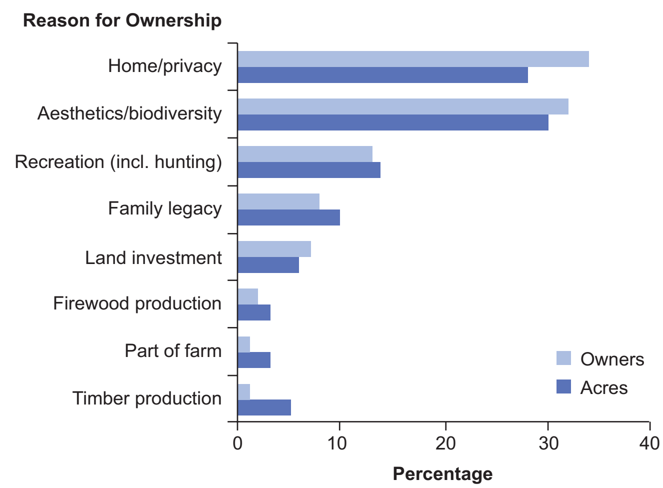


Figure 9.—Area and number of family forests by reason for owning forest land, New Hampshire, 2006. Numbers include landowners who ranked each objective as very important (1) or important (2) on a seven-point Likert scale.

hold fewer than 10 acres of forest land, but represent only 10 percent of the total family forest land base in New Hampshire (Fig. 8). Family forest owners have a wide variety of reasons for holding forest land and objectives for land management. The most widely cited reason for forest land ownership in New Hampshire is that the forest land is part of residential property. Other common reasons are related to aesthetics, recreation, and family legacy (Fig. 9). Although only 1 percent of individual or family forest owners listed timber production as an important reason for owning forest land, 65 percent of family forest owners (holding 75 percent of family forest area) have harvested trees from their properties and 19 percent (holding 55 percent of family forest area) have harvested saw logs (Fig. 10).

Only 5 percent of family forest owners have a written management plan, but 31 percent of the family owned

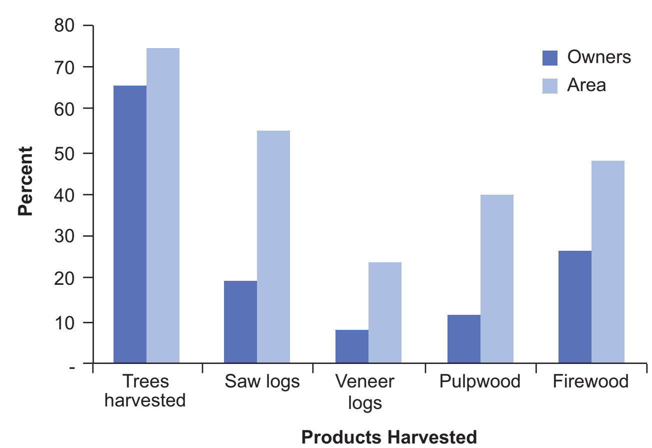


Figure 10.—Area and number of family forests by harvesting experience and products harvested, New Hampshire, 2006. Products Harvested categories are not mutually exclusive.

forest land is governed by one. However, 10 percent of the owners holding 42 percent of the family forest acreage have sought management advice. Private consultants and the State Division of Forests and Lands were most often contacted for advice (Fig. 11). Additionally, approximately 78 percent of eligible privately owned forest land is currently enrolled in New Hampshire's Current Use program (NHDRED 2010). The Current Use program enables landowners who practice long-term forest management to have their enrolled land appraised for property taxes based on its value for forestry, rather than its fair market (development) value.

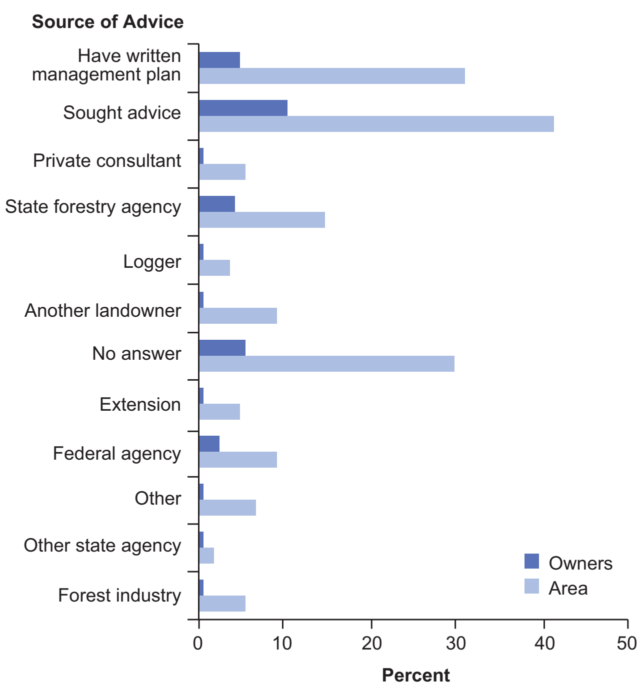


Figure 11.—Area and number of family forests who have a written management plan, who have sought advice, and advice source, New Hampshire, 2006.

Nearly 50 percent of New Hampshire's family forest owners are at least 65 years old. This group of owners also controls more than 42 percent of the family forest acreage (nearly one million acres) in the State (Fig. 12). The 10 percent of family forest owners who have owned their forest for less than 10 years presumably reflects the increase in the number of owners over the past decade.

On the other hand, the tenure of family forest ownership is often much longer. Twenty-eight percent of the family forest acreage has been under the same ownership for more than 25 years (Fig. 13). The majority of family forest owners (66 percent) have no activity planned for their forest land over the next 5 years (Fig. 14). The most common activities planned within the next 5 years are harvesting firewood (36 percent) and selling some or all forest land (33 percent).

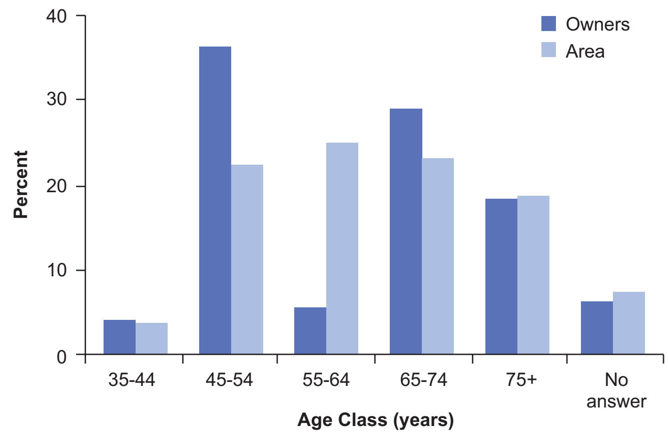


Figure 12.—Area and number of family forests by age of primary decisionmaker, New Hampshire, 2006.

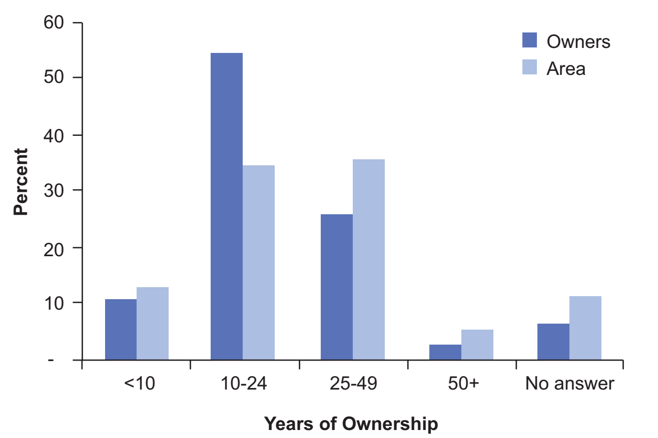


Figure 13.—Area and number of family forests by ownership tenure, New Hampshire, 2006.

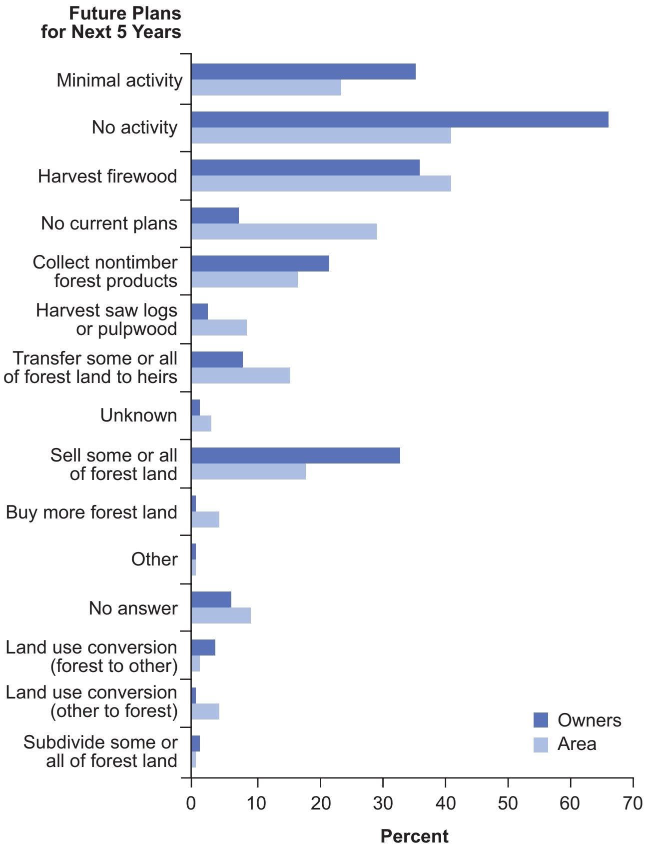


Figure 14.—Area and number of family forests by plans for the next 5 years, New Hampshire, 2006.

What this means

Public ownership of forest land has increased slightly in New Hampshire over the past 25 years. This increase reflects increases in forest land ownership on the White Mountain National Forest and within state and local governments. The number of forest land acres in public ownership is likely to increase modestly in the coming years as more lands are conserved.

Because the majority of New Hampshire's forest land is in the custody of private landowners, future forest conditions will be greatly influenced by the decisions these owners make. The small parcels held by many landowners complicate the economics of forest management and the delivery of government programs. The trend of greater numbers of landowners controlling smaller parcels will only increase this problem into the future. If this trend continues, access to New Hampshire's timber resources by the forest industry could decrease. Furthermore, landowners of smaller tracts of forest are less likely to allow access to their lands for recreation. This could lead to a decrease in forest-related recreation opportunities for people in New Hampshire.

Although the vast majority of landowners did not give a high priority to timber production, most appear to be willing to harvest when conditions are right. Because most owners do not have a written management plan, many harvests are unlikely to be a part of long-term planning.

The large number of landowners who are 65 years or older are likely to represent a large turnover of forest land ownership. When ownership of forest land changes hands, parcelization and unsustainable harvesting practices are more likely to occur. In addition, increasing numbers of new landowners may make it more difficult for government agencies to provide advice, education, and services to family forest owners.

Urbanization and Fragmentation of Forest Land

Background

Forest fragmentation and habitat loss diminish biodiversity (Honnay et al. 2005). Fragmentation of forests is also recognized as a major threat to animal populations worldwide (Rosenberg et al. 1999a), particularly for bird species that are sensitive to habitat fragmentation (Donovan and Lamberson 2001), and species that are wide ranging, slow moving, and/or slow reproducing (Forman et al. 2003, Maine Audubon 2007).

The expansion of urban lands that accompanies human population growth often results in the fragmentation of natural habitat (Wilcox and Murphy 1985). Honnay et al. (2005) point out that spatial/physical fragmentation of habitats is only one of the human-induced processes affecting natural habitats and their biodiversity. Urbanization, increasing the proximity of people, development, and other anthropogenic pressures to natural habitats, and changes in the ways in which humans use those natural habitats, can also lead to overexploitation of species, environmental/habitat deterioration, and the introduction of exotic species. In addition to the negative effects on forested ecosystems, the fragmentation and urbanization of forest land may have direct economic and social effects as well. For example, smaller patches of forest or those in more populated areas are less likely to be managed for forest products (e.g., Kline et al. 2004, Wear et al. 1999) and are more likely to be "posted" (i.e., not open for public use) (Butler et al. 2004), potentially affecting local forest industry, outdoor recreation opportunities, and local culture. Forest land is also a significant factor in the protection of surface and groundwater, and fragmentation and urbanization of that forest land has been observed to affect both water quality and quantity (e.g., Hunsaker et al. 1992, McMahon and Cuffney 2000, Riva-Murray et al. 2010).

The metrics presented here relate to some aspect of urbanization or fragmentation that is suspected of, or has been documented to have, an effect on the forest, its management, or its ability to provide ecosystem services and products (Riemann et al. 2008). These measures are forest edge versus interior, proximity to roads, patch size, local human population density, and the extent of houses intermixed with forest.

What we found

In New Hampshire, 75 percent of the forest land is more than 300 feet from an agriculture use or developed edge. This ranges from 47 percent in more fragmented Rockingham County to 90 percent in Coos County (Table 1).

Figures 15 and 16 show where and to what extent forest land is affected by roads. As both Forman (2000) and Riitters and Wickham (2003) reported, this can be quite extensive, even in areas that appear to be continuous

Table 1.—The distribution of forest land with respect to several urbanization and fragmentation factors, expressed as a percent of the forest land in each county, New Hampshire, 2007

County	% forest land in county[a]	Forest land with house density > 15.5 per square mile[b]	Forest land > 300 feet from an ag or developed edge[c]	Forest land > 980 feet from a road[d]	Forest land located in patches > 100 acres in size[e]	Forest land located in a block with population densities > 150 per square mile[f]
Belknap	83	58	69	34	97	12
Carroll	89	38	80	53	98	5
Cheshire	86	42	70	42	97	8
Coos	91	8	90	69	99	1
Grafton	90	24	84	61	99	3
Hillsborough	74	67	55	29	92	30
Merrimack	83	55	69	40	97	13
Rockingham	66	85	47	29	87	46
Strafford	70	67	58	33	93	27
Sullivan	85	33	69	42	97	7
State Total	84	37	75	50	97	10

[a] Percent forest estimate based on NLCD 2001. Values are generally higher than estimates from FIA plot data.
[b] Approximating the forest land potentially affected by underlying development.
[c] Approximating the forest land undisturbed by edge conditions.
[d] Approximating the forest land outside the effects of roads.
[e] Approximating the forest land with potentially enough core area for sustainable interior species populations.
[f] Approximating the forest land not available for commercial forestry.

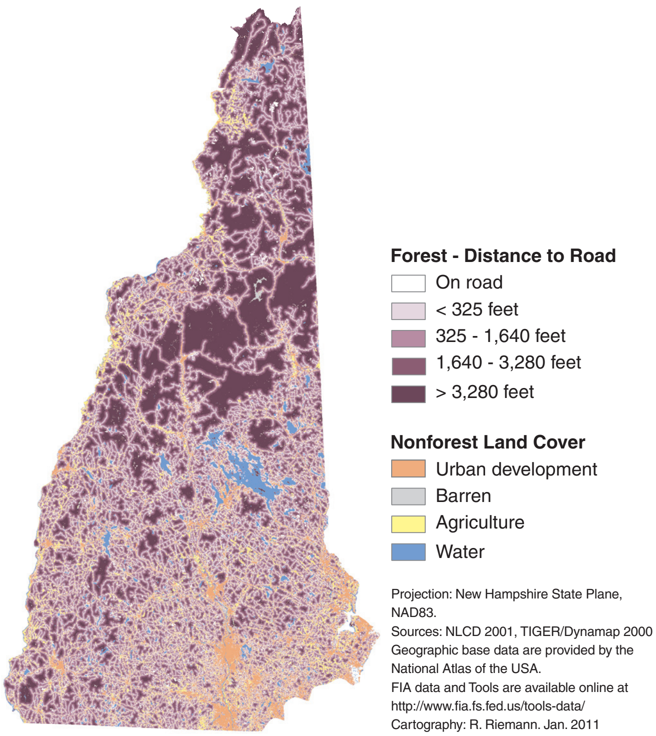


Figure 15.—Distribution of forest land in distance to the nearest road classes (includes all roads), New Hampshire, 2000/2001.

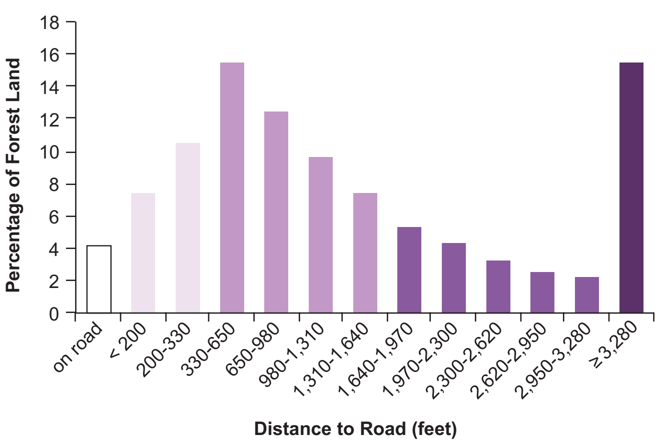


Figure 16.—Distribution of forest land in distance to road classes (includes all roads), New Hampshire, 2000/2001.

forest land from the air. In New Hampshire, for example, 21 percent of the forest land is within 330 feet of a road of some sort and 48 percent is within 980 feet.

Forest land in New Hampshire occurs primarily as a relatively contiguous forest matrix within which urban development, agriculture, roads, and other nonforest areas occur (Riiters et al. 2000). Forested areas containing higher proportions of small patches (patches <100 acres) occur in the more urbanized southeastern part of New Hampshire (Fig. 17). Most counties have a very low proportion of forest land in small patches (Fig. 18). Rockingham is the only county with more than 10 percent of its forest land in patches under 100 acres.

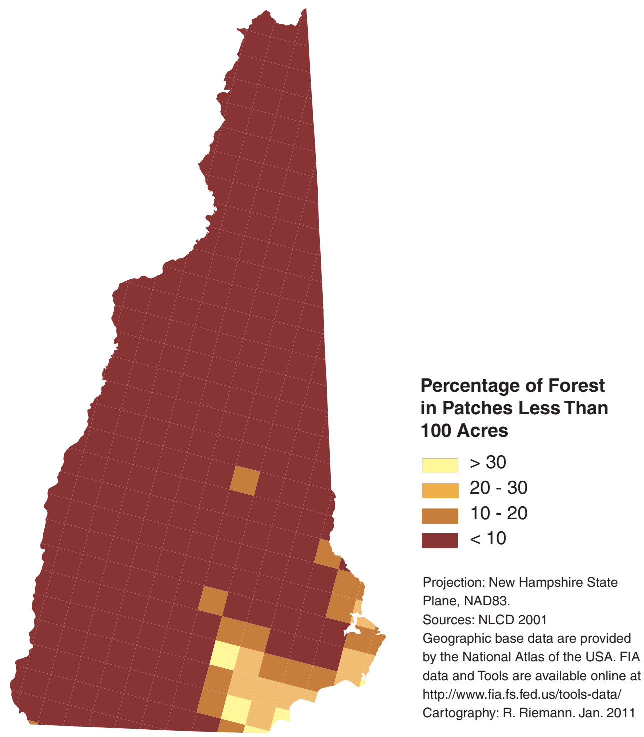


Figure 17.—Percent of forest cover in patches less than 100 acres, by 62.1 square mile grid cell, New Hampshire, 2000.

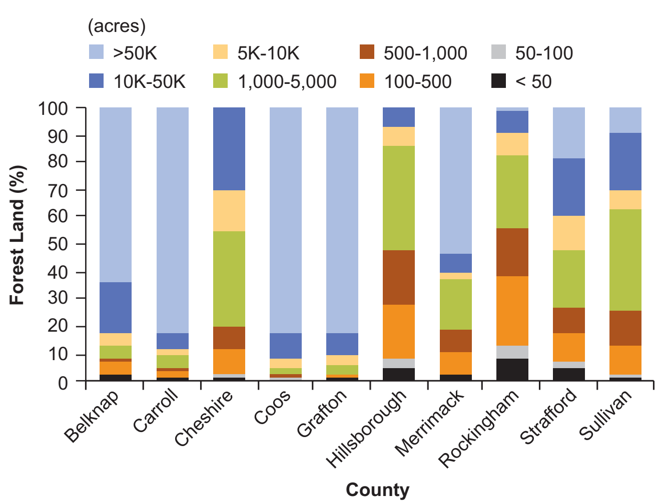


Figure 18.—Distribution of forest land by patch size by county, New Hampshire, 2000.

The Wildland-Urban Interface (WUI) is commonly described as the zone where human development meets or intermingles with undeveloped wildland vegetation, and it is associated with a variety of human-environment conflicts (Radeloff et al. 2005). Radeloff et al. (2005) define this area in terms of the density of houses (greater than 15.5 houses per square mile), the percentage of vegetation coverage present, and proximity to developed areas. Figures 19 and 20 illustrate how much forest land in New Hampshire is affected by house densities greater than the threshold of 15.5 houses per square mile. Counties range from 8 percent (Coos) to 85 percent (Rockingham) of the forest intermixed with house densities of >15.5 per square mile. Thirty-seven percent of the live-tree basal area in New Hampshire is within the WUI, but this proportion is much higher for eastern white pine (*Pinus strobus*) (Fig. 21). Close proximity between humans and forest land has also been observed to affect the viability of commercial forestry in the area, and this relationship has been described most clearly to be related to local human population density near forested areas (Wear et al. 1999). In New Hampshire, only a very small amount of forest land is located in a U.S. census block with population densities above 150 people per square mile (Table 1).

Table 1 brings many of these factors together and presents the extent to which the current forest land base is being influenced by one or more of the factors. For example, in Coos County, which is 91 percent forested, 8 percent of the forest land is potentially affected by house densities greater than 15.5 per square mile, and 90 percent of the forest land is far enough from an edge to be considered interior forest conditions. Nearly all of the forest land is in large patches (>100 acres), but only 69 percent is more than 980 feet from a road. On the other end of the spectrum are the forests in Rockingham County that occupy 66 percent of the land area and occur largely mixed with housing densities above 15 per square mile (85 percent of the forest land). The forests tend to occur in smaller patches (13 percent of the forest is in patches > 100 acres in size), and the county has correspondingly much less interior forest land than other areas (47 percent).

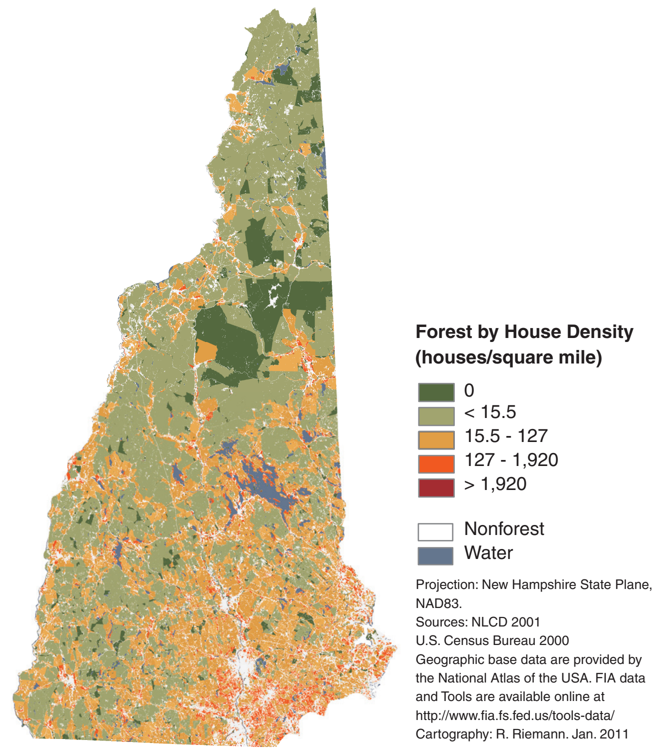


Figure 19.—Distribution of forest land by house density classes, New Hampshire, 2000/2001.

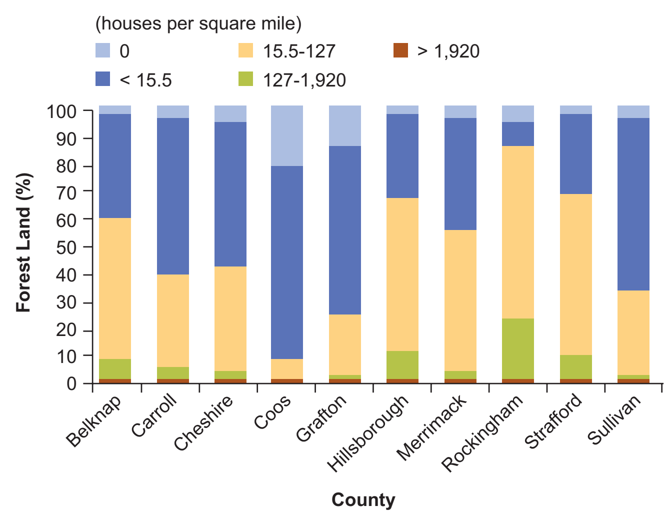


Figure 20.—Distribution of forest land by county and house density class, New Hampshire, 2000/2001.

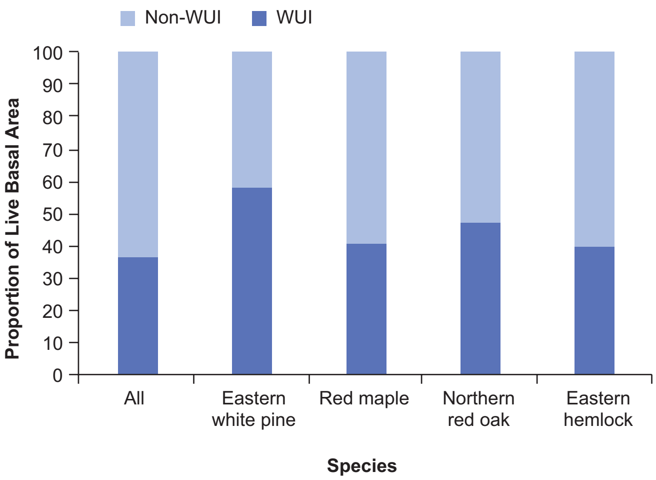


Figure 21.—Proportion of basal area in the Wildland-Urban Interface (WUI) by species, New Hampshire, 2007.

What this means

Edge effects vary somewhat with distance from forest edge, depending on the type of effect and species of vegetation or wildlife (e.g., Chen et al. 1992, Flaspohler et al. 2001, Rosenberg et al. 1999a), but 100 to 300 feet is frequently used as a general range for the "vanishing distance" or the distance into a patch where the edge effect disappears and interior forest conditions begin.

Figures 16 and 17 depict the pervasiveness of roads in the landscape, even in New Hampshire. Road effects diminish when distances range from about 330 feet for secondary roads (a rough estimate of a highly variable zone), 1,000 feet for primary roads in forest (assuming 10,000 vehicles per day), and 2,650 feet from roads in urban areas (50,000 vehicles per day) (Forman 2000). Roads have a variety of effects. including hydrologic, chemical (salt, lead, nutrients), sediment, noise, as vectors for the introduction of invasive species, habitat fragmentation and increases in human access, impacting forest ecosystem processes, wildlife movement and mortality, and human use of the surrounding area. New Hampshire and the northern New York-New England forest region have some of the few areas in the eastern United States with less than 60 percent of their land area within 1,250 feet of the nearest road (Riitters and Wickham 2003). With 58 percent of New Hampshire's forest land within 1,310 feet of a road statewide, cumulative ecological impacts from roads should be a very real consideration. Actual ecological impacts of roads will vary by the width of the road and its maintained right-of-way, number of cars, level of maintenance (salting, etc.), number of wildlife-friendly crossings, hydrologic changes made, perviousness of road surfaces, location with respect to important habitat, etc. These variables also suggest some of the changes that can be made to moderate the impact of roads (Forman 2000, Forman et al. 2003, Maine Audubon 2007).

Habitat requirements for wildlife vary by species, but for reporting purposes it is often helpful to summarize forest-patch data using general guidelines. Many wildlife species prefer contiguous forest patches that are at least 100 acres. This patch area is often used as a minimum size that still contains enough interior forest to be a source rather than a sink for populations of some wildlife species. Without considering the impact of roads that don't break the tree canopy, the majority of New Hampshire's forest land is in patches larger than 100 acres.

Human population is generally recognized as having a negative effect on the viability and practice of commercial forestry (Barlow et al. 1998, Kline et al. 2004, Munn et al. 2002, Wear et al. 1999). Working in Virginia, Wear et al. (1999) identified a threshold of 150 people per square mile as that population density at which the probability of commercial forestry dropped to practically zero. Only 10 percent of forest land in New Hampshire is near population centers that exceed the threshold of 150 people per square mile, but this proportion is higher in southeast New Hampshire (Table 1).

Forest intermixed with houses represents areas of forest cover most likely to be in nonforest land use and/or more likely to be experiencing pressures from recreation, invasive plant species, and other local human effects. This intermix area also represents a challenge to managing forest fires. A threshold of 15.5 houses per square mile represents the approximate density at which firefighting switches from "wildland" to "structure" firefighting techniques and costs (Radeloff et al. 2005). Although the other pressures from high housing densities are likely to be more of an issue than forest fires in New Hampshire, thresholds with respect to those issues are less developed at this point. Therefore, the map should be interpreted as identifying where areas of increased pressure from intermixed residential development are likely to occur (Fig. 19). Nationwide, increases in lower density, "exurban" development have been forecast by both Theobald (2005) and Hammer et al. (2004), particularly at the urban fringe and in amenity rich rural areas.

Forest health, sustainability, management opportunities, and the ability of forest land to provide the products and ecosystem services we often require of it are affected to varying degrees, and in different ways, by changes in the fragmentation of forests and urbanization.

Stand Size and Structure – A Growing, Maturing Forest

Background

Tree diameter measurements are used by FIA to assign one of three stand-size classes to sampled stands that give a general indication of stand development. The categories are determined by the class that accounts for the most stocking of live trees per acre. Small-diameter stands are dominated by trees less than 5 inches in d.b.h. Medium-diameter stands have a majority of trees at least 5 inches d.b.h. but less than the large-diameter stands. Large-diameter stands consist of a preponderance of trees at least 9 inches in d.b.h. for softwoods and 11 inches d.b.h. for hardwoods.

Stocking is a measure of relationship between the growth potential of a site and the occupancy of the land by trees. The relative density (or stocking) of a forest is important for understanding growth, mortality, and yield. Five classes of stocking are reported by FIA: nonstocked (0-9 percent), poor (10-34 percent), moderate (35-59 percent), full (60-100 percent), and overstocked (>100 percent). Stocking levels in New Hampshire are examined using all live trees and growing-stock trees only to identify the amount of growing space that is being used to grow trees of commercial value as opposed to the amount that is occupied by trees of little to no commercial value. For a tree to qualify as growing stock, it cannot be a noncommercial species (e.g., striped maple (*Acer pensylvanicum*), eastern hophornbeam (*Ostrya virginiana*), and pin cherry (*Prunus pensylvanica*)) or contain large amounts of cull (rough and rotten wood). The growth potential of a stand is considered to be reached when it is fully stocked. As stands become overstocked, trees become crowded, growth rates decline, and mortality rates increase. Poorly stocked stands can result from poor harvesting practices or forest growth on abandoned agricultural land; in contrast to moderately stocked stands, poorly stocked stands are not expected to grow into a fully stocked condition within a practical amount of time for timber production.

What we found

The distribution of forest land by size class has changed since 1983 (Fig. 22). A statistically significant decrease in area of medium-diameter stands and a statistically significant increase in area of large-diameter stands have both occurred. The increasing trend toward large-diameter trees is even more evident when current estimates are compared with those from the 1948 inventory (USDA Forest Service 1954; Fig. 23). Timberland area in small-

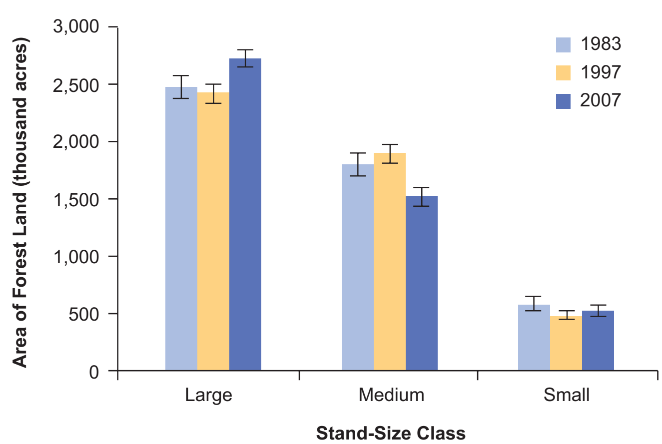


Figure 22.—Area of forest land by stand-size class, New Hampshire, 1983, 1997, and 2007. Error bars represent one sampling error (68%).

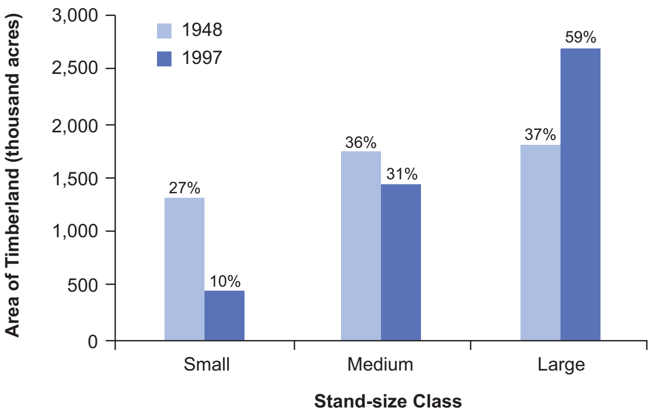


Figure 23.—Area of timberland by stand-size class, New Hampshire, 1948 and 2007.

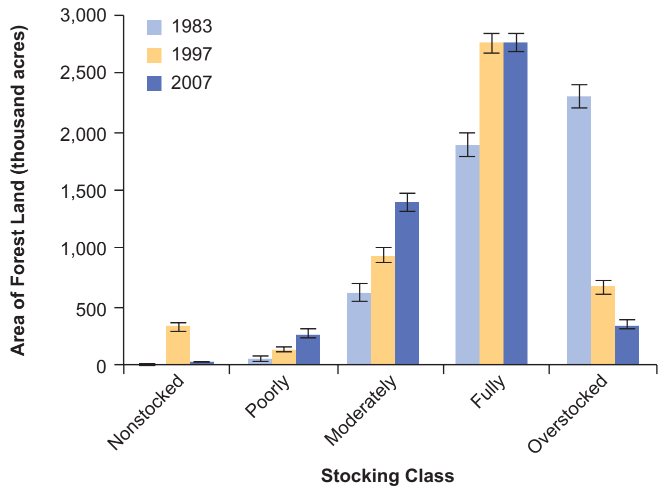


Figure 24.—Area of forest land by stocking class of all live trees, New Hampshire, 1983, 1997, and 2007. Error bars represent one sampling error (68%).

diameter stands decreased from 27 percent in 1948 to only 10 percent in 2007, and timberland area in large-diameter stands increased from 37 percent in 1948 to 59 percent in 2007.

Since 1983, forest land area in the moderately and fully stocked classes for all live trees and growing-stock trees has increased by 1.7 million acres for all trees and by 900,000 acres for growing-stock trees; at the same time overstocked area has decreased by 2 million acres for all trees and by 1.3 million acres for growing-stock trees. Only about 35 percent of stands are less than fully stocked as of 2007. A comparison of nonstocked or poorly stocked stands for all live trees and growing-stock trees in 2007 reveals that the area is 1.6 times greater for growing-stock trees (468,000 to 291,000 acres) (Figs. 24, 25). Out of the nearly one-half million acres that are poorly or nonstocked with growing-stock trees, nearly 35 percent are less than 40 years old and 93 percent are less than 80 years old (Fig. 26).

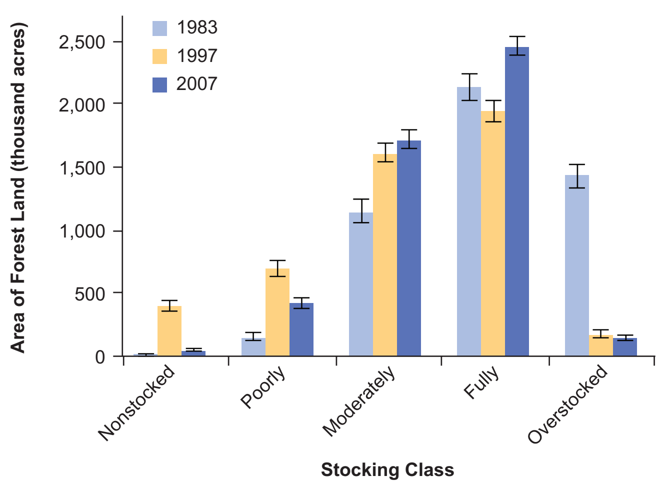


Figure 25.—Area of forest land by stocking class of growing-stock trees, New Hampshire, 1983, 1997, and 2007. Error bars represent one sampling error (68%).

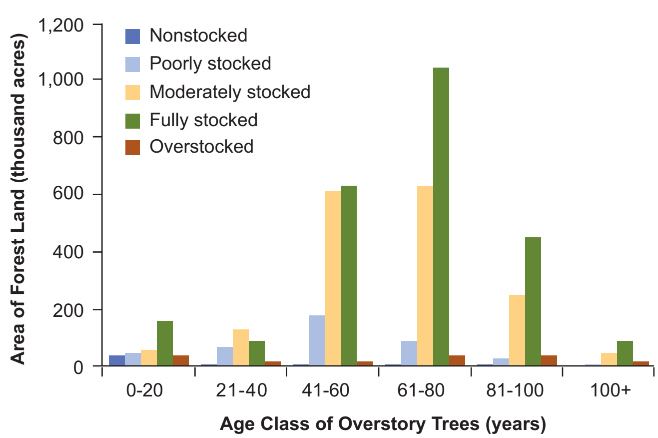


Figure 26.—Area of forest land by stocking class of growing-stock trees and stand-age class, New Hampshire, 2007.

What this means

The trend of increasing forest land area in large-diameter stands demonstrates clearly the continuing maturing of New Hampshire's forests to stands of larger, older trees. An important component of forest biodiversity is complex structural features. Although the area of forest in smaller diameter stands is decreasing, mature stands do provide diverse structures due to gap dynamics and the presence of shade tolerant species in the understory. The diversity of tree ages and sizes present in mature forests provides a broad range of habitats for wildlife and other organisms and makes forests more dynamic and better able to recover from disturbance.

The shifts in forest area out of nonstocked, poorly stocked, and overstocked stands into moderately and fully stocked stands indicate that forest management practices over the past three decades have improved the general stocking condition across the State. The majority of New Hampshire's forest land is well stocked with tree species of commercial importance. From a commercial perspective, continued management of these stands should keep them growing optimally by preventing them from becoming overstocked. From an ecological perspective, New Hampshire has a very low percentage of older forests, so consideration may be given to allowing some areas to continue growing beyond commercial benchmarks in order to allow the development of some ecologically mature forests that support certain wildlife species and ecological processes. Although the nearly one-half million acres of forest land that is poorly or nonstocked with commercially important species represents a loss of potential growth, these forests do contribute to biodiversity. The higher light levels and open growing conditions in these poorly or nonstocked stands may make them more susceptible to invasion by nonnative plant species (e.g., common barberry (*Berberis vulgaris*), multiflora rose (*Rosa multiflora*)).

Numbers of Trees

Background

A basic component of forest inventory is the number of trees; these estimates are simple, reliable, and comparable with estimates from past inventories. When combined with species and size, estimates of numbers of trees are valuable for showing the structure of forests and changes that are occurring over time. Young forests generally have many more trees per acre than older forests, but the latter usually have much more wood volume (or biomass) than younger forests.

What we found

Since 1983, the number of trees in the 12-inch and smaller d.b.h. classes has decreased while the number of trees in the larger classes has increased. The curves of numbers of trees by diameter class have shifted to the right (Fig. 27). In general, the percentage increase in the number of trees by diameter class increased with increasing diameter class except for the largest classes (Fig. 28).

When we look at growing-stock trees 5 inches and larger d.b.h., red maple (*Acer rubrum*) continues to be the most numerous tree species in New Hampshire. Most abundant species in New Hampshire either decreased in number during that time period—eastern white pine,

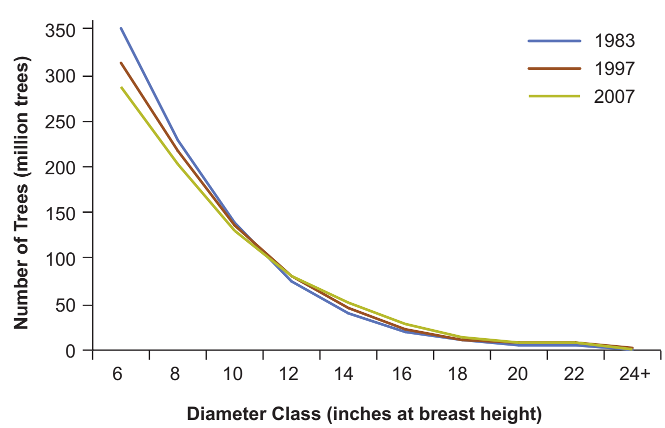


Figure 27.—Number of growing-stock trees on timberland by diameter class, New Hampshire, 1983, 1997, and 2007.

balsam fir (*Abies balsamea*), sugar maple (*Acer saccharum*), paper birch (*Betula papyrifera*)—or remained stable—eastern hemlock (*Tsuga canadensis*), yellow birch (*Betula alleghaniensis*), and American beech (*Fagus grandifolia*). Northern red oak (*Quercus rubra*) and red spruce (*Picea rubens*) increased in numbers (Fig. 29).

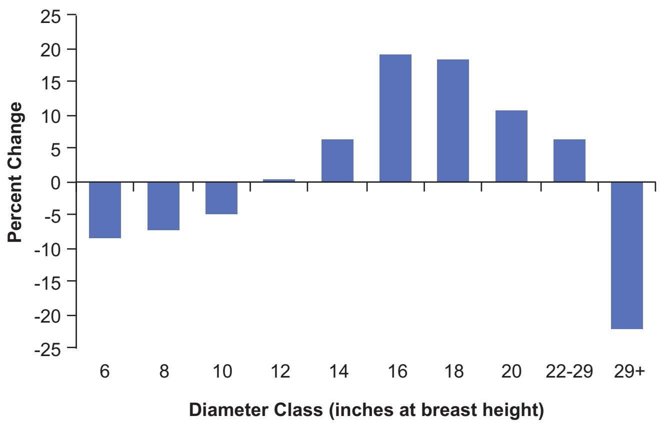


Figure 28.—Percent change in the numbers of growing-stock trees by diameter class, New Hampshire, 1997-2007.

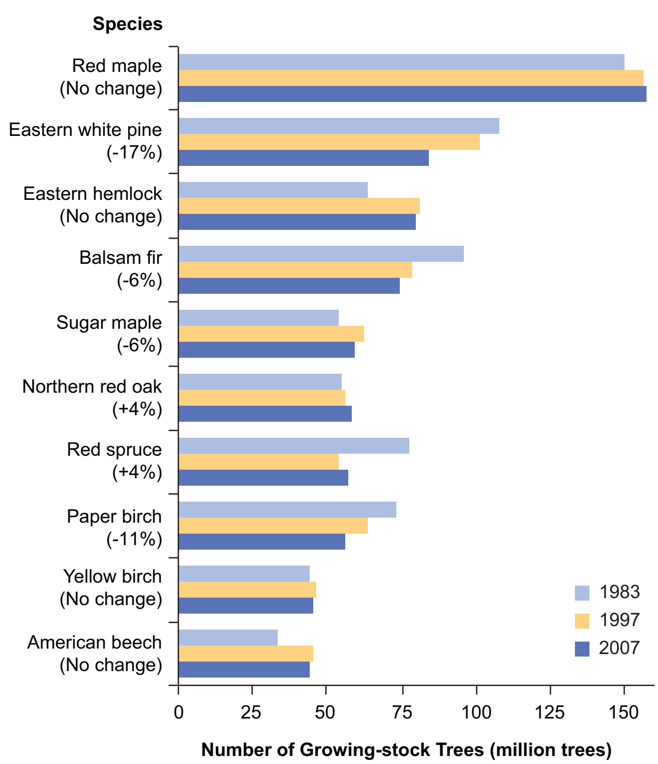


Figure 29.—Number of growing-stock trees on timberland by species, New Hampshire, 1983, 1997, and 2007, and percent change New Hampshire, 1997-2007.

By contrast, most tree species have increased in numbers of sapling-size trees (1 to 4.9 inches d.b.h.). Balsam fir is the most numerous sapling in New Hampshire and continued to increase in numbers between 1997 and 2007. American beech showed the largest increase in number of saplings during that period. Other abundant tree species to show large increases in the number of saplings during this time period are red spruce, yellow birch, and eastern hemlock. The only major species to show a decrease in the number of saplings are red maple and sugar maple (Fig. 30).

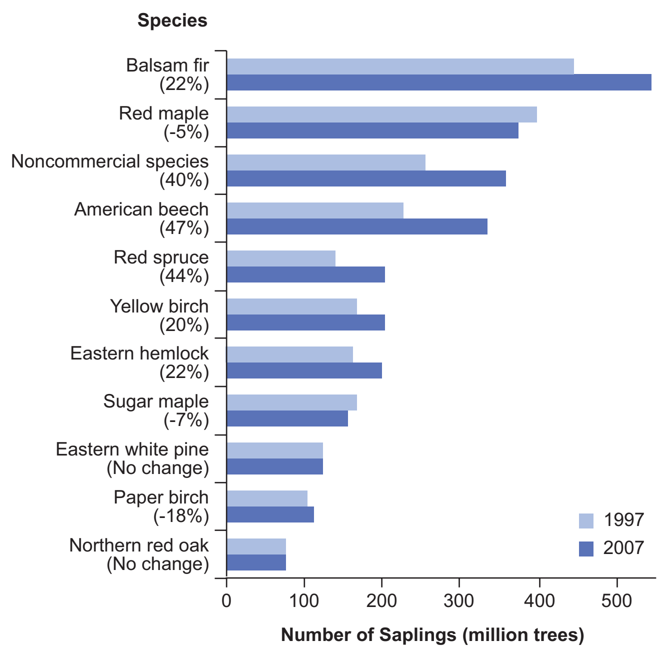


Figure 30.—Number of saplings (1 to 4.9 inches in d.b.h.) on timberland by species, New Hampshire, 1997 and 2007, and percent change, New Hampshire, 1997-2007. Noncommercial species include striped maple, eastern hophornbeam, pin cherry, mountain maple, and other species with poor form.

What this means

Since 1983, the number of large-diameter trees has been increasing steadily in New Hampshire. More recently, the number of trees in the 6- through 10-inch d.b.h. classes has been decreasing, indicating that as trees grow into larger size classes they are not being replaced by smaller trees growing into the medium-diameter classes; however, the number of trees in the medium-diameter category may increase when ingrowth from the small-diameter classes occurs (Fig. 31).

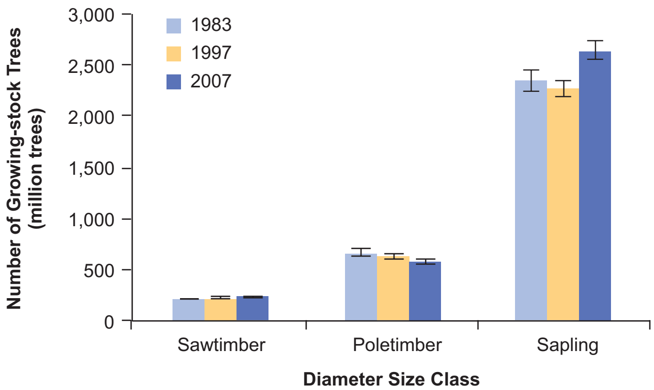


Figure 31.—Number of growing-stock trees by size class, New Hampshire, 1983, 1997, and 2007. Error bars represent one sampling error (68%).

Saplings in today's forest are a prime indicator of the composition of the future forest. Saplings eventually replace large trees that are harvested or killed by insects, diseases, or weather events. The increasing dominance of American beech and balsam fir in the understory will have an impact on the future species composition of New Hampshire's forests.

Biomass

Background

Due to the important role of trees in the carbon cycle, forests act as a major sink for carbon by removing carbon dioxide from the atmosphere and storing it in wood tissue. About half of a tree's biomass is made up of carbon. The increasing interest in carbon dynamics for questions related to carbon sequestration, emission reduction targets, production of biofuels, and forest fire fuel loadings makes estimates of biomass a critical component of the FIA program. Biomass is defined by FIA as the aboveground weight of live trees composed of the boles, aboveground portion of stumps, tops, and limbs (but excluding foliage). Due to increases in tree volume, New Hampshire's forests contribute significantly to carbon sequestration (uptake and storage).

What we found

The forest land of New Hampshire has an estimated 273.3 million dry tons of aboveground tree biomass (an average of 57.1 tons per acre). The distribution of biomass per acre on forest land is displayed in Figure 32. Biomass per acre is highest in southwestern New Hampshire.

The largest portion of the biomass is in the boles of growing-stock trees (64 percent), but this is also the part of the tree resource that can be converted into valuable wood products. The other 36 percent of the biomass is in tops, limbs, stumps, cull trees, or trees of noncommercial species (Fig. 33).

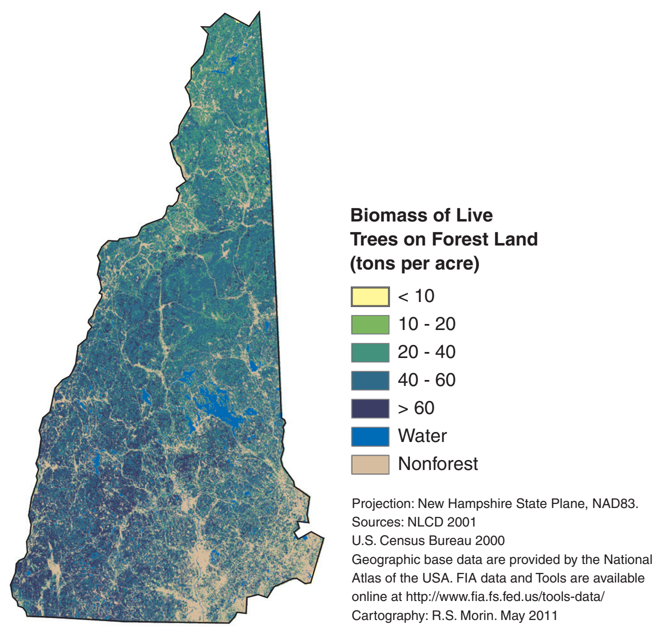


Figure 32.—Live-tree biomass per acre of trees at least 1 inch d.b.h. (dry tons), New Hampshire, 2006.

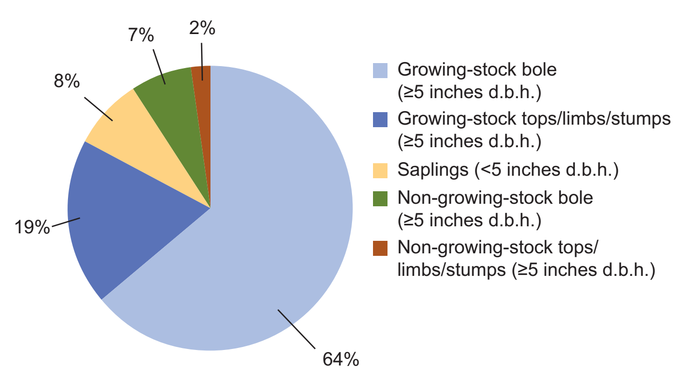


Figure 33.—Percentage of live-tree biomass (trees 1 inch d.b.h. and larger) on forest land by aboveground component, New Hampshire, 2007.

Total live dry biomass on timberland has increased by 22 percent since 1983 (217.8 to 266.7 million dry tons). This increase is primarily due to the increasing size of sawtimber trees in New Hampshire. Biomass also increased slightly in the sapling size class. By contrast, biomass decreased in poletimber-size trees during this time period (Fig. 34).

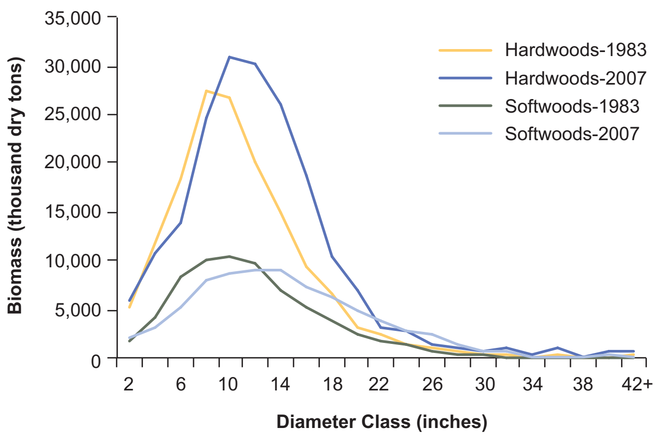


Figure 34.—Distribution of live-tree biomass (trees at least 1 inch d.b.h.) on timberland by species group and 2-inch diameter class, New Hampshire, 1983 and 2007.

What this means

New Hampshire's forests are continuing to accumulate biomass as the forests mature. Because most of the biomass is contained in the boles of growing-stock trees, and most of the gains in biomass stocks are found in the high value sawtimber-size trees, only a fraction of the accumulated material is available for use as fuel. If the demand for biomass increases with increases in heating, power production, and (potentially) the production of liquid fuels, the market would become more competitive as the wood products industry looks for more material. This creates an opportunity for enhancing forest management practices to benefit both traditional forest products supplies and those for bioenergy. The Biomass Energy Resource Center produced a detailed report on supply and sustainability of woody biomass that includes the western counties of New Hampshire (Sherman 2007).

Private forest landowners are the holders of the majority of New Hampshire's biomass (75 percent). Thus they play an important role in sustaining this resource. Currently, forest landowners are not financially compensated for the carbon sequestration service that is provided by the trees on their land. The markets for forest carbon sequestration are growing so this scenario could change in the future. If carbon trading and biomass production become more common, reliable estimates of biomass and carbon in forests, both in the aboveground biomass and in soils, will become more important. The future of this scenario depends on political decisions and crude oil prices.

Carbon Stocks

Background

Collectively, forest ecosystems represent the largest terrestrial carbon sink on earth. The accumulation of carbon in forests through sequestration helps to mitigate emissions of carbon dioxide to the atmosphere from sources such as forest fires and burning of fossil fuels. The FIA program does not directly measure forest carbon stocks in New Hampshire. Instead, a combination of empirically derived carbon estimates (e.g., standing live trees) and models (e.g., carbon in soil organic matter is based on stand age and forest type) are used to estimate New Hampshire's forest carbon stocks. Estimation procedures are detailed by Smith et al. (2006).

What we found

New Hampshire forests currently contain almost 400 million tons of carbon. Live trees and saplings represent the largest forest ecosystem carbon stock in the State at almost 165 million tons, followed by soil organic matter (SOM) at nearly 157 million tons (Fig. 35). Within the live tree and sapling pool, merchantable boles contain the bulk of the carbon (~ 96 million tons) followed by roots (~ 28 million tons) and tops and limbs (~ 23 million tons). The majority of New Hampshire's forest carbon stocks are found in relatively young stands aged 41 to 80 years (Fig. 36). Early

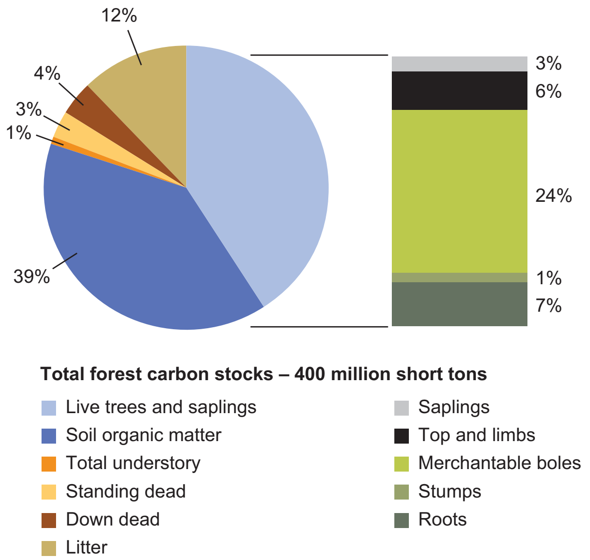


Figure 35.—Estimated total carbon stocks on forest land by forest ecosystem component, New Hampshire, 2007.

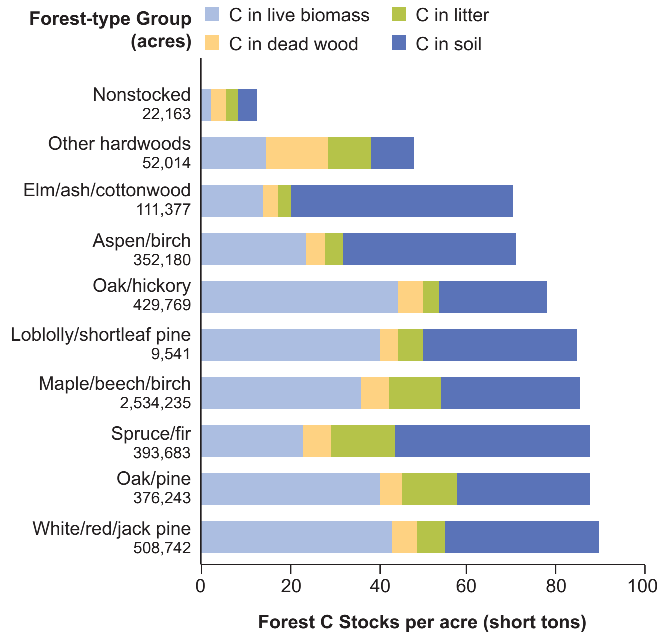


Figure 37.—Estimated carbon stocks on forest land by forest-type group and carbon pool per acre, New Hampshire, 2007.

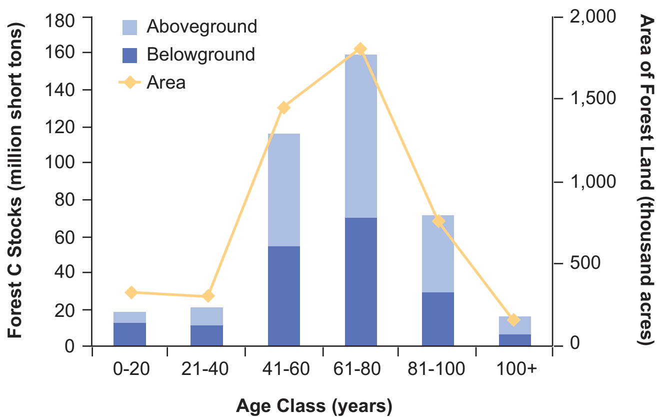


Figure 36.—Estimated aboveground and belowground carbon stocks on forest land by stand-age class, New Hampshire, 2007.

in stand development, most forest ecosystem carbon is in the SOM and belowground tree components. As forest stands mature, the ratio of aboveground to belowground carbon shifts and by age 41 to 60 years the aboveground components represent the majority of ecosystem carbon. This continues well into stand development as carbon accumulates in live and dead aboveground components. A look at carbon by forest-type group on a per unit area basis found that 8 of the 10 groups have between 70 and 90 tons of carbon per acre (Fig. 37). Despite the similarity in per acre estimates, the distribution of forest carbon stocks by forest type is quite variable. In the elm/ash/cottonwood group, for example, 71 percent (~ 50 tons) of the forest carbon is in the SOM, whereas in the oak/ hickory group, only 31 percent is in the SOM.

What this means

Carbon stocks in New Hampshire's forests have increased substantially over the last several decades. The majority of forest carbon in the State is found in relatively young stands dominated by moderately long-lived species. This suggests that New Hampshire's forest carbon will continue to increase as stands mature and accumulate carbon in aboveground and belowground components. Given the age class structure and species composition of forests in New Hampshire, there are many opportunities to increase forest carbon stocks. That said, managing for carbon in combination with other land management objectives will require careful planning and creative silviculture beyond simply managing to maximize growth and yield.

Volume of Growing-stock Trees

Background

To assess the amount of wood potentially available for commercial products, the FIA program computes growing-stock volumes for trees that meet requirements for size, straightness, soundness, and species, that are growing on timberland. Growing-stock volume includes only trees at least 5 inches d.b.h. and excludes rough, rotten, and dead trees in addition to noncommercial tree species. The forest products industry relies on this estimate of growing-stock volume as its resource base. Current volumes and changes in volume over time can characterize forests and reveal important resource trends. This is especially important concerning trend information because many past FIA inventories have only growing-stock estimates available.

What we found

The total growing-stock volume of the State has increased steadily since the 1960s. The 2007 estimate of 9.4 billion cubic feet is a statistically significant increase since the 1997 inventory. That increase in growing-stock volume of about 0.5 percent annually is a reduction compared with the 1- to 4.5-percent annual increases in previous decades (Fig. 38). Distributions of growing-stock volumes by diameter class from the current and two previous inventories reveal a steady shift in timber volume toward larger diameter trees (Fig. 39). During the most recent inventory period (2002-2007), volume increased in all d.b.h. classes greater than 10 inches, but decreased in the 6-, 8-, and 10-inch diameter classes (Fig. 40).

There are nearly 9.5 billion cubic feet of growing-stock volume on timberland in New Hampshire (approximately 2,051 cubic feet/acre). Of this volume, 60 percent is in hardwood species and 40 percent is in softwood species. Red maple (26 percent), northern red oak (18 percent), sugar maple (14 percent), yellow birch (9 percent), and paper birch (8 percent) make up 75 percent of the

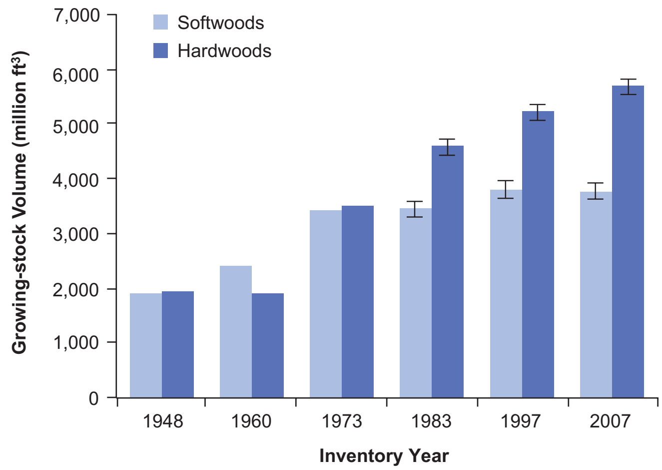


Figure 38.—Growing-stock volume on timberland by species group and inventory year, New Hampshire, 1948, 1960, 1973, 1983, 1997, and 2007. Error bars represent one sampling error (68%).

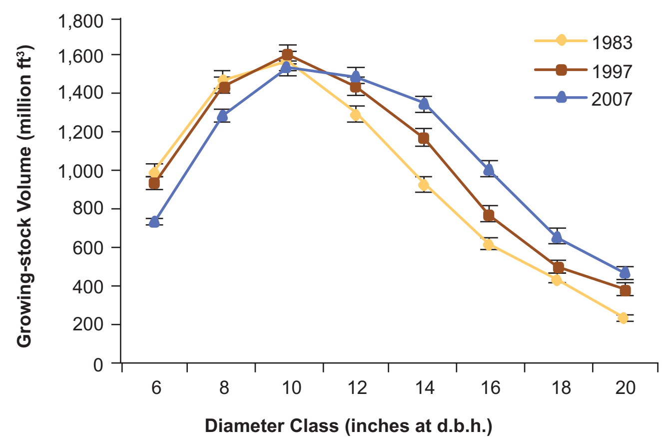


Figure 39.—Growing-stock volume on timberland by diameter class and inventory year, New Hampshire, 1983, 1997, and 2007.

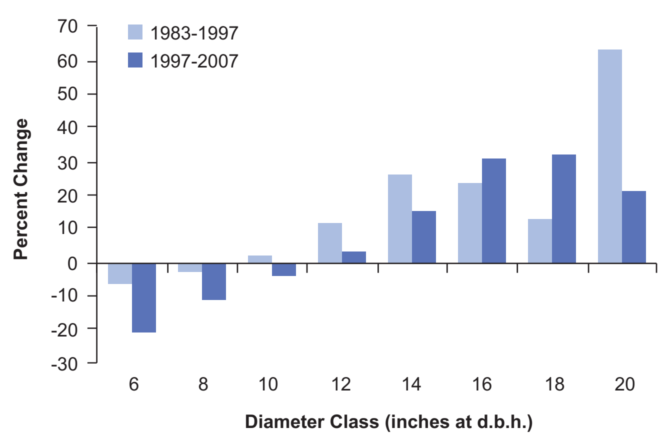


Figure 40.—Percent change in growing-stock volume by diameter class on timberland, New Hampshire, 1983-1997 and 1997-2007.

hardwood growing-stock volume. Eastern white pine (51 percent), eastern hemlock (22 percent), red spruce (13 percent), and balsam fir (11 percent) account for nearly 97 percent of softwood growing-stock volume.

Eastern white pine continues to make up the largest amount of growing-stock volume followed by red maple, northern red oak, and eastern hemlock. These species make up 56 percent of the total growing-stock volume in New Hampshire. The only species that showed significant increases in growing-stock volume were red maple and northern red oak; no species had significant decreases (Fig. 41).

When we estimate board-foot volume, the order of the top four species by volume is slightly different than for growing-stock volume. The increase in total board-foot volume is statistically significant (18 percent).

Eastern white pine remains the leading species by a large margin, but northern red oak replaces red maple as the second highest. Eastern white pine makes up more than 31 percent of the total sawtimber volume in New Hampshire (Fig. 42). Northern red oak, red maple, and yellow birch increased significantly in sawtimber volume between the 1997 and 2007 inventories.

The distribution of total growing-stock volume and for the top four species is shown in Figure 43. Total volume increases from north to south with higher volumes in the southern portion of the State and along the White Mountains to the north. Volume per acre varies spatially by species. Eastern white pine, northern red oak, and eastern hemlock are concentrated in southern New Hampshire. Red maple is distributed throughout the State with the highest volumes in the south.

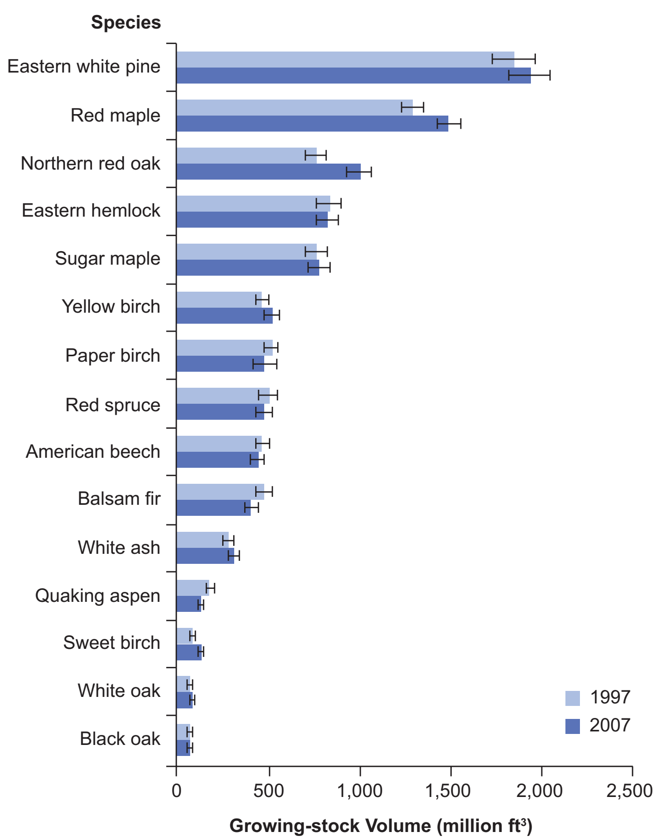


Figure 41.—Growing-stock volume on timberland by species, New Hampshire, 1997 and 2007. Error bars represent one sampling error (68%).

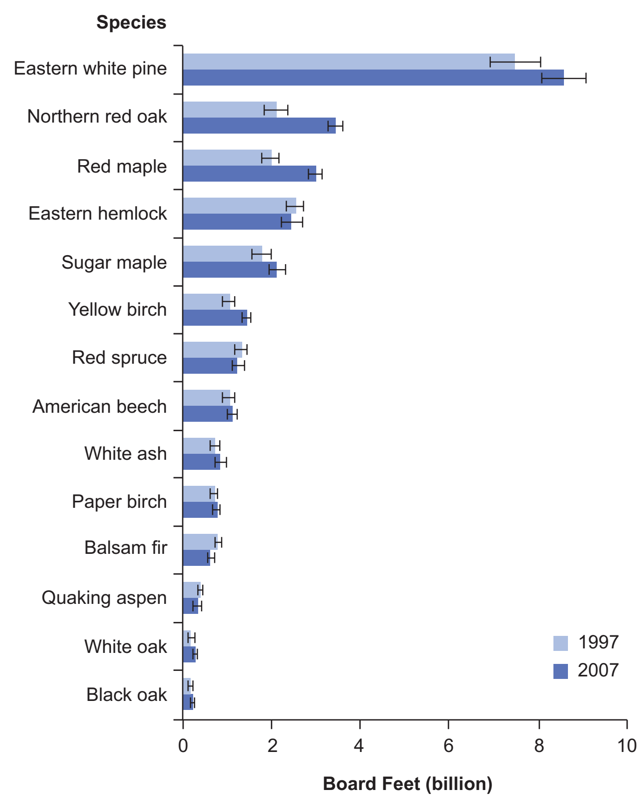


Figure 42.—Board-foot volume on timberland by species, New Hampshire, 1997 and 2007. Error bars represent one sampling error (68%).

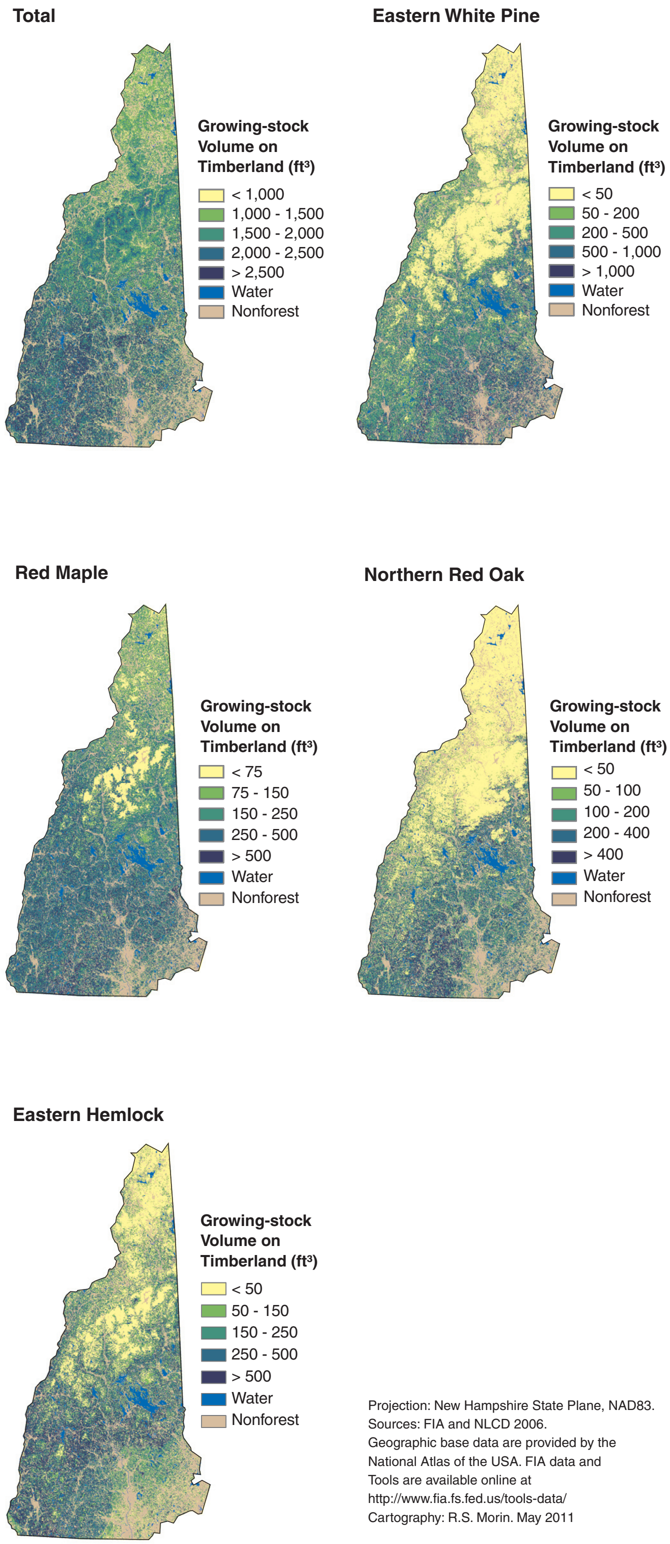


Figure 43.—Growing-stock volume per acre (trees at least 5 inches d.b.h.) on forest land, New Hampshire, 2006.

What this means

Due to the continuing increases in volume, New Hampshire's timber resources are at record levels since FIA began doing inventories in 1948. Although growing-stock volumes continue to increase, this increase has slowed and growth rates may decrease further as the forest ages. By contrast, significant increases are concentrated in sawtimber-size trees, illustrated by the significant increase in sawtimber volume. Even though the rate of increase is leveling off, the forests of New Hampshire are adding value at an increasing rate due to growth that is occurring on the higher valued trees. Landowners and the forest products industry can benefit from the increase in value, but care in management and harvesting practices will be important to ensure a steady supply into the future as the population of poletimber-size trees replaces the sawtimber-size trees.

Hardwood Sawtimber Quality

Background

Species, size, and quality of a tree determine its value in the forest products market. The highest quality timber, used in the manufacture of cabinets, furniture, flooring or other millwork, is the most valuable. Lower quality trees are utilized as pallets, pulpwood, and fuelwood. The quality of an individual tree varies by species as well as diameter, growth rate, and management practice. Hardwood trees must be at least 11 inches d.b.h. to qualify as sawtimber. FIA assigns tree grades to sawtimber-size trees as a measure of quality. Tree grade is based on tree diameter and the presence or absence of defects such as knots, decay, and curvature of the bole. The grades decrease in quality from grade 1 (high grade lumber) to tie/local use material.

What we found

The proportion of sawtimber volume in tree grades 1 and 2 increased from 33 percent in 1997 to 38 percent in 2007, an increase from 3.6 to 5.4 billion board feet.

Volume in the lowest grade (tie/local use) increased from 1.6 to 3.3 billion board feet and increased as a proportion of the total from 10 percent to 15 percent (Fig. 44).

In New Hampshire, northern red oak, white oak, and white ash are the only species with more than 50 percent of their sawtimber volume in tree grades 1 and 2. Sugar maple and black oak have at least 35 percent of their sawtimber volume in grades 1 and 2. By contrast, red maple and American beech have less than 20 percent of their sawtimber volume in grades 1 and 2 (Fig. 45). Many beech trees contain large amounts of rotten wood due to the impacts of beech bark disease. Red maple typically has more defects than other species.

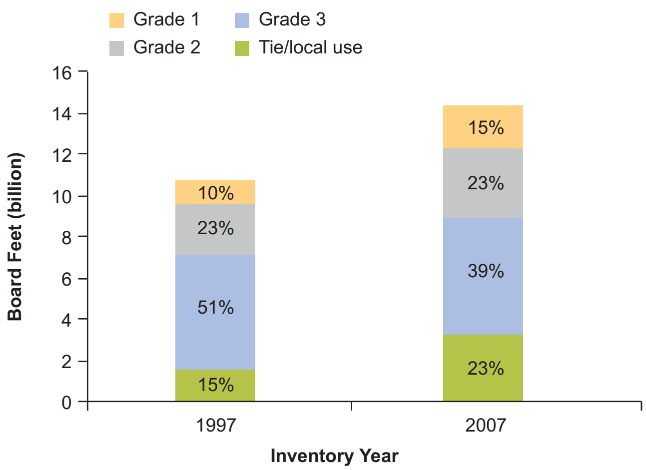


Figure 44.—Hardwood board-foot volume by tree grade, New Hampshire, 1997 and 2007.

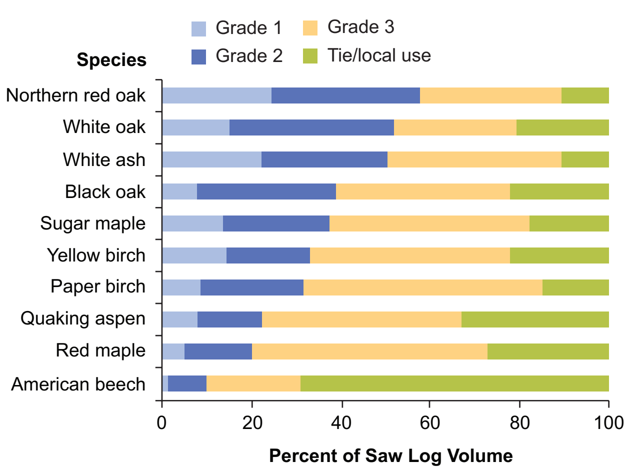


Figure 45.—Percentage of saw log volume on timberland by species and tree grade, New Hampshire, 2007.

What this means

The quality of saw logs in New Hampshire has remained stable since the last inventory, but the value of sawtimber has increased based on the increase in available board-foot volume. For example, northern red oak board-foot volume increased significantly between 1997 and 2007 (Fig. 42), and it has the highest proportion of its volume in grade 2 or better trees (58 percent). Changes in species composition point toward potential reductions in tree quality into the future. The species with the highest proportion of low-grade volume, American beech (Fig. 45), shows the largest increase in saplings (Fig. 30).

Average Annual Net Growth and Removals

Background

Forests provide a renewable resource if they are well managed to provide a constant supply of useful products without impacting long-term productivity. The rate of growth is an indicator of the overall condition of a stand as well as forest health, successional stage, and tree vigor. Average annual net growth (gross growth minus mortality) is calculated by measuring trees at two points in time and by determining the average annual change over the time period. Net growth is negative when mortality exceeds gross growth. A useful measure to assess growth is the percentage of annual net growth to current inventory volume. Average annual net growth estimates are based on change in volume of growing stock on timberland between the 1997 and 2007 inventories.

What we found

Since 1973, average annual net growth has been steadily decreasing (Fig. 46). Net growth averaged 164 million cubic feet annually between 1997 and 2007, about 2 percent of growing-stock volume on timberland. In

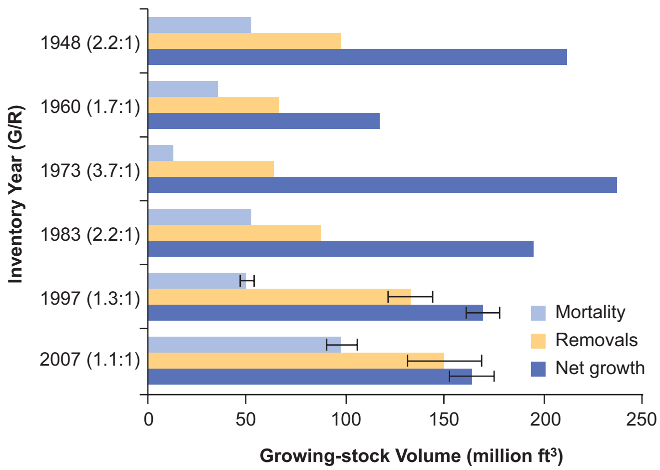


Figure 46.—Net growth, removals, mortality, and growth-to-removal ratio of growing stock on timberland, New Hampshire, 1948, 1960, 1973, 1983, 1997, and 2007.

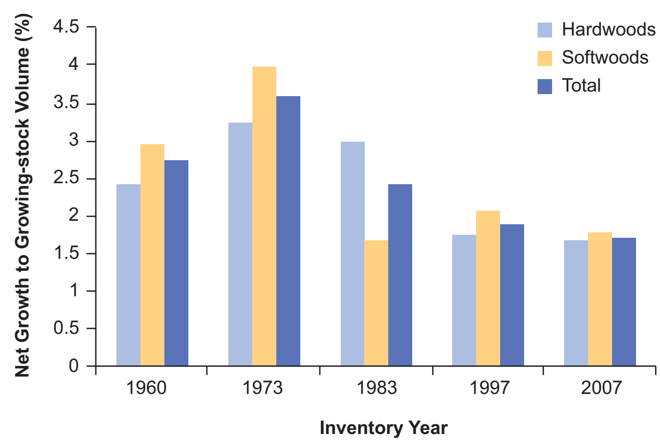


Figure 47.—Net growth of growing stock on timberland as a percent of growing-stock volume on timberland, New Hampshire, 1960, 1973, 1983, 1997, and 2007.

comparison to previous inventories, the 1997 and 2007 proportions of annual net growth to growing-stock volume are the lowest ever reported (Fig. 47). In 2007, about 60 percent of net annual growth was in hardwoods and 77 percent was on privately owned land.

The top 10 species by growing-stock volume accounted for 97 percent of the average annual net growth of growing stock on timberland from 1997 to 2007. The ratio of growth-to-removals averaged 1.1:1.0 for 1997-2007, but variation between species was considerable. Net growth exceeded removals for most major species, but eastern white pine and red spruce removals exceeded net growth. American beech net growth was even with removals at 1.0:1.0. Red maple, northern red oak, and sugar maple had the highest growth-to-removals ratios at 2.4:1, 2.6:1, and 2.3:1.0, respectively (Fig. 48).

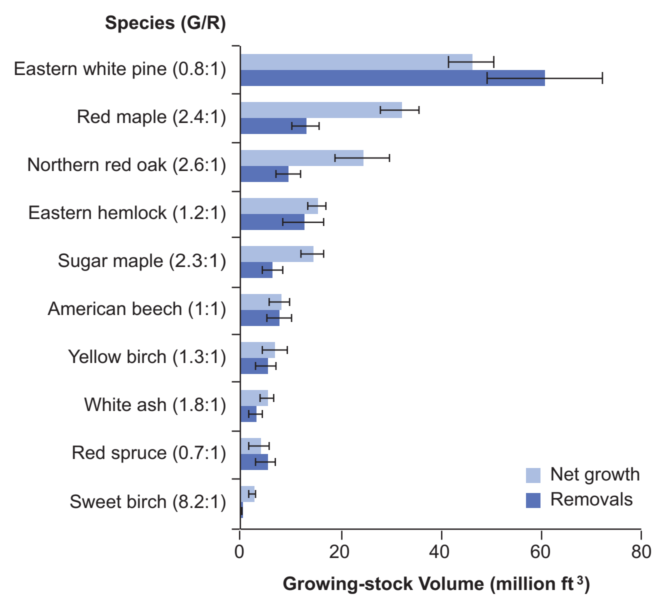


Figure 48.—Average annual net growth, removals, and growth-to-removals (G/R) ratio for major species, New Hampshire, 2007. Error bars represent one sampling error (68%). G/R for all species= 1.1:1.

What this means

The well-stocked stands in the current forests of New Hampshire developed as a result of the growth-to-removal ratios being well above 1.0:1.0 for most of the second half of the 20th century, but more recently, New Hampshire's forests have matured and the rate of growth has slowed. In fact, the 1983 to 1997 and 1997 to 2007 periods are the first time the growth-to-removal ratio has dropped below 2.0:1.0 since the 1960s (Fig. 46). Even with the slower growth rate, the current level of removals appears to be sustainable for the near term barring more increases in mortality. Nunery and Keeton (2010) concluded that unmanaged stands will sequester more carbon than those that are actively managed. Therefore, even with slowing net growth rates, as long as removals are less than net growth, the forests of New Hampshire should continue to sequester more carbon than they emit. Fortunately, more than 90 percent of the removals volume is due to harvesting and not land use change. Trees will regenerate because the land remains in timberland.

A comparison of the growth-to-removals ratios of individual species to the average for all species is an indicator of which species may be decreasing or increasing in abundance. The low growth-to-removals ratios of eastern white pine (0.8:1.0) and balsam fir (0.7:1.0) suggest that both of those species could be decreasing in abundance (Fig. 45). This could especially be true for eastern white pine given the low number of eastern white pine saplings present in the State. By contrast, balsam fir has the highest number of saplings in the State and appears to be increasing in numbers (Fig. 30).

Average Annual Mortality

Background

Mortality is a natural part of stand development in healthy forest ecosystems. Many factors contribute to mortality including competition, succession, insects, disease, fire, human activity, drought, and many others. Mortality is often initiated by one causal agent (inciting factor), then followed by contributing stress factors making the underlying cause difficult to identify. Although mortality is a natural event in a functional forest ecosystem, dramatic increases in mortality can be an indication of forest health problems. Average annual growing-stock mortality estimates represent the average cubic-foot volume of sound wood that died each year between the 1997 and 2007 inventories. During this time interval, New Hampshire has experienced a range of disturbances that have stressed forests, either as inciting factors or as contributors to mortality.

What we found

The estimated average annual mortality rate for growing-stock trees in New Hampshire for 2007 was 98 million cubic feet, which is approximately 1.0 percent of growing-stock volume. This is the highest mortality rate ever reported in an FIA inventory of New Hampshire. Earlier estimates ranged from 0.6 to 0.7 percent. Softwoods have had a higher mortality rate than hardwoods during every inventory period (Fig. 49). Despite the increase, New Hampshire's mortality rate is similar to many other states in the region. For example, Vermont's rate is 0.9 percent, Maine's is 1.2 percent, and New York's is 0.9 percent. The rate of mortality increased between 1997 and 2007 for nearly all diameter classes. The highest mortality rates are generally found in the smaller diameter classes (Fig. 50).

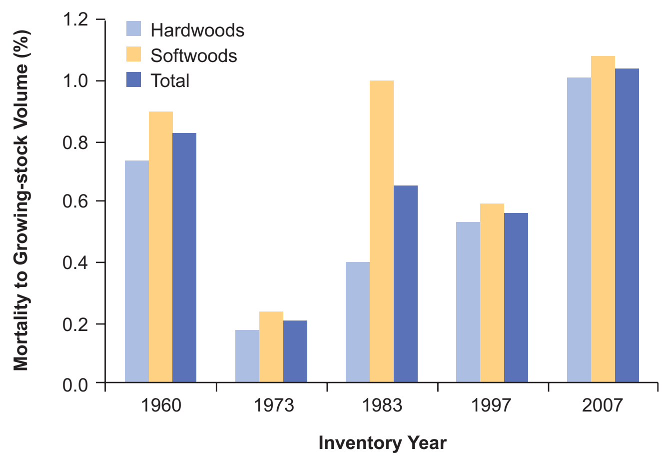


Figure 49.—Mortality of growing stock on timberland as a percent of growing-stock volume on timberland, New Hampshire, 1960, 1973, 1983, 1997, and 2007.

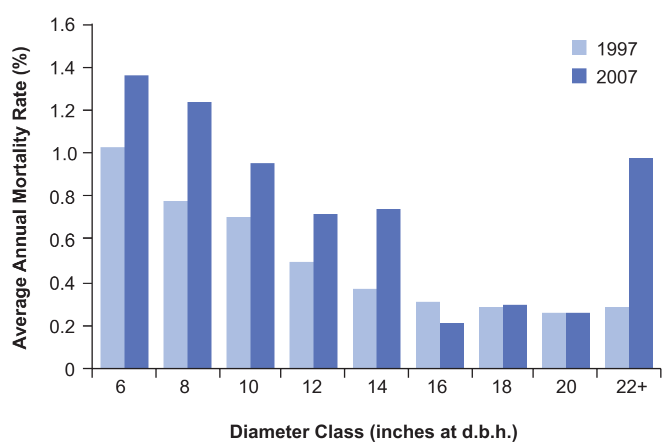


Figure 50.—Average annual mortality rate (in percent) of growing-stock volume on timberland by diameter class, New Hampshire, 1997 and 2007.

Mortality also increased across nearly all species between 1997 and 2007. Paper birch had the largest increase in mortality rate, but balsam fir, red maple, eastern white pine, red spruce, and sugar maple also increased significantly (Fig. 51). Although mortality rates have generally increased over time, most of the abundant species in New Hampshire have relatively low mortality rates. The annual average mortality rates of red maple, northern red oak, sugar maple, eastern hemlock, and eastern white pine are all below the 1 percent annual average for tree species combined (Fig. 52). By contrast, balsam fir and paper birch have mortality rates that are more than double the statewide averages.

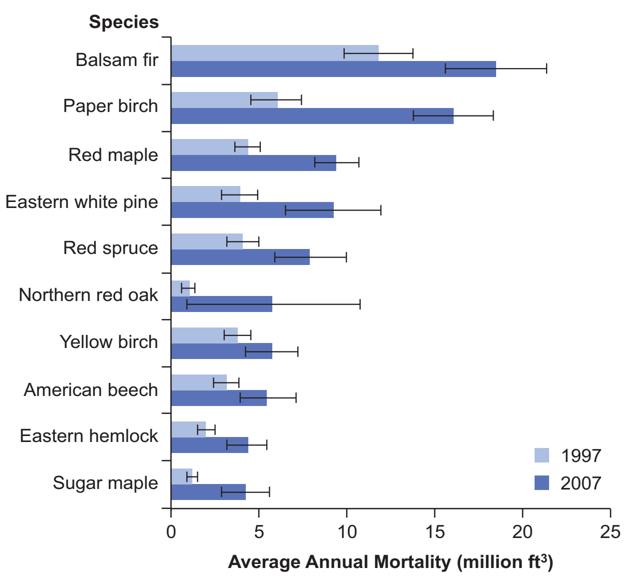


Figure 51.—Average annual mortality of growing stock on timberland for major species, New Hampshire, 1997 and 2007. Error bars represent one sampling error (68%).

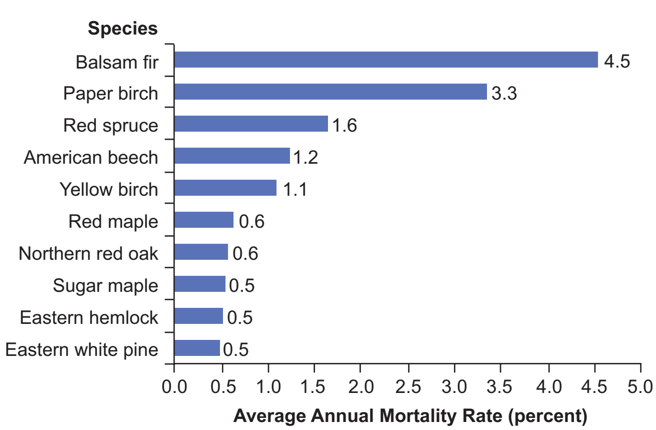


Figure 52.—Average annual mortality rate (in percent) for major species, New Hampshire, 2007. Average for all species = 1.0%.

What this means

Tree mortality rates in New Hampshire have increased over the rates reported in previous inventories, but these rates are comparable to those in surrounding states. Some of the mortality can be explained by stand dynamics (e.g., competition and succession) and the impacts of insects and diseases that affect specific species (e.g., beech bark disease on American beech). In the normal maturation process, some trees lose vigor and eventually die from being outcompeted or succumb to insect and disease during their weakened state; this is especially apparent in trees 12 inches and smaller d.b.h. (Fig. 50).

Most species in New Hampshire have low mortality rates, but some have elevated rates. Species such as balsam fir, paper birch, red spruce, and American beech have increased the overall statewide mortality rate. American beech has been heavily impacted by beech bark disease for many decades. Weather-related events that significantly affected tree health during this time period include the aftereffects of the 1998 ice storm and droughts during 1999 and 2001. Recovery from the ice storm was particularly poor for beech and paper birch trees. Drought effects were especially significant for species with shallow root systems such as birch and beech, or for species likely growing on sites with shallow soils such as balsam fir and red spruce. Additional health problems were observed from forest tent caterpillar defoliation, beech bark disease, spruce winter injury, and balsam woolly adelgid. Recovery following stress events is often dependent on soil fertility; trees growing on calcium rich sites are more likely to recover (Schaberg et al. 2006, Shortle and Smith 1988).

Species Composition

Background

The species composition of a forest is the result of the interaction of climate, soils, disturbance, competition among trees species, and other factors over time. Causes of forest disturbance in New Hampshire include ice storms, logging, droughts, insects and diseases, and land clearing followed by abandonment. The species composition of the growing-stock volume and large-diameter trees represents today's forest, while the species composition of the smaller diameter classes represents the potential future forest. Comparisons of species composition by diameter class can provide insights into potential changes in overstory species composition.

What we found

In New Hampshire, balsam fir is the most numerous sapling (1 to 4.9 inches d.b.h.) accounting for 19 percent of all saplings, followed by red maple at 13 percent and American beech at 10 percent (Fig. 53). Noncommercial tree species (combined) also represent a large portion of saplings at 9 percent. Striped maple is the most numerous of these noncommercial species followed by pin cherry and eastern hophornbeam. Eastern white pine is the dominant species within nearly all diameter classes 5 inches d.b.h. and larger, but it is poorly represented in the sapling classes (less than 5 percent) although it makes up a large portion of trees greater than 20 inches d.b.h (Fig. 54). Other species, which have lower representation in the sapling classes compared to the larger diameter classes, include eastern hemlock, northern red oak, sugar maple, and paper birch. In addition to American beech, balsam fir and red spruce make up a higher portion of total saplings relative to their share of larger trees. Since the 1960 inventory, sugar maple, red maple, and northern red oak have increased in the proportion of total growing-stock volume they represent (Fig 55). Species that have decreased as a percentage of the total growing-stock volume include spruce, yellow birch, American beech, paper birch, balsam fir, and eastern white pine (Fig. 56).

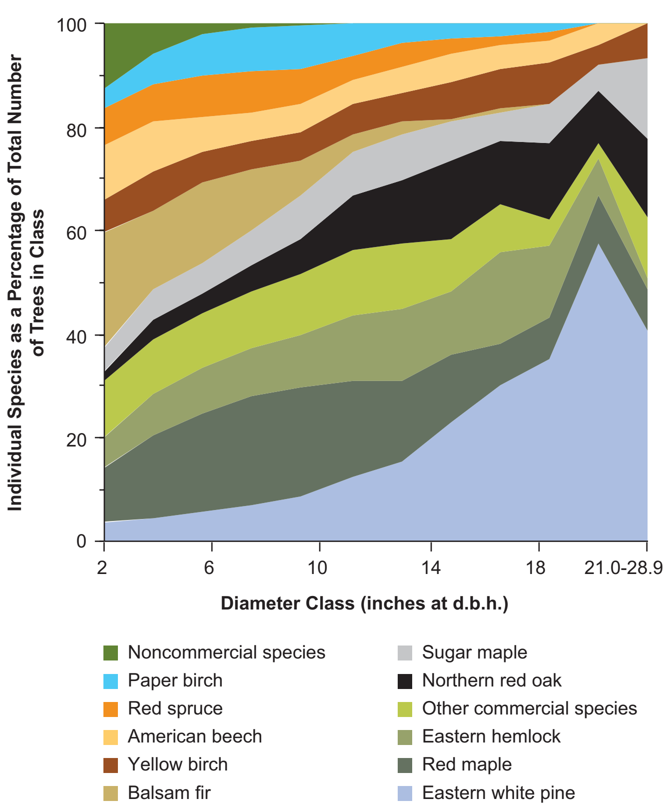


Figure 53.—Species composition by diameter class on forest land, New Hampshire, 2007.

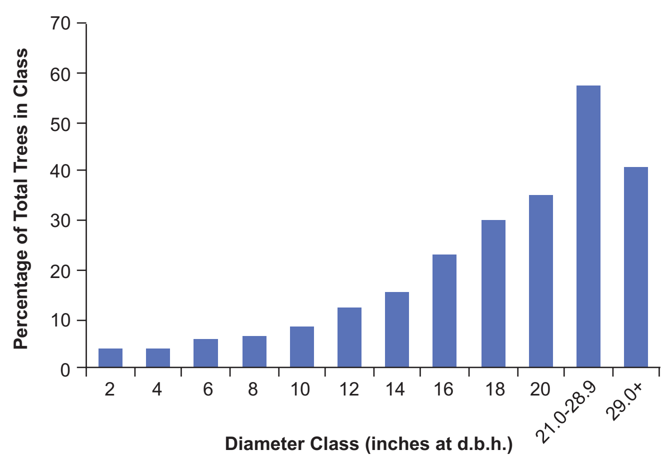


Figure 54.—White pine as a percentage of the total number by diameter class on forest land, New Hampshire, 2007.

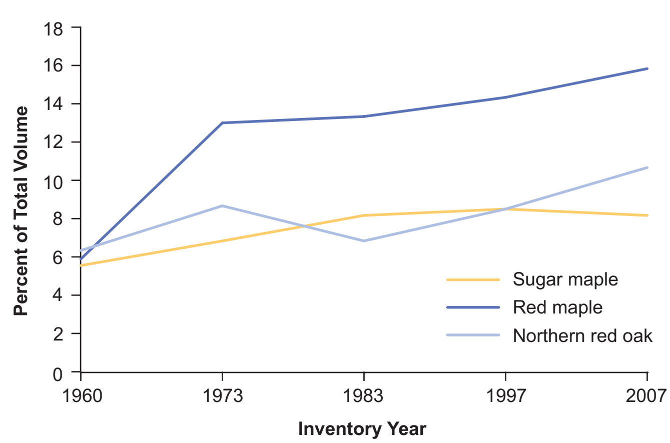


Figure 55.—Species that have increased as a percentage of total growing-stock volume on timberland, New Hampshire, 1960-2007.

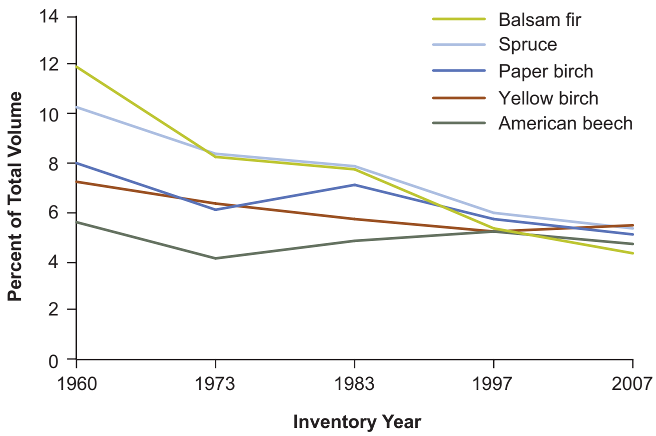


Figure 56.—Species that have decreased as a percentage of total growing-stock volume on timberland, New Hampshire, 1960-2007.

What this means

Conditions in the understory favor reproduction of shade tolerant species as shown by the higher proportion of beech, balsam fir, and red spruce in the sapling diameter classes compared to the larger diameter classes. Besides being shade tolerant, large numbers of sapling-size American beech trees are likely the result of root sprouts following beech bark disease. Many of these young beech trees will eventually succumb to the disease before they have the opportunity to grow into the overstory, while occupying valuable growing space and inhibiting the growth of other more valuable species. By contrast, eastern hemlock, another shade tolerant species, makes up a lower percentage of tree numbers in the sapling diameter classes when compared to the larger diameter trees. This indicates that hemlock is not regenerating as well as it would be expected to do in the maturing forest of New Hampshire. Noncommercial species provide habitat diversity in the understory, although they can interfere with the reproduction of commercial species if they become too numerous. Striped maple now makes up 7 percent of trees in the 2- inch diameter class. Land managers should be made aware of this species' potential to cause problems in forest regeneration.

Eastern white pine is well represented in the large-diameter classes; it ranks first statewide in sawtimber volume (Fig. 42). But because it is poorly represented in the small-diameter classes (less than 5 percent of saplings), it will probably be replaced by other species as the larger eastern white pine trees die or are harvested. Red maple and balsam fir represent the largest portion of trees in diameter classes from 4 to 14 inches. Those two species are positioned to increase in dominance in New Hampshire's forest in future decades. Trends in volume show that, since 1960, sugar maple, red maple, and northern red oak have increased in the proportion of total volume they represent. If the current species composition remains constant as saplings mature, these data foretell a future forest overstory with more red maple and balsam fir trees and less eastern white pine than today. Long-term changes in New Hampshire's forest composition will alter wildlife habitats and affect the value of the forest for timber products. Close examination of species composition changes in the future will be necessary due to the potential impacts of climate change on species.

Wooded stream in Franconia State Park, NH. Photo by Elizabeth Morin.

Forest Products

Skidder on landing from timber harvest on private land in NH. Photo by Andy Fast, UNH Cooperative Extension.

Timber Products

Background

The harvesting and processing of timber products produces a stream of income shared by timber owners, land managers, marketers, loggers, truckers, and processors. The wood products and paper manufacturing industries in New Hampshire employed more than 4,700 people, with an average annual payroll of more than $181 million, and a total value of shipments of $979 million (U.S. Census Bureau 2007). To better manage the State's forests, it is important to know the tree species, amounts, and locations of timber being harvested.

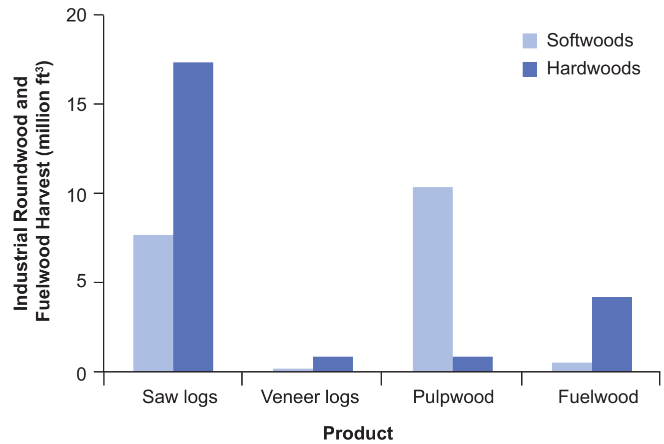


Figure 57.—Roundwood harvest by product, New Hampshire, 2006.

What we found

Surveys of New Hampshire's wood-processing mills are conducted periodically to estimate the amount of wood volume that is processed into products. This is supplemented with the most recent surveys conducted in surrounding states that processed wood harvested from New Hampshire. In 2006, approximately 85 active primary wood-processing mills were surveyed to determine what species were processed and where the wood material came from. These mills processed more than 220 million board feet of saw and veneer logs.

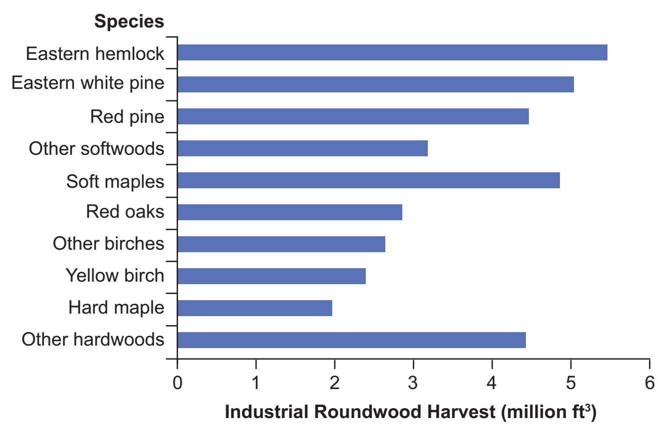


Figure 58.—Roundwood harvest by major species group, New Hampshire, 2006.

A total of 37.4 million cubic feet of industrial roundwood was harvested from New Hampshire during 2006. Saw logs accounted for 67 percent of the total industrial roundwood harvested, followed by pulpwood at 30 percent (Fig. 57). Eastern hemlock, white pine, and red pine, combined, accounted for 40 percent of the total industrial roundwood harvest. Other important species groups harvested were the maples, birches, and oaks (Fig. 58). An additional 4.8 million cubic feet of wood was harvested for residential fuelwood.

Figure 59.—Logging residue by tree class and species group, New Hampshire, 2006.

During the process of harvesting industrial roundwood, 36 million cubic feet of harvest residues were left on the ground (Fig. 59). Approximately 80 percent of the logging residue came from nongrowing-stock sources such as crooked or rotten trees, tops and limbs, and noncommercial species. The remaining 20 percent was growing-stock volume left on site. The processing of industrial roundwood in the State's primary wood-using mills generated another 22 million cubic feet (335,000 dry tons) of wood and bark residues. Most of the mill residue generated was used for industrial and residential fuelwood, fiber products such as pulp and composite panels, and other miscellaneous products such as mulch or animal bedding. Only 2 percent of the mill residues were not used for other products (Fig. 60).

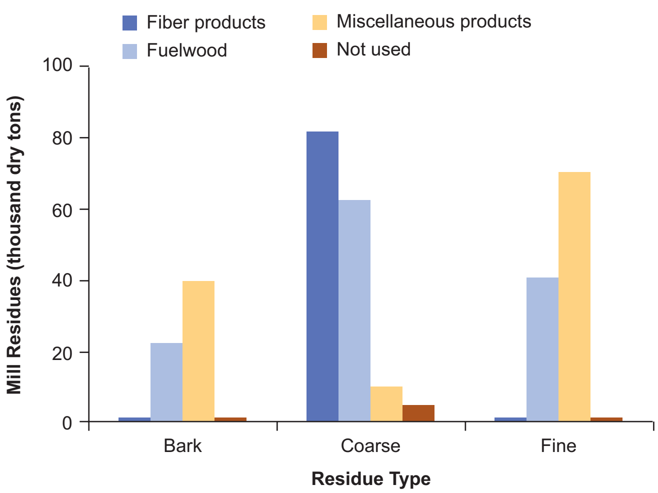


Figure 60.—Logging residue by residue type and product, New Hampshire, 2006.

What this means

The last two pulp mills, which were two of the largest wood-consuming mills in the State, closed in 2005 and 2006. Now, all pulpwood harvested goes to mills in other states or to Canada. Wood-fired energy plants like the Schiller facility in Portsmouth remain markets for the low-grade wood material that once went to New Hampshire's pulp mills.

The demand for wood products is likely to increase, placing a greater demand on the resource. An important consideration for the future of the primary wood-products industry is its ability to retain industrial roundwood processing facilities. The number of wood-processing mills has been steadily declining. The loss of processing facilities makes it harder for landowners to find markets for the timber harvested from their forest land.

Another important issue is the volume of harvest residues generated in New Hampshire that go unused. More than 20 percent of the harvest residue is from growing-stock sources that could be used for products. Improved industrial fuelwood or pulpwood markets could lead to better utilization of merchantable trees. The use of logging slash and mill residues for industrial fuelwood at cogeneration facilities and pellet mills could also result in better utilization of the forest resource.

Cow moose and calf near a forest edge in northern New Hampshire. Photo by Randall Morin, U.S. Forest Service.

Forest Indicators

Decaying yellow birch tree. Photo by Jack Tracy.

Tree Crown Conditions

Background

The crown condition of trees is influenced by various biotic and abiotic stressors. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, soil physical properties affecting soil moisture and aeration, or toxic pollutants. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals.

Seasonal or prolonged drought periods have long been a significant and historical stressor in New Hampshire. Since the 1997 FIA inventory, droughts have occurred in some regions during 1999 and 2001; alternatively, some of the wettest years on record were 2006 and 2008 (Fig. 61; NCDC 2010). These extreme precipitation events can produce conditions that facilitate insect and/or disease outbreaks and can be even more devastating to trees that are stressed by pest damage or other agents.

Invasions by exotic diseases and insects are one of the most important threats to the productivity and stability of forest ecosystems around the world (Liebhold et al. 1995, Pimentel et al. 2000, Vitousek et al. 1996). Over the last century, New Hampshire's forests have suffered the effects of native insect pests such as forest tent caterpillar (*Malacosoma disstria*) and well-known exotic and invasive agents such as Dutch elm disease (*Ophiostoma ulmi*), chestnut blight (*Cryphonectria parasitica*), European gypsy moth (*Lymantria dispar*), and the beech bark disease complex. A more recent invasion in New Hampshire included hemlock woolly adelgid (*Adelges tsugae*), and potential future invaders include emerald ash borer (*Agrilus planipennis*) and Asian longhorned beetle (*Anoplophora glabripennis*).

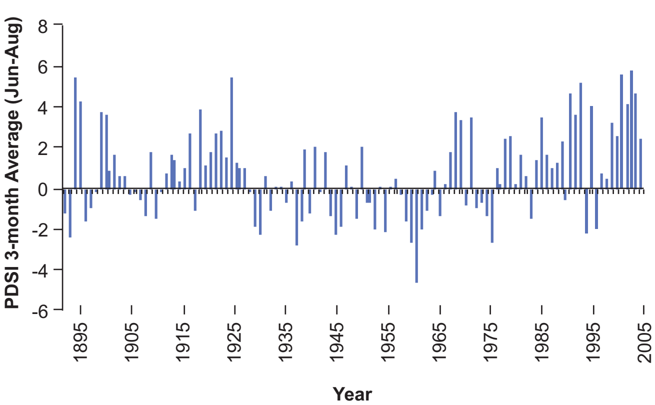


Figure 61.—Palmer Drought Severity Index 3-month average (June-August), New Hampshire, 1895-2010.

Tree-level crown measurements are collected on P3 plots. They include vigor class, crown ratio, light exposure, crown position, crown density, crown dieback, and foliage transparency. Three factors were used to determine the condition of tree crowns: crown dieback, crown density, and foliage transparency. Crown dieback is defined as recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. Secondly, crown density is defined as the amount of crown branches, foliage, and reproductive structures that block light visibility through the crown and can serve as an indicator of expected growth in the near future. Finally, foliage transparency is the amount of skylight visible through the live, normally foliated portion of the crown. Changes in foliage transparency can also occur because of defoliation or from reduced foliage resulting from stresses during preceding years. A crown was labeled as "poor" if crown dieback was greater than 20 percent, crown density was less than 35 percent, or foliage transparency was greater than 35 percent. These three thresholds were based on preliminary findings by Steinman (2000) that associated crown ratings with tree mortality.

What we found

The incidence of poor crown condition is evenly distributed across New Hampshire (Fig. 62). The two species with the highest proportion of live basal area containing poor crowns are red maple and paper birch at 15 and 12 percent, respectively. Conversely, the occurrence of poor crowns in eastern hemlock, yellow birch, balsam fir, sugar maple, northern red oak, and red spruce is very low (Table 2).

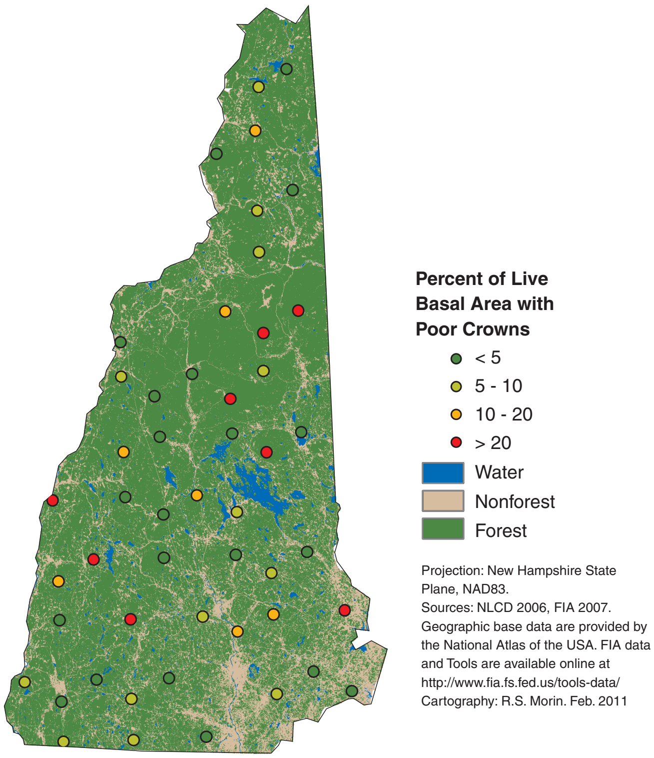


Figure 62.—Percent of live basal area with poor crowns, New Hampshire, 2007.

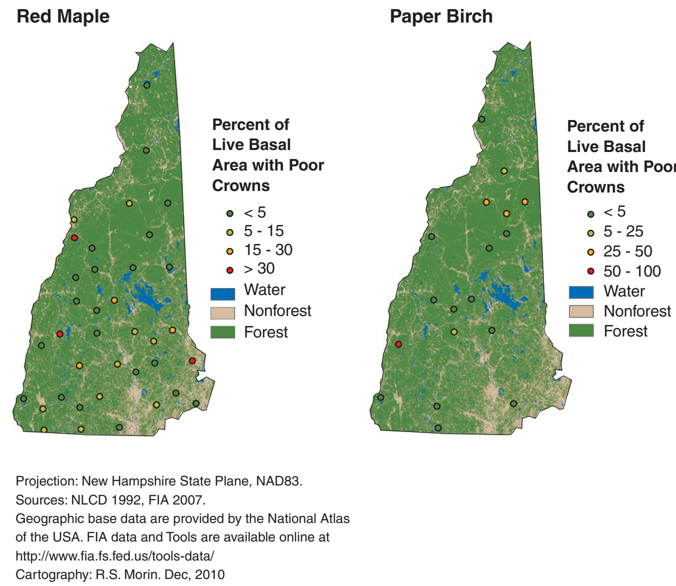


Figure 63.—Percent of live basal area with poor crowns by species, New Hampshire, 2007.

Table 2.—Percent of live basal area with poor crowns, New Hampshire, 2007

Species	Percent of Basal Area with Poor Crowns
Red maple	15
Paper birch	12
American beech	8
Eastern white pine	7
Eastern hemlock	5
Yellow birch	5
Balsam fir	4
Sugar maple	3
Northern red oak	2
Red spruce	1

The highest proportion of red maple basal area containing poor crowns was found in the southern half of New Hampshire. By contrast, poor crowns were more prevalent in paper birch in the northern part of the State (Fig. 63).

What this means

Red maple is the most numerous tree species in New Hampshire and contains the second highest volume of wood. It is a very important species in New Hampshire due to its value as a timber and pulp species and its attractive fall foliage. Levels of red maple mortality have increased since the 1997 inventory (Fig. 51), but the mortality and incidence of poor crowns is likely unrelated to a forest health problem. Many insects and diseases occur on red maple, but none of them typically have major impacts.

Paper birch is a minor species in New Hampshire's forests, but it is valued as a timber and pulpwood species and has showy fall foliage. Levels of paper birch mortality have increased considerably since the 1997 inventory (Fig. 51), but the mortality and incidence of poor crowns is likely unrelated to a forest health problem. Instead, decline due to the age of most stands is likely to be a major factor because paper birch rarely lives more than 140 years.

Lichen Communities

Background

Lichens are symbiotic, composite organisms made up of members of as many as three kingdoms. The dominant partner is a fungus. Fungi are incapable of producing their own food, so they typically feed as parasites or decomposers. The lichen fungi (*kingdom Fungi*) cultivate partners that manufacture food by photosynthesis. Sometimes the partners are algae (*kingdom Protista*), other times cyanobacteria (*kingdom Monera*), formerly called blue-green algae. Some enterprising fungi associate with both at once (Brodo et al. 2001).

Lichen community monitoring is included in the FIA P3 inventory to address key assessment issues such as the impact of air pollution on forest resources, or spatial and temporal trends in biodiversity. This long-term lichen monitoring program in the U.S. dates back to 1994. The objectives of the lichen indicator are to address key assessment issues such as the impact of air pollution on forest resources, spatial and temporal trends in biodiversity, and the sustainability of timber harvesting. Lichens occur on many different substrates (e.g., rocks), but FIA sampling is restricted to standing trees or branches/twigs that have recently fallen to the ground. Samples are sent to lichen experts for species identification.

A close relationship exists between lichen communities and air pollution, especially acidifying or fertilizing nitrogen- and sulfur-based pollutants. A major reason lichens are so sensitive to air quality is their total reliance on atmospheric sources of nutrition. By contrast, it is difficult to separate tree-growth responses specific to air pollution (McCune 2000).

What we found

A total of 85 lichen species (gamma diversity) were sampled on the lichen plots in New Hampshire (Table 3). The most common lichen genus, *Parmelia*, was present on 10 percent of the plots (Table 4). The genus with the highest number of species sampled was *Cladonia* (16 species).

Table 3.—Lichen communities summary table for New Hampshire, 1994-2003

Parameter	New Hampshire, 1994-2003
Number of plots surveyed	27
Number of plots by species richness category	
0-6 species (low)	1
7-15 species (medium)	20
16-25 species (high)	6
Median	12
Range of species richness score per plot (low-high)	1-20
Average species richness score per plot (alpha diversity)	12.6
Standard deviation of species richness score per plot	4
Species turnover rate (beta diversity)[a]	6.8
Total number of species per area (gamma diversity)	85

[1]Beta diversity is calculated as gamma diversity divided by alpha diversity.

Table 4.—Percentage of specimens and number of species for lichen genera sampled, New Hampshire, 1994-2003

Genus	All Specimens	All Species
Parmelia	10.1	3
Phaeophyscia	9.4	3
Melanelia	8.9	5
Cetraria	8.2	6
Cladonia	8.1	16
Usnea	6.7	7
Hypogymnia	6.4	4
Physcia	6.4	4
Flavoparmelia	6.1	2
Punctelia	6.1	2
Evernia	5.6	1
Myelochroa	4.6	2
Physconia	2.2	3
Bryoria	2.0	4
Candelaria	1.8	1
Pyxine	1.7	1
Lobaria	1.0	2
Platismatia	0.8	3
Parmeliopsis	0.7	3
Leptogium	0.6	1
Unknown	0.4	3
Cetrelia	0.4	1
Ramalina	0.4	1
Anaptychia	0.3	1
Imshaugia	0.3	1
Xanthoria	0.3	2
Cladina	0.1	1
Peltigera	0.1	1
Physciella	0.1	1
Total	100	85

The easiest way to measure species diversity is to count the number of species at a site; this measure is termed species richness. However, species richness does not provide a complete picture of diversity in an ecosystem because abundance is excluded. Richness values generally fell into the medium and high categories across New Hampshire (Table 3). The spatial distribution of lichen species richness scores is shown in Figure 64. In general, species richness scores were highest in the southern half of the State where eastern white pine is more abundant. The lichen species richness and diversity scores reported here will serve as baseline estimates for future monitoring at the state and regional level.

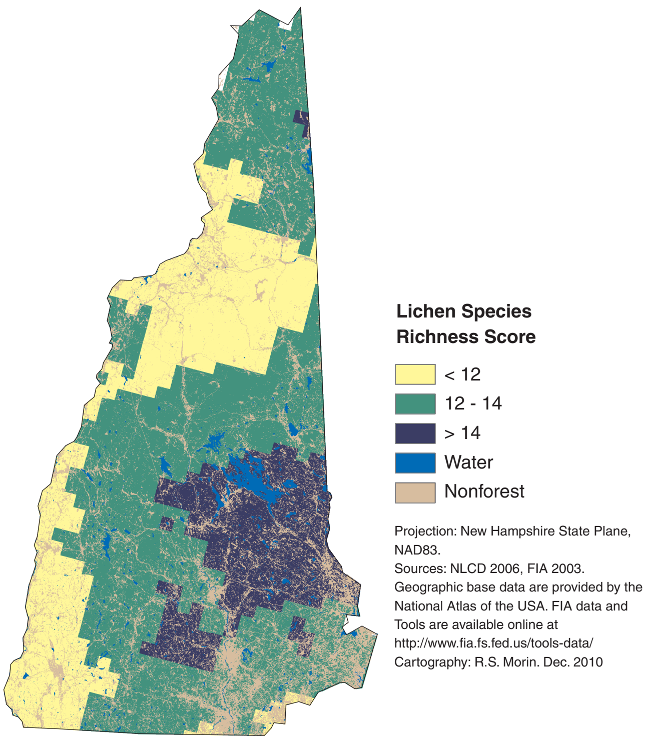


Figure 64.—Estimated lichen species richness, New Hampshire, 2000-2003.

What this means

Due to the sensitivity of many lichen species to airborne pollution, it is useful to look at acid deposition levels. Showman and Long (1992) reported that mean lichen species richness was significantly lower in areas of high sulfate deposition than in low deposition areas. Sulfate deposition levels have been relatively homogeneous across New Hampshire and are relatively low compared to other areas in the northeastern United States (Fig. 65). A general pattern of lower lichen species richness scores in high deposition areas and vice versa is evident (Fig. 66). But other factors may affect the distribution of lichen species including intrinsic forest characteristics and long-term changes in climate.

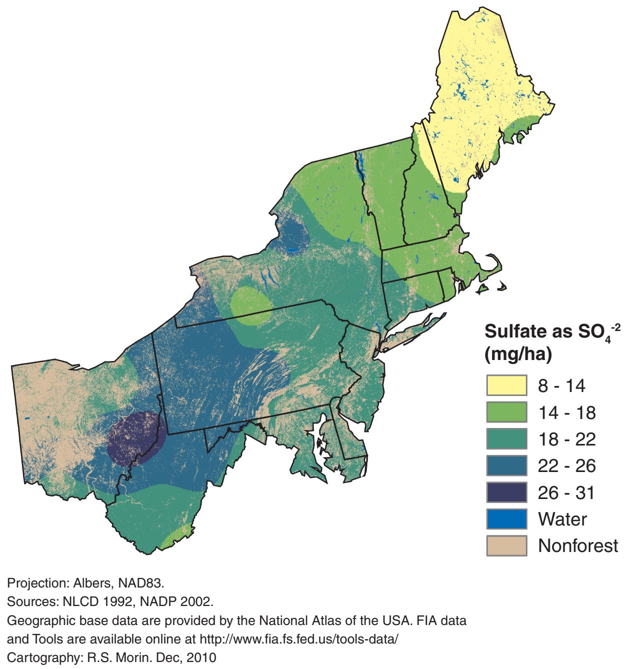


Figure 65.—Mean sulfate ion wet deposition, Northeastern U.S., 1994-2002. Data source: National Atmospheric Deposition Program.

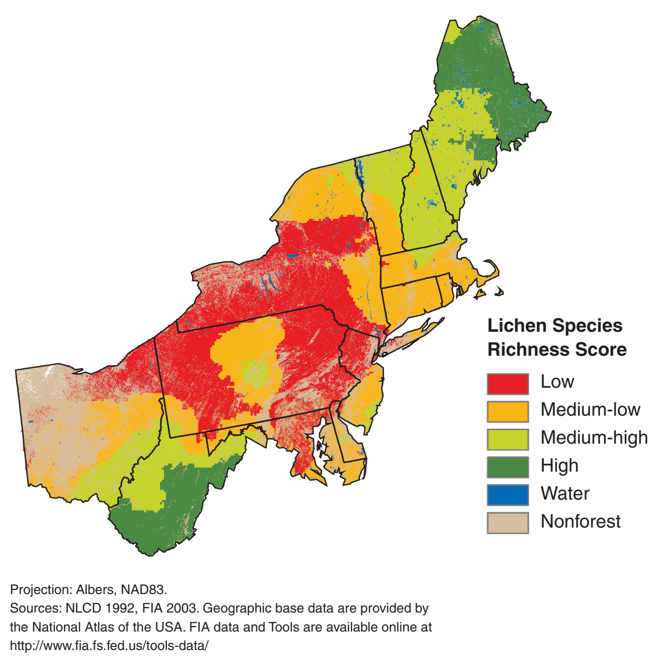


Figure 66.—Estimated lichen species richness, Northeastern U.S., 2000-2003.

Forest Soils

Background

The soils that sustain forests are influenced by a number of factors, including climate; the trees, shrubs, herbs, and animals living there; landscape position; elevation; and the passage of time.

Forest carbon sequestration is a topic of public concern. Carbon stocks in soils are important long-term stores of carbon accumulated from woody biomass and foliage. The accumulation and subsequent decay of leaf litter adds carbon to forest soils. Tree roots—and translocation from the forest floor—add carbon to the mineral soil. Measurements of current carbon stocks help managers understand the importance of different forest types and landscapes in the carbon cycle.

Atmospheric pollution is one significant pathway that humans influence the character and quality of the soil and indirectly affect the forest. For example, industrial emissions of sulfur and nitrogen oxides lead to "acid rain." The deposition of acids strips the soil of important nutrients, notably calcium and magnesium. The loss of calcium and magnesium results in a shifting balance of soil elements toward aluminum, which is toxic to plants in high concentrations. We can use the ratio of aluminum to calcium as a measure of the impact of acid deposition on forest soils; high ratios suggest a shift toward more aluminum.

What we found

Forest floor carbon in New Hampshire's forests is strongly influenced by two factors: forest-type group and ecological section – a type of semi-homogeneous landscape unit (Table 5 and Fig. 67). Maple/beech/basswood forests tend to store the largest amounts of carbon in their forest floor, but other hardwood forests store the greatest amount of forest floor carbon in section M211A.

By contrast, carbon in the mineral soil under New Hampshire's forests is related only to ecological province, a more extensive semi-homogeneous landscape unit than ecological sections (Table 6 and Fig. 67). This is unusual because forest-type group is often a strong predictor for mineral soil carbon. In this case, the FIA soil sample is collected almost exclusively in the maple/beech/birch forest-type group, so it is hard to detect the effect of other forest-type groups.

By focusing on all species, it is possible to evaluate tree: soil interactions with some statistical rigor. In this case, linkages between soils and the crowns of all species are

Table 5.—Predicted forest floor carbon in New Hampshire, $Mg\ ha^{-1}$

	Ecological Section		
Forest type	221A	M211A	M211B
Maple/beech/basswood	15.7	11.7	9.5
Other Hardwoods	12	25.5	5.8

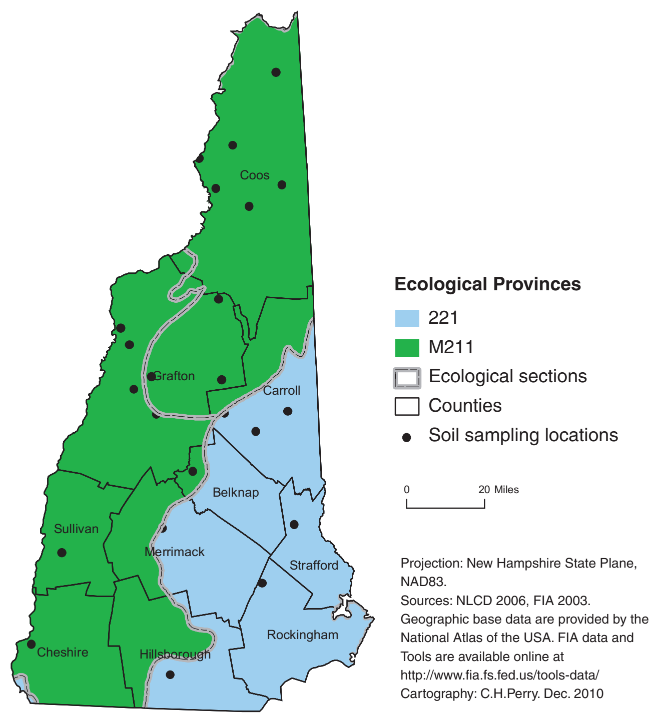


Figure 67.—P3 soils plots and ecological sections.

Table 6.—Predicted forest floor carbon in New Hampshire, $Mg\ ha^{-1}$

Ecological Province	Carbon Content
221	81.1
M211	75.2

evaluated. The plot data suggest that aluminum:calcium ratios in the soil are important predictors of crown vigor in New Hampshire.

The nuances of these relationships are difficult to explain in the space of this report, but some examples are illustrative. The uncompacted live crown ratio is determined by dividing the live crown length by the actual tree length. Larger values are associated with healthier trees; low values of this ratio can be related to self pruning and shading from other tree crowns, but other reasons include defoliation due to dieback, and loss of branches due to breakage or mortality. The aluminum:calcium ratio is a significant predictor of the uncompacted live crown ratio (Fig. 68). The lowest crown ratios overall are associated with higher levels of aluminum. This observation is consistent with intensive site studies conducted in New England (Schaberg et al. 1996, Shortle and Smith 1988).

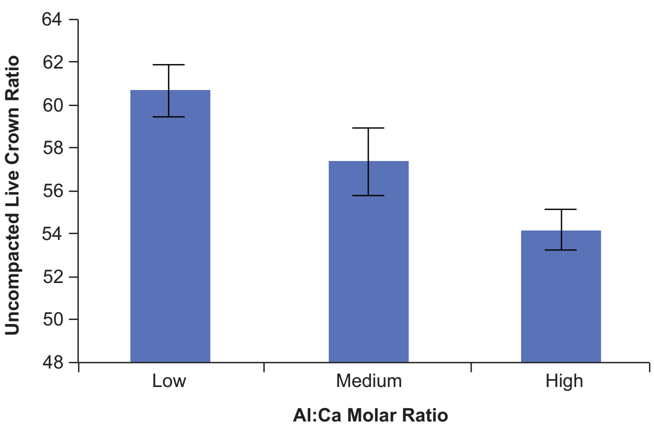


Figure 68.—Uncompacted live crown ratio by aluminum to calcium ratio in the soil. Error bars represent one sampling error (68%).

What this means

Tree species occupy different niches in the landscape. This provides a competitive advantage for colonization, growth, and reproduction. Atmospheric deposition of different compounds changes the soil substrate through additions and/or removals of nutrients and pollutants. These changes in the soil influence the ability of existing trees to thrive and reproduce in their current locations, as well as the ability of other trees to colonize new landscapes. It is important to document and understand natural and anthropogenic processes in the soil because they profoundly influence the current forest and success of future forest management plans. In turn, these changes in tree species composition across the landscape influence carbon sequestration rates by forests.

Down Woody Materials

Background

Down woody materials, in the form of fallen trees and branches, fill a critical ecological niche in New Hampshire's forests. Down woody materials both provide valuable wildlife habitat in the form of coarse woody debris and contribute toward forest fire hazards via surface woody fuels. Pieces of wood are selected into the coarse woody debris sample if they are at least 3 inches in diameter and intersect one of three transects emanating from the center of each FIA plot (Woodall and Monleon 2008).

What we found

The fuel loadings of down woody materials (time-lag fuel classes) are not exceedingly high in New Hampshire (Fig. 69). When compared to the neighboring states of Vermont and Maine, New Hampshire's fuel loadings of all time-lag fuel classes are not substantially different (for time-lag definitions, see Woodall and Monleon 2008). Although 100-hr time lag fuels averaged nearly 5 tons/acre, relatively large standard errors indicated a lack of statistical difference with neighboring states. The size class distribution of coarse woody debris appears to be heavily skewed (79 percent) toward pieces less than 8 inches in diameter at point of intersection with plot sampling transects (Fig. 70A). There appears to be a fairly uniform distribution of stages of coarse woody decay across the State, except for decay class three and four logs (68 percent) (Fig. 70B). Decay class three and four coarse woody pieces are typified by moderate to heavily decayed logs that are sometimes structurally sound but missing most/all of their bark with extensive sapwood decay. There is no strong trend in coarse woody debris volumes/acre among classes of live-tree density (basal area/acre) (Fig. 71).

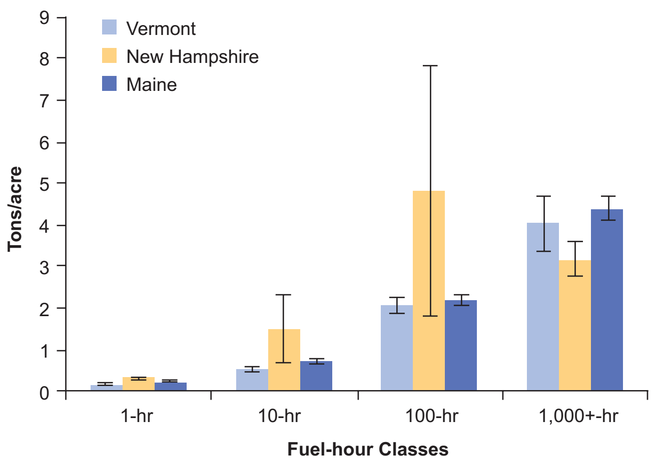


Figure 69.—Means and associated standard errors of fuel loadings (tons/acre, time-lag fuel classes) on forest land in New Hampshire and neighboring states, 2004-2008.

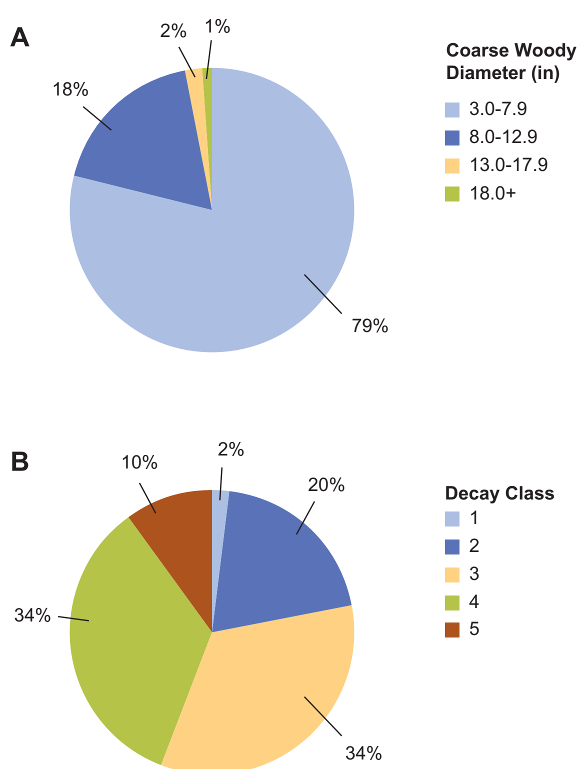


Figure 70.—Mean proportions of coarse woody debris total pieces per acre by (A) transect diameter (inches) and (B) decay classes on forest land in New Hampshire, 2004-2008.

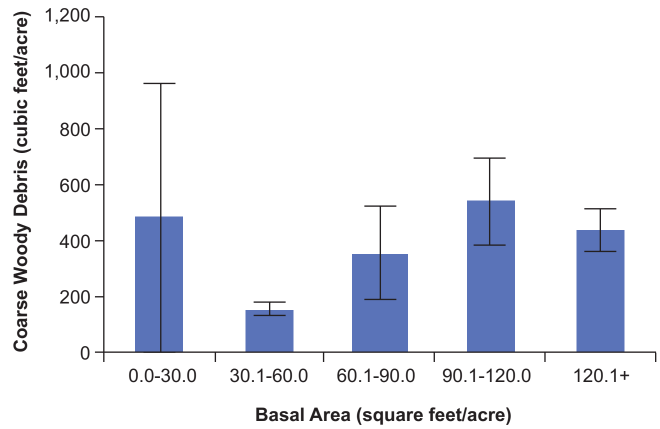


Figure 71.—Means and associated standard errors of coarse woody debris volumes (cubic feet/acre) on forest land in New Hampshire, 2004-2008.

What this means

The down woody fuel loadings in New Hampshire's forests are not exceedingly different from those found in neighboring states. Therefore, only in times of extreme drought would these low amounts of fuels pose a hazard across the State. Of all down woody components, coarse woody debris (i.e., 1,000+-hr fuels) made up the largest amounts, but coarse woody debris volumes were still relatively low and were represented by small, moderately decayed pieces. The scarcity of large coarse woody debris resources may also indicate lower quality habitat for some wildlife species. Overall, because fuel loadings are not very high across New Hampshire, associated fire dangers are outweighed by the benefits of down woody material for producing wildlife habitat and carbon sinks.

Vegetation Diversity and Invasives

Background

Ground flora play many important roles in the forests of northern New England. Vegetation helps curtail erosion and runoff, regulate soil temperature, sequester carbon, and provide food and cover for forest animals.

In addition, plants have the ability to filter pollutants and influence nutrient availability. Data on species composition help resource managers determine site quality, which serves as a guide for developing management goals. In New Hampshire and Vermont, plant species data were collected on the P2 Invasive plots and P3 plots. Due to the small number of plots, the data from the two states were analyzed together. For 2007-2008 there were 125 P2 Invasive plots (63 in Vermont and 62 in New Hampshire) and 36 P3 plots (17 in Vermont and 19 in New Hampshire).

What we found

All species

On the P3 plots, 343 species were found with the greatest quantity of classified species (140) occurring in the forb/herb category based on classification by the USDA Natural Resources Conservation Service's PLANTS Database (Table 7). Forty-four plants were classified as graminoids (grass or grass-like plants). Beyond these categories, there were 62 trees, 48 shrubs, and 10 vines. For the P3 plots, 274 (79.9 percent) of the 343 plant species were native to the U.S. and 25 species (7.3 percent) were introduced (Table 8). Canada mayflower (*Maianthemum canadense*) was the most commonly observed understory species and occurred on 92 percent (33 plots) of all P3 plots in New Hampshire and Vermont (Table 9). The most commonly observed tree species was American beech, which was found on 29 plots or 81 percent of all P3 plots. Of the 20 most commonly observed species, 12 were of woody growth form.

Nonnative invasive species

None of the 43 invasive plant species FIA monitors on P2 Invasive plots (Table 10) were among the top 20 species on P3 plots. On the P3 plots, broadleaf helleborine (*Epipactis helleborine*) was the most commonly observed nonnative plant species (8 plots; 22 percent of P3 plots), with common dandelion (*Taraxacum officinale*) being the second most common nonnative plant species (6 plots; Table 11). On the P2 Invasive plots, common barberry was the most frequently occurring invasive plant species (4 plots; Table 12), followed by glossy buckthorn (*Rhamnus frangula*), common buckthorn (*Rhamnus cathartica*), and multiflora rose (3 plots). All of the invasive species found on New Hampshire and Vermont P2 Invasive plots were woody species, except for bull thistle (1 plot). The high number of woody plants observed reflects the high number selected for monitoring on the P2 Invasive plots.

Table 7.—Number of species on New Hampshire and Vermont P3 plots by growth habit (per PLANTS Database, USDA Natural Resources Conservation Service), 2007-2008

Growth Habit	Number of Species or Undifferentiated Genuses
Forb/herb	140
Graminoid	44
Shrub	25
Shrub, subshrub, vine	2
Subshrub, forb/herb	2
Subshrub, shrub	13
Subshrub, shrub, forb/herb	6
Tree	33
Tree, shrub	27
Tree, shrub, subshrub	2
Vine	3
Vine, forb/herb	3
Vine, shrub	1
Vine, subshrub	1
Vine, subshrub, forb/herb	2
Unclassified	39
Total	343

Table 8.—Number of species on New Hampshire and Vermont P3 plots by domestic or foreign origin (per PLANTS Database, USDA Natural Resources Conservation Service), 2007-2008

Origin	Number of Species or Undifferentiated Genuses	Percentage
Introduced to the U.S.	25	7.3
Native and introduced to the U.S.	5	1.4
Native to the U.S.	274	79.9
Unclassified	39	11.4
Total	343	100

Invasive plants were widely distributed throughout New Hampshire and Vermont. Common barberry was only found on plots in Vermont (Fig. 72) even though, according to the NRCS PLANTS database, it is known to occur in New Hampshire. Another trend observed was that common buckthorn was found only in the southern part of New Hampshire and Vermont (the southernmost plot in Vermont that shows multiflora rose present also had common buckthorn present), and glossy buckthorn and multiflora rose were observed on plots only in the central portion of each of these states.

Table 9.—The top 20 plant species or undifferentiated genera or categories on New Hampshire and Vermont P3 plots, the number of plots the species were found on (in parentheses), and the mean number of tree saplings and seedlings per acre on the plots, 2007-2008

Species	Tree Saplings per acre	Tree Seedlings per acre
Canada mayflower (33)	705	2,483
American beech (29)	622	2,453
Sugar maple (28)	714	2,775
Red maple (26)	659	1,949
Eastern hayscented fern (25)	741	2,400
Sedge (25)	616	2,579
Striped maple (25)	685	2,848
Wild sarsaparilla (25)	688	2,644
Starflower (23)	748	2,760
Eastern white pine (20)	632	2,260
Sensitive fern (20)	772	3,069
Yellow birch (20)	658	2,732
American red raspberry (18)	483	2,977
Paper birch (17)	813	2,515
Common ladyfern (16)	595	2,600
Eastern hemlock (16)	555	2,222
Northern red oak (16)	481	2,014
Red spruce (16)	597	2,883
Sessileleaf bellwort (16)	618	2,563
White ash (16)	661	3,130

Table 10.—Invasive plant species target list for Northern Research Station FIA P2 Invasive plots, 2007 to present

Tree Species

Acer platanoides (Norway maple)
Ailanthus altissima (tree of heaven)
Albizia julibrissin (silktree)
Elaeagnus angustifolia (Russian olive)
Melaleuca quinquenervia (punktree)
Melia azedarach (Chinaberry)
Paulownia tomentosa (princesstree)
Robinia pseudoacacia (black locust)
Tamarix ramosissima (saltcedar)
Triadica sebifera (tallow tree)
Ulmus pumila (Siberian elm)

Woody Species

Berberis thunbergii (Japanese barberry)
Berberis vulgaris (common barberry)
Elaeagnus umbellata (autumn olive)
Frangula alnus (glossy buckthorn)
Ligustrum vulgare (European privet)
Lonicera x. bella (showy fly honeysuckle)
Lonicera maackii (Amur honeysuckle)
Lonicera morrowii (Morrow's honeysuckle)
Lonicera tatarica (Tatarian bush honeysuckle)
Rhamnus cathartica (common buckthorn)
Rosa multiflora (multiflora rose)
Spiraea japonica (Japanese meadowsweet)
Viburnum opulus (European cranberrybush)

Vine Species

Celastrus orbiculatus (Oriental bittersweet)
Hedera helix (English ivy)
Lonicera japonica (Japanese honeysuckle)

Herbaceous Species

Alliaria petiolata (garlic mustard)
Centaurea biebersteinii (spotted knapweed)
Cirsium arvense (Canada thistle)
Cirsium vulgare (bull thistle)
Cynanchum louiseae (black swallow-wort)
Cynanchum rossicum (European swallow-wort)
Euphorbia esula (leafy spurge)
Hesperis matronalis (dames rocket)
Lysimachia nummularia (creeping jenny)
Lythrum salicaria (purple loosestrife)
Polygonum cuspidatum (Japanese knotweed)
Polygonum x. bohemicum (*P. cuspidatum/P. sachalinense* hybrid)
Polygonum sachalinense (giant knotweed)

Grass Species

Microstegium vimineum (Japanese stiltgrass)
Phalaris arundinaceae (reed canarygrass)
Phragmites australis (common reed)

Table 11.—Nonnative plant species found on New Hampshire and Vermont P3 plots, the number of plots (in parentheses), and the mean number of tree saplings and seedlings per acre on the plots (Some plots may have multiple nonnative plant species and thus may be counted more than once in the table)

Species	Tree Saplings per acre	Tree Seedlings per acre
Broadleaf helleborine (8)	562	2,141
Common dandelion (6)	587	2,479
Claspleaf twistedstalk (4)	600	3,017
Common yarrow (4)	600	1,151
Bird vetch (3)	526	2,158
Common buckthorn (2)	114	2,187
Common St. Johnswort (2)	487	2,699
Meadow hawkweed (2)	225	2,661
Broadleaf Solomon's seal (1)	1,199	1,649
Bull thistle (1)	225	3,598
Climbing nightshade (1)	750	1,799
Coltsfoot (1)	225	3,598
Common barberry (1)	1,199	375
Common mallow (1)	1,574	5,098
Common mullein (1)	300	6,597
Dovefoot geranium (1)	1,199	375
European black currant (1)	750	1,799
European columbine (1)	77	3,324
European cranberrybush (1)	77	3,324
Glossy buckthorn (1)	750	1,349
Hedge false bindweed (1)	260	1,822
Japanese barberry (1)	450	1,499
Multiflora rose (1)	750	1,349
Narrowleaf cattail (1)	675	150
Orange hawkweed (1)	1,199	375
Oxeye daisy (1)	225	3,598
Redtop (1)	1,349	1,424
Scots pine (1)	675	3,224
Smooth crabgrass (1)	750	1,349
Threadstalk speedwell (1)	1,574	1,499

Table 12.—Invasive plant species found on New Hampshire and Vermont P2 Invasive plots, the number of plots (in parentheses), and the mean number of tree saplings and seedlings per acre on the plots, 2007-2008

Species	Tree Saplings per acre	Tree Seedlings per acre
Common barberry (4)	918	656
Glossy buckthorn (3)	500	4,798
Common buckthorn (3)	126	4,332
Multiflora rose (3)	423	4,436
Japanese barberry (2)	1,050	1,649
European cranberrybush (1)	77	3,324
Autumn olive (1)	371	3,338
Oriental bittersweet (1)	150	1,874
Bull thistle (1)	225	3,598
Black locust (1)	750	1,799

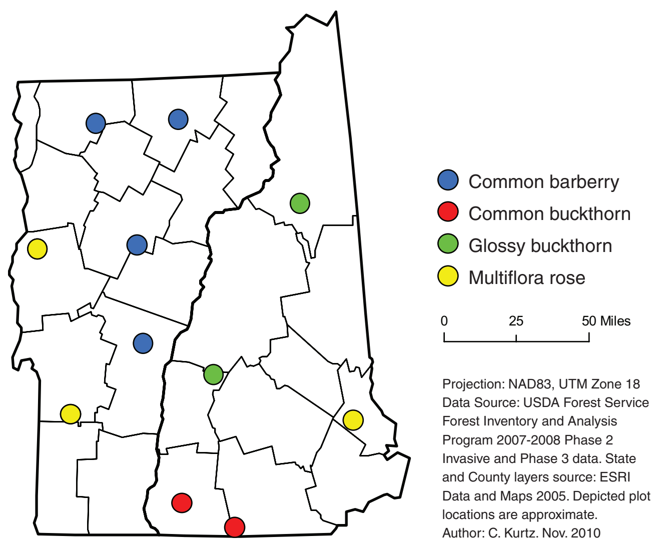


Figure 72.—Distribution of the four most frequently occurring invasive species (common barberry, common buckthorn, glossy buckthorn, and multiflora rose) observed on 2007-2008 Forest Inventory and Analysis P2 Invasive and P3 plots in New Hampshire and Vermont, approximate plot locations depicted. Note that common and glossy buckthorn each appeared on three plots; however, these species co-occurred on plots with multiflora rose so their presence is not indicated on those plots.

What this means

New Hampshire and Vermont's forests support a variety of species distributed across five growth habits (forb/herb, graminoid, shrub, tree, and vine). The presence of nonnative invasive plants in these states poses risk to the forests because these plants can inhibit regeneration of native species and change the overall forest structure. Additionally, these species can change resource availability and the habitat quality for flora and fauna.

In New Hampshire and Vermont, the presence of the 43 invasive plant species monitored for is relatively low (12.8 percent) compared to neighboring New England states, Maine (14.2 percent) (McCaskill et al. 2011) and Massachusetts (45.1 percent) (Butler et al. in press). Even though the occurrence of invasive plant species is low, the presence of these particular species causes concern as vigorous individuals have the potential to rapidly increase in cover and extent and impact co-occurring native species. Currently, in New Hampshire and Vermont, the data suggest presence of invasive plants may cause a reduction in seedling cover. This conclusion is supported by comparing Table 9, which shows the top 20 plant species found on P3 plots—none of which are invasives—with Figure 73, which shows the nonnative species found on P3 plots. Table 9 shows only one species (red maple) with an average number of tree seedlings less than 2,000 per acre while Figure 73 shows 15 of the 30 species have covers of less than 2,000 tree seedlings per acre[1]. Furthermore, plotting the percent cover of invasive plant species against the number of seedlings and saplings per acre (Fig. 74), suggests that, as invasive cover increases, the number of seedlings decreases. Although the sample size is small and only 2 percent of the 161 plots have invasive cover of 6 percent or more, this analysis raises concerns because it suggests those sites that do have invasives might suffer regeneration failures, eventually resulting in a reduction in future forest density.

The measurement of additional P2 Invasive and P3 plots will provide a better understanding of invasive plant distribution and facilitate analyses of the impact and spread of these species. Such knowledge can help forest managers understand where invasive species might be successful in establishing themselves and allow managers to craft strategies of treatment and mitigation, where necessary.

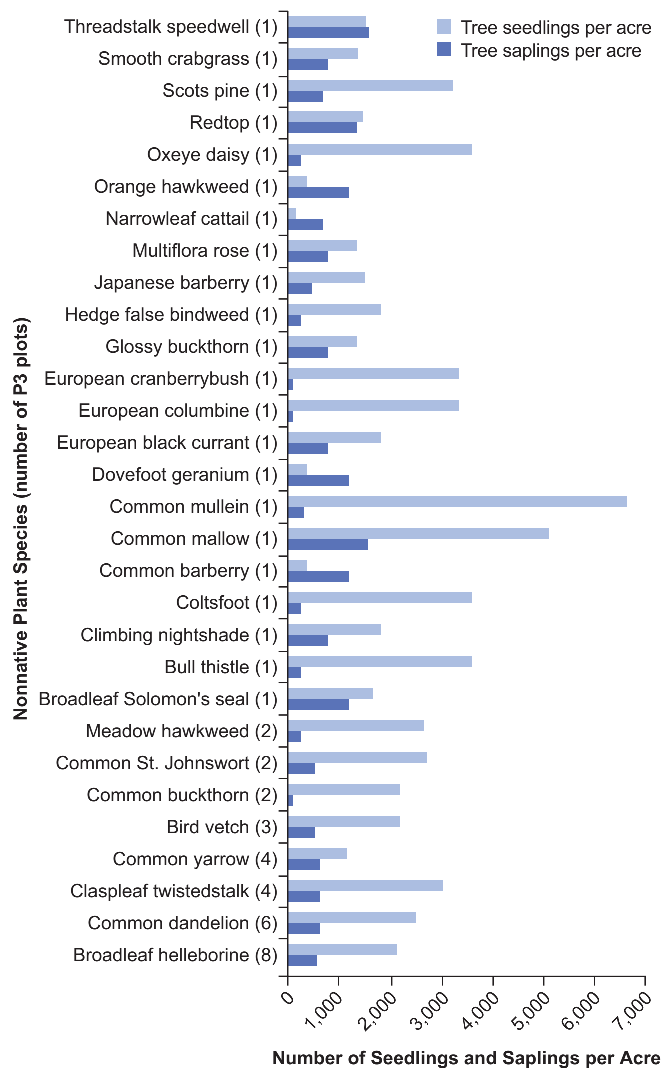


Figure 73—Nonnative species on New Hampshire and Vermont P3 plots, the number of plots (in parentheses), and the mean number of tree seedlings and saplings per acre on the plots, 2007-2008.

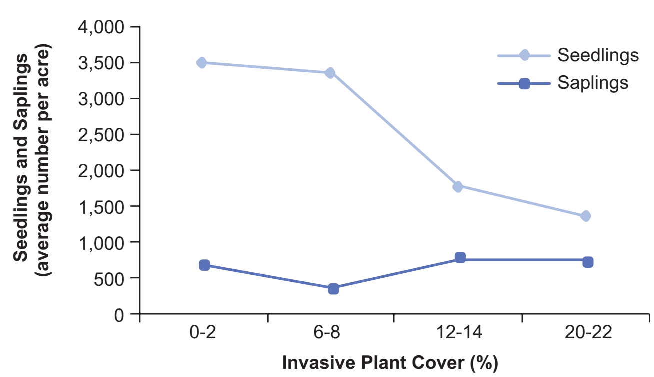


Figure 74.—Average number of seedlings and saplings per acre by invasive plant cover class for invaded P2 Invasive and P3 Forest Inventory and Analysis plots in New Hampshire and Vermont, 2007-2008.

[1] Caution must be used when analyzing these data due to the low overall number of plots.

Ozone Bioindicator Plants

Background

Ozone is a byproduct of industrial development and is found in the lower atmosphere. Ozone forms when nitrogen oxides and volatile organic compounds go through chemical transformation in the presence of sunlight (Brace et al. 1999). Ground-level ozone is known to have detrimental effects upon forest ecosystems. Certain plant species exhibit visible, easily diagnosed foliar symptoms to ozone exposure. Ozone stress in a forest environment can be detected and monitored by using these plants as indicators. The FIA program uses these indicator plants to monitor changes in air quality across a region and to evaluate the relationship between ozone air quality and the indicators of forest condition.

The ozone-induced foliar injury on indicator plants is used to describe the risk of impact within the forest environment using a national system of sites (Smith et al. 2003, 2007). These sites are not co-located with FIA samples. Ozone plots are chosen for ease of access and optimal size, species, and plant counts. As such, the ozone plots do not have set boundaries and vary in size. At each plot, between 10 and 30 individual plants of three or more indicator species are evaluated for ozone injury. Each plant is rated for the proportion of leaves with ozone injury and the mean severity of symptoms using break points that correspond to the human eye's ability to distinguish differences. A biosite index is calculated based on amount and severity ratings where the average score (amount * severity) for each species is averaged across all species at each site and multiplied by 1,000 to allow risk to be defined by integers (Smith et al. 2007).

Table 13.—Distribution of plants sampled for ozone injury by species, New Hampshire, 1994-2007

Species	Number	Percent
Milkweed	3,315	31.9
Blackberry	2,200	21.2
Black cherry	1,922	18.5
White ash	1,743	16.8
Spreading dogbane	630	6.1
Pin cherry	591	5.7

What we found

The majority of the plants sampled were milkweed (*Asclepias* spp.) or blackberry (*Rubus* spp.) (Table 13). The findings for New Hampshire indicate that risk of foliar injury due to ozone has been trending downward since the mid-1990s (Table 14 and Fig. 75) as have ozone exposure levels (Fig. 76).

Table 14.—State-level summary statistics for ozone bioindicator program, New Hampshire, 1994-2007

Parameter	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of biosites evaluated	6	23	24	21	25	23	20	19	5	5	5	8	6	5
Number of biosites with injury	5	10	7	1	10	4	1	3	0	0	1	3	2	1
Average biosite index score	16.48	1.7	1.98	0.01	5.37	0.53	0.24	1.47	0	0	5.46	0.55	0.16	0.12
Number of plants evaluated	325	1,001	1,032	887	1,205	1,014	947	1,214	405	258	321	790	524	487
Number of plants injured	68	67	27	2	88	8	7	14	0	0	5	7	4	1
Maximum SUM06 value (ppm-hr)[2]	17.63	16.61	13.13	12.78	10.56	16.73	6.26	12.9	16.07	10.86	11.46	14.85	10.04	9.86

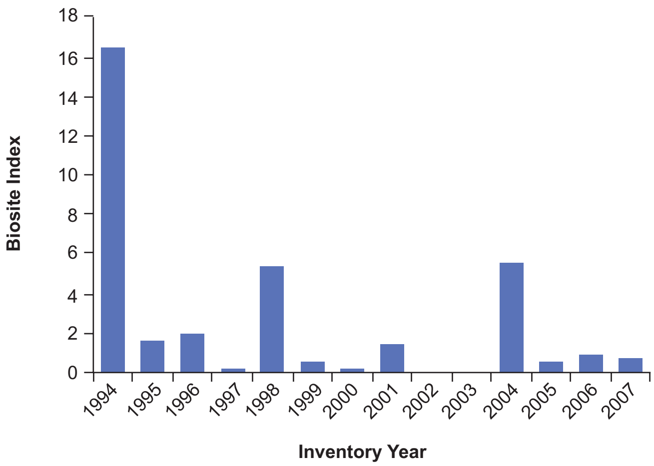


Figure 75.—Biosite index, New Hampshire, 1994-2007.

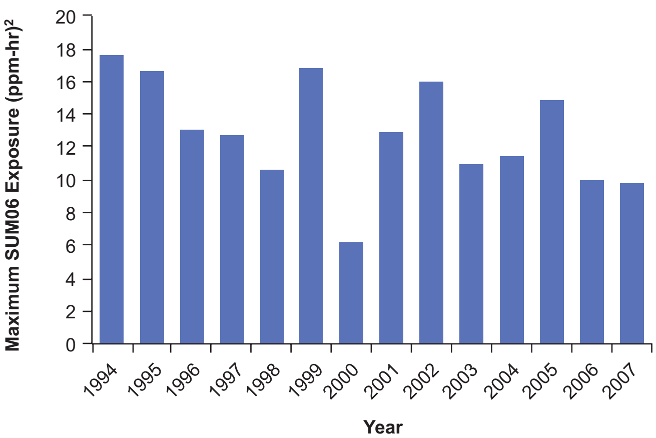


Figure 76.—Maximum SUM06 exposure levels (ppm-hr)^2, New Hampshire, 1994-2007.

What this means

Ozone exposure rates have been decreasing with corresponding decreases in foliar injury. This is in contrast to evidence of medium and high risk in portions of the Mid-Atlantic region (Coulston et al. 2003).

A typical summer ozone exposure pattern for the northeastern United States is shown in Figure 77. The term SUM06 is defined as the sum of all valid hourly ozone concentrations that equal or exceed 0.06 ppm. Controlled studies have found that high ozone levels (shown in orange and red) can lead to measurable growth suppression in sensitive tree species (Chappelka and Samuelson 1998). Smith et al. (2003) reported that even when ambient ozone exposures are high, the percentage of injured plants can be reduced sharply in dry years.

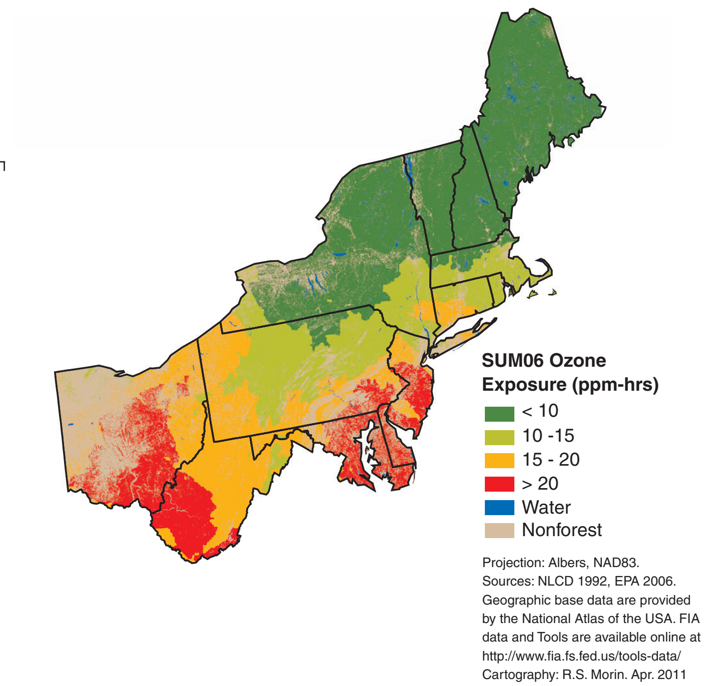


Figure 77.—Typical June through August 12-hour SUM06 ozone exposure rates in the Northeastern U.S., 2000-2006.

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View of the White Mountains in northern New Hampshire. Photo by Elizabeth Morin.

Tree overhanging stream in Franconia State Park, NH. Photo by Elizabeth Morin.

Morin, Randall S.; Barnett, Chuck J.; Brand, Gary J.; Butler, Brett J.; Domke, Grant M.; Francher, Susan; Hansen, Mark H.; Hatfield, Mark A.; Kurtz, Cassandra M.; Moser, W. Keith; Perry, Charles H.; Piva, Ron; Riemann, Rachel; Woodall, Chris W. 2011. **New Hampshire's Forests 2007.** Resour. Bull. NRS-53. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 56 p. [DVD included].

The first full annual inventory of New Hampshire's forests reports nearly 4.8 million acres of forest land with an average volume of nearly 2,200 cubic feet per acre. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 53 percent of total forest land area. Fifty-seven percent of forest land consists of large-diameter trees, 32 percent contains medium-diameter trees, and 11 percent contains small-diameter trees. The volume of growing stock on timberland has been rising since the 1980s and currently totals nearly 9.5 billion cubic feet. The average annual net growth of growing stock on timberland from 1997 to 2007 is approximately 164 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, timber products, and forest health. Detailed information on forest inventory methods and data quality estimates is included in a DVD at the back of the report. Tables of population estimates and a glossary are also included.

KEY WORDS: forest resources, forest health, forest products, volume, biomass

DVD Contents

New Hampshire's Forests 2007 (PDF)

New Hampshire's Forests: Statistics and Quality Assurance (PDF)

New Hampshire Inventory Database (CSV file folder)

New Hampshire Inventory Database (Access file)

Field guides that describe inventory procedures (PDF)

Database User Guides (PDF)

New Hampshire's Forests 2007
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