Although other formats could be used to present this information, the Montréal Process is well developed, widely used, and especially well suited to making comparisons with forest conditions elsewhere. In addition to the usual statistics for forest area, volume, utilization, and economic output, the broad criteria of the Montréal Process emphasize other important forest characteristics that typically receive less attention or that have a shorter monitoring history: biodiversity, forest fragmentation, forest soils, water quality and quantity, carbon cycling, social benefits, and institutional frameworks. Understanding the Montréal Process is not a precondition for interpreting or understanding this chapter. However, knowledge of the Montréal Process will be helpful for those who wish to contrast the conditions of northern forests with those of the entire United States or other participating nations. Ultimately the purpose of the criteria and indicators is to provide information relevant to understanding and interpreting forest sustainability.

The following eight subsections address the eight broad sustainability criteria identified for northern forests and include information about many of the individual indicators associated with each criterion. Montréal Process indicators that lack suitable data for northern forests are omitted.

Criterion 1:

CONSERVATION OF BIOLOGICAL DIVERSITY

Montréal Process Criterion 1 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 1.1-1.5, 2.1-2.3, 3.1-3.5, 4.1–4.4, 15.3–15.6 (USDA FS 2010d)[1]

The importance of conserving biological diversity

Biological diversity, or biodiversity, is the variety of life. It encompasses the variability among living organisms and includes diversity within species, among species, and among ecosystems. High biodiversity enables a forest ecosystem to respond to external influences, absorb and recover from disturbances, and still maintain essential ecosystem processes such as regeneration, nutrient cycling, support of wildlife, and purification of air and water.

The Convention on Biological Diversity (2010) defines forest biological diversity as encompassing the multitude of plants, animals, and micro-organisms that inhabit forest areas and their associated genetic diversity. Both human activities and natural processes can reduce biological diversity by altering and fragmenting habitats, introducing invasive species, or reducing a species' population size or range. Sustaining biodiversity is among the top concerns commonly expressed about northern forests (Chapter 2).

[1] *This and similar information at the beginning of subsequent sections cross-reference information for Northern forests with the Montréal Process Criteria and Indicator system and with information in the Northern Area Forest Sustainability Indicators System.*

Although measuring biological diversity in forests is not simple, it is important because forests are a major source of biodiversity in the North and are relatively undisturbed compared to the agricultural or developed lands that dominate in some areas. Biodiversity is often reported at three scales: (1) diversity of ecosystems on the landscape; (2) species diversity including the total number of species and their relative frequency; and (3) genetic diversity, which is difficult to measure directly and often inferred from population size.

In general, forest ecosystems that have greater diversity are considered more resilient. Northern forests are long-lived and widespread so they are inevitably afflicted by catastrophic weather, wildfires, insects, diseases, invasive species, atmospheric pollution, and climate change. Forests with diversity at landscape, species, and genetic scales are more likely to remain fully functioning forest ecosystems over the long run.

Key Findings for Criterion 1

- **Forests cover 172 million acres in the Northern States or 42 percent of the land area.**
- **Forest area in the region increased by 28 percent over the last 100 years.**
- **The region's forests are 74 percent privately owned.**
- **There are 5 million private forest owners**
- **Oak-hickory and maple-beech-birch are the most common forest types; together they account for 64 percent of the forest area.**
- **Young forests and old forests are relatively rare; 70 percent of the forest area is between 40 and 100 years old.**
- **About 1 percent of the region's forest-associated species are presumed extinct; populations of 85 percent of forest-associated species appear to be secure. Populations of the remaining forest-associated species are at some degree of risk.**
- **The number of extirpated forest-associated species is greater in the Northern States than elsewhere in the United States.**

Indicators of biodiversity for northern forests

Forest area

Forests cover 42 percent of the northern land base (Table 1), a greater percentage than the three other large regions of the country and far greater than the entire U.S. coverage of 33 percent (Fig. 1, Table 1, Appendix). Over the past century, forest cover in the North has increased by 28 percent, from 134 to 172 million acres (Fig. 2), mostly the result of natural succession after the abandonment of marginal farmlands that earlier replaced native forest. Simultaneously, as urban populations have increased, adjacent forests have been converted to nonforest land uses. From 1990 to 2000 the total area of urban land in the North increased by 4 million acres of which 1.5 million acres were forest (see Criterion 8).

Although most Northern States have seen a net increase in forest land over the past century, many have experienced periods of decrease as well as periods of increase over that time (Fig. 2). The increases in forest area for the North appear to be leveling off (Drummond and Loveland 2010); over the past 20 years about half the States increased in forest area and the other half decreased. Although total forest area is expected to remain relatively stable in the near term, forest locations will shift as some areas are cleared for development or agriculture, and others are returned to forest cover.

Most northern forest land (128 million acres, 74 percent) is privately owned (Fig. 7, Table 2). Families are the largest owner group, representing 4.7 million of the 5 million private owners. The other 300,000 private owners include forest products companies, corporations, trusts, nongovernmental organizations, and investment companies.

Most private ownerships are small; the average size is about 26 acres, and 3 million private owners have fewer than 10 acres of forest land. Conversely, the 10 percent of private owners with the most forest land collectively own more than half of all private forest acreage in the North (Butler 2008, Smith et al. 2009).

The other 44 million acres of northern forest land are publicly owned. Public forest land usually occurs in larger blocks and is managed for different purposes than private land. Compared to the U.S. average (44 percent), the North has relatively little public forest land (26 percent); the only region with less is the South (13 percent). Overall, the East trails far behind the Western States in public ownership of forests: 67 percent for the Pacific Coast and 75 percent for the Interior West. The amount of public forest land varies considerably among Northern States, ranging from 6 percent in Maine to 57 percent in Minnesota (Table 2).

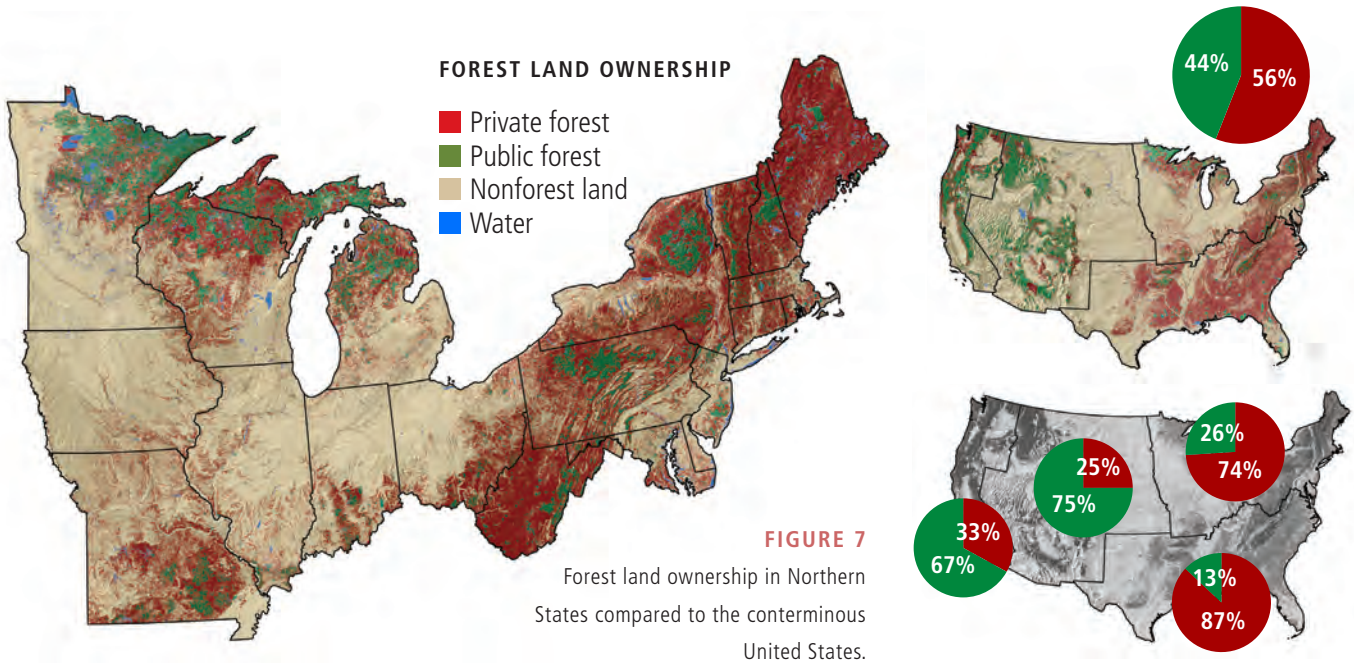


FIGURE 7
Forest land ownership in Northern States compared to the conterminous United States.

Table 2—Forest characteristics of the Northern States, 2007, ordered from most to least forest land (Smith et al. 2009). Note that data are standardized to an inventory year of 2007 and that newer State-specific data for some attributes are available from online sources (Miles 2010, USDA FS 2009b).

State	Land area	Forest land	Forest land	Reserved forest area	Reserved forest area	Public forest land	Private forest land	No. of private forest owners
	(1,000 acres)	(1,000 acres)	(percent of all land)	(1,000 acres)	(percent of forest land)	(percent of forest land)	(percent of forest land)	(1,000)
Michigan	36,275	19,545	54	325	1.7	38	62	498
New York	30,217	18,669	62	2,501	13.4	23	77	687
Maine	19,752	17,673	89	318	1.8	6	94	252
Pennsylvania	28,683	16,577	58	458	2.8	29	71	497
Minnesota	51,024	16,391	32	820	5.0	57	43	202
Wisconsin	34,791	16,275	47	107	0.7	32	68	362
Missouri	44,093	15,078	34	241	1.6	18	82	359
West Virginia	15,415	12,007	78	174	1.4	13	87	251
Ohio	26,207	7,894	30	228	2.9	12	88	345
New Hampshire	5,740	4,850	85	128	2.6	25	75	128
Indiana	22,980	4,656	20	123	2.6	16	84	225
Vermont	5,920	4,618	78	114	2.5	16	84	88
Illinois	35,608	4,525	13	162	3.6	18	82	184
Massachusetts	5,018	3,171	63	131	4.1	31	69	293
Iowa	35,842	2,879	8	15	0.5	11	89	150
Maryland	6,256	2,566	41	180	7.0	24	76	157
New Jersey	4,748	2,132	45	160	7.5	38	62	122
Connecticut	3,101	1,794	58	31	1.7	23	77	108
Delaware	1,251	383	31	0	0	8	92	55
Rhode Island	669	356	53	0	0	15	85	38
North total	413,586	172,039	42	6,216	3.6	26	74	5,002
U.S. total	2,263,870	751,228	33	74,664	9.9	44	56	11,322

Protected forests

Protected forest areas occur in a variety of forms including designated wilderness, parks, natural areas, conservation partnerships on private lands, and areas protected by nongovernmental organizations. Collectively protected areas comprise approximately 16 percent of northern forest land (see also Criterion 7). Protected forests can be categorized by their level of protection. Some have almost no human management intervention. Others allow active management to maintain biodiversity (using prescribed fire for example) but exclude timber harvesting. Other areas—such as national forests, State forests, and some private forests—may be actively managed for multiple resources with an emphasis on sustaining biodiversity.

Reserved forest land is a category of protected forest (such as State and Federal parks and wildernesses), mostly in public ownership, that has been permanently excluded from timber harvesting, either by law or by administrative order. Six million acres (3.6 percent) of all northern forest land is in reserved forests (Table 2), a relatively small amount compared to western forests (Fig. 8).

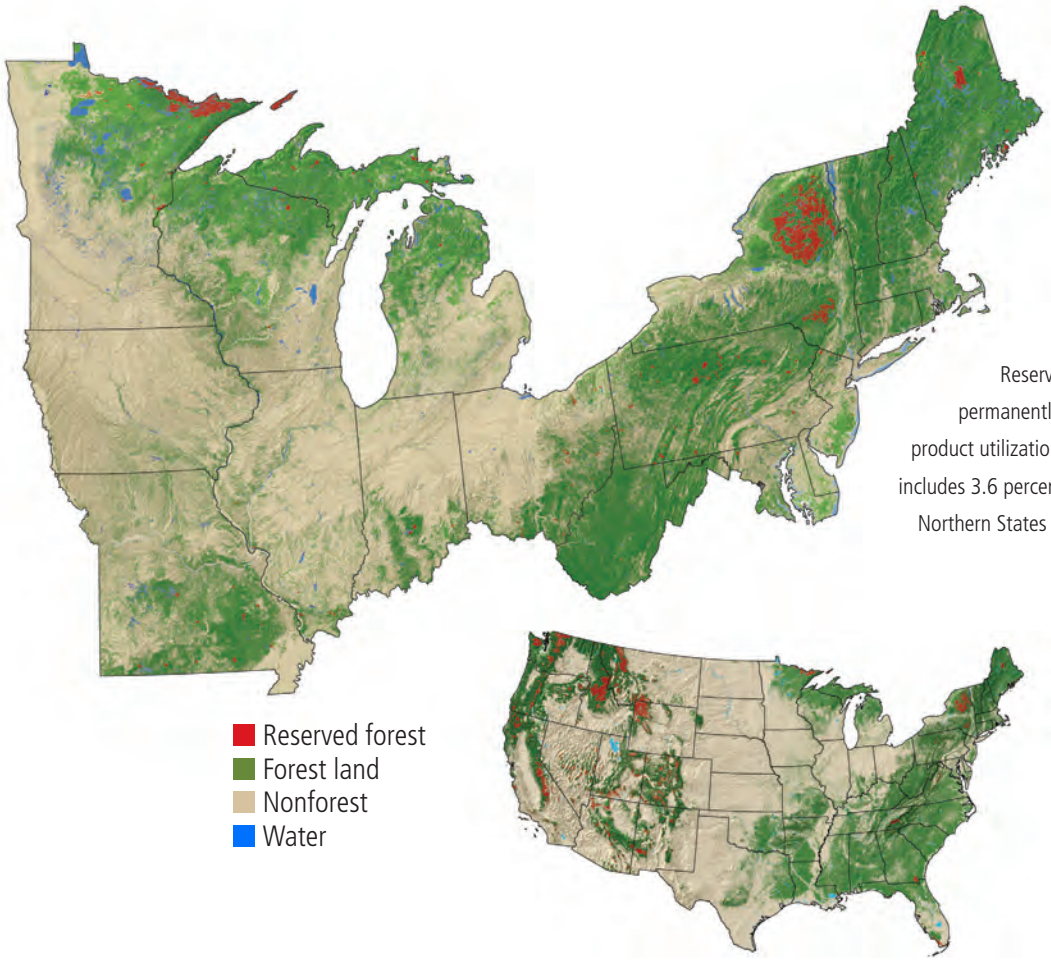


FIGURE 8

Reserved forest land (land is permanently removed from wood product utilization) in public ownership includes 3.6 percent of forest land in the Northern States and nearly 10 percent in the United States.

Forest land preservation agreements, trusts, and other voluntary land protection agreements have increased the area of protected private forest acreage in recent years. Developing a full inventory of private forests with conservation partnerships and other forms of protection is a work in progress. State and Federal conservation agreements on private forest land cover nearly 6 million acres of northern forests (3.5 percent of all forest land). Seventeen percent (28 million acres) of private northern forest land is voluntarily enrolled in State tax reduction programs that establish forest management guidelines and land use restrictions. Approximately 24 million acres of public and private forest land (14 percent of northern forest land) are enrolled in the Forest Stewardship Council third-party forest certification program. These categories of protection are not mutually exclusive; rather they represent a range of alternative methods to maintain forest cover and sustain forest values (USDA FS 2010e, 2010f).

Forest cover types and age classes

Although nine broad forest type groups—each named for its dominant tree cover—can be found in northern landscapes (Table 3, Fig. 9), the most common are the oak-hickory and the maple-beech-birch forest-type groups occupying 35 percent and 29 percent of the forest area, respectively.

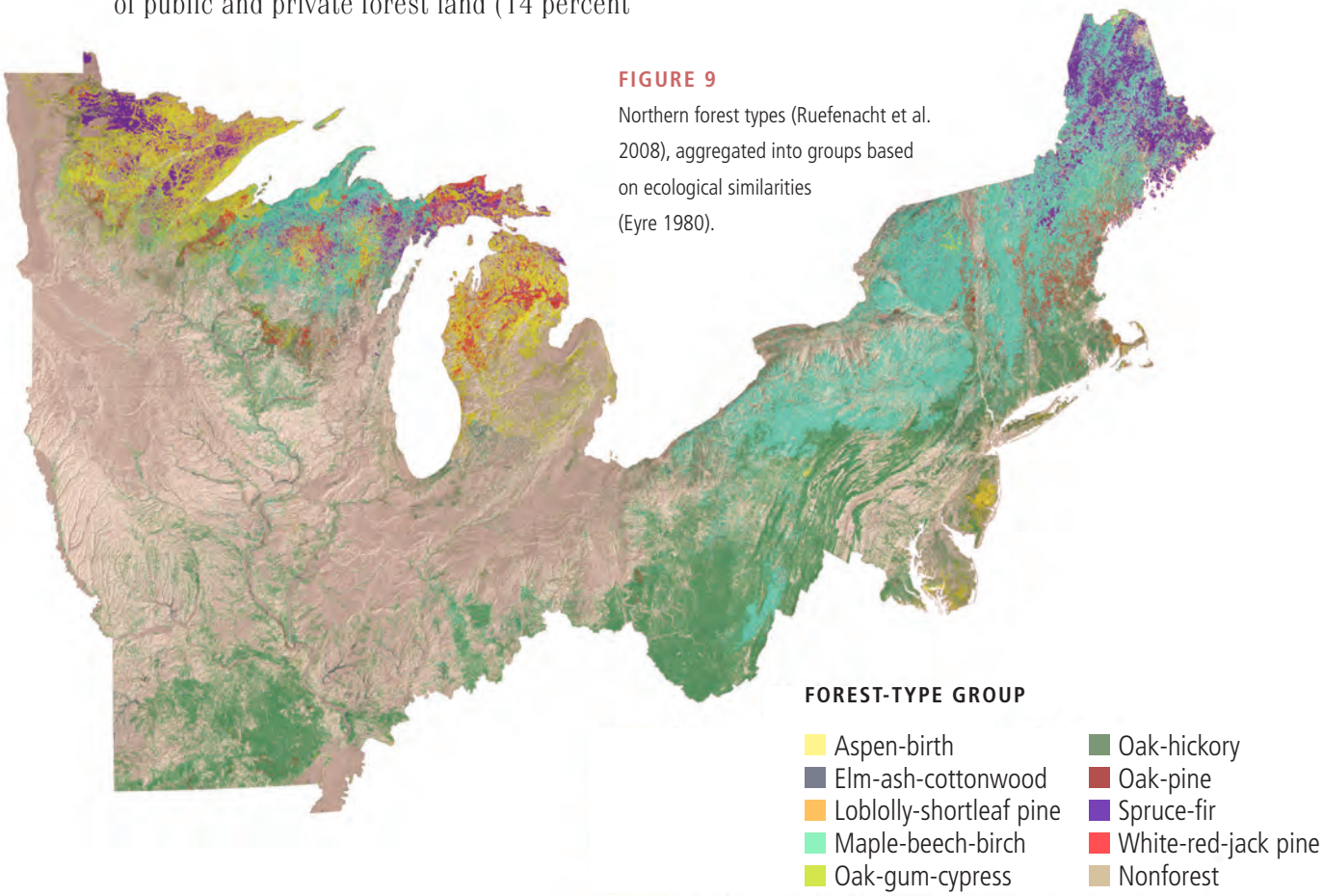


FIGURE 9
Northern forest types (Ruefenacht et al. 2008), aggregated into groups based on ecological similarities (Eyre 1980).

Table 3—Forest area for the Northern States by forest-type group, 2007, with States ordered from most to least timberland area and forest-type groups ordered from most to least proportion of area for the region (Miles 2010, Smith et al. 2009). Note that data have been standardized to an inventory year of 2007 and that newer State-specific data for some attributes are available from online sources (Miles 2010).

State and region	Forest land	Proportion of all Northern forest land	Oak hickory	Maple beech birch	Aspen birch	Spruce fir	Elm ash cotton-wood	White red jack pine	Oak pine	Loblolly short-leaf pine	Oak gum cypress	Non-stocked	Other types
	(1,000 acres)	(percent)	(percent of forest-type group area by state or region)										
Michigan	19,545	11.4	16	32	16	13	7	10	3	0	0	1	1
New York	18,669	10.9	21	54	4	3	4	7	3	0	0	1	2
Maine	17,673	10.3	2	40	13	33	2	8	2	0	0	0	0
Pennsylvania	16,577	9.6	51	39	2	0	2	3	2	1	0	1	1
Minnesota	16,391	9.5	9	10	40	23	9	6	2	0	0	2	0
Wisconsin	16,275	9.5	23	26	20	9	9	9	4	0	0	1	0
Missouri	15,078	8.8	80	2	0	0	7	0	7	1	0	0	3
West Virginia	12,007	7.0	67	26	0	0	2	1	3	1	0	0	0
Ohio	7,894	4.6	62	23	1	0	8	1	2	1	0	1	1
New Hampshire	4,850	2.8	8	54	7	8	2	14	7	0	0	0	0
Indiana	4,656	2.7	62	19	0	0	11	1	3	1	1	0	1
Vermont	4,618	2.7	4	68	6	7	2	11	2	0	0	0	1
Illinois	4,525	2.6	67	5	0	0	22	1	1	1	1	1	1
Massachusetts	3,171	1.8	30	27	1	0	6	15	14	2	2	1	0
Iowa	2,879	1.7	57	11	0	0	24	0	3	0	0	3	1
Maryland	2,566	1.5	64	5	0	0	2	0	10	11	4	1	1
New Jersey	2,132	1.2	46	11	0	0	2	0	8	22	8	1	2
Connecticut	1,794	1.0	71	11	0	0	6	6	3	0	2	1	0
Delaware	383	0.2	72	0	0	0	4	0	6	10	7	1	0
Rhode Island	356	0.2	56	16	1	0	5	6	8	4	3	1	1
North total	172,039	100.0	35	29	10	9	6	6	3	1	0	1	1

Northern forests are aging. Most of the primary (old-growth) forests were cut more than a century ago, and cutover areas that were not converted to agricultural or residential use typically regenerated naturally to second-growth forest. For about the last 40 years disturbances that regenerate new forests (such as timber harvesting or intense wildfires) have been relatively infrequent. Thus, about 70 percent of northern forest land is between 40 and 100 years old, creating a distinctly bell-shaped forest age distribution (Fig. 10). Young forests and very old forests are relatively rare, so there is relatively little habitat for species that depend on these forest age classes. This reduces forest diversity compared to landscapes that have a more balanced age structure with a similar proportion of forest area in each age class. If current rates of forest disturbance and regeneration continue, the average forest age will increase over time.

Fragmentation and parcelization

Forest fragmentation occurs when patches of nonforest land are created within a forest, patches of forest land are reduced in area, and/or forested corridors connecting forest patches are broken. This reduces forest area and increases the amount of edge habitat between forest and nonforest land. As fragmentation continues, forest patches can become disconnected from one another within a mosaic of other land uses. Fragmentation alters habitat suitability for forest-dwelling species.

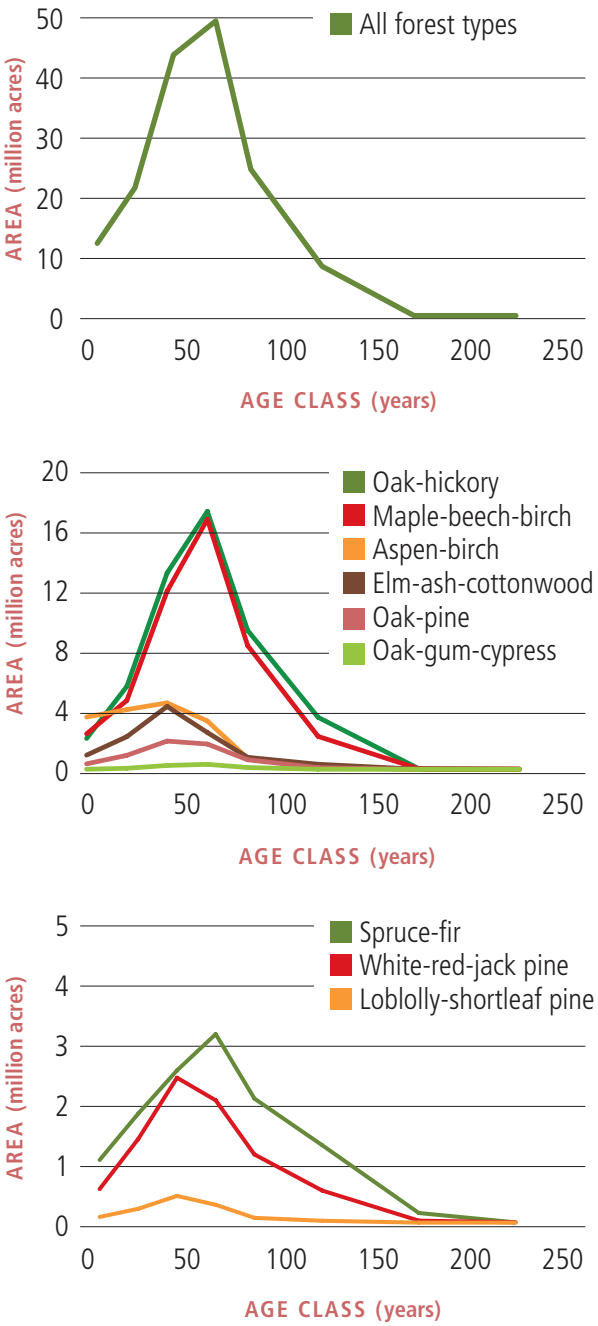


FIGURE 10

Forest age class distribution by forest-type group, Northern States, 2007 (Smith et al. 2009).

Fragmentation can reduce connectivity among forest patches, potentially restricting species movement and limiting genetic diversity within isolated plant and animal populations. Edge habitats favor different species than do the increasingly rare interior habitats of northern forests. Generally, retaining large forest patches is desirable because (1) large contiguous forest patches are relatively rare compared to small forest patches, and (2) over time human and natural disturbances tend to increase fragmentation, reduce forest patch size, and reduce the amount of forest interior habitat.

The degree of forest fragmentation cannot be distilled into a single number, because fragmentation statistics are affected by the spatial scale of analysis. For example, a relevant patch size opening in forest cover could be one-tenth of an acre, 1 acre, or 10 acres, depending on which forest-associated species are of interest. Likewise different forest-associated species (e.g., salamanders versus migrant birds versus humans) differ in the spatial scales at which they perceive and respond to fragmentation effects. In addition to patch size, the total area of forest land, density of forest land within a particular locale, the shape and pattern of forest patches, and rates of conversion of land to or from forest all play a role in fragmentation computations. Figures 7, 11, and 12 illustrate forest fragmentation in different ways and/or at different spatial scales.

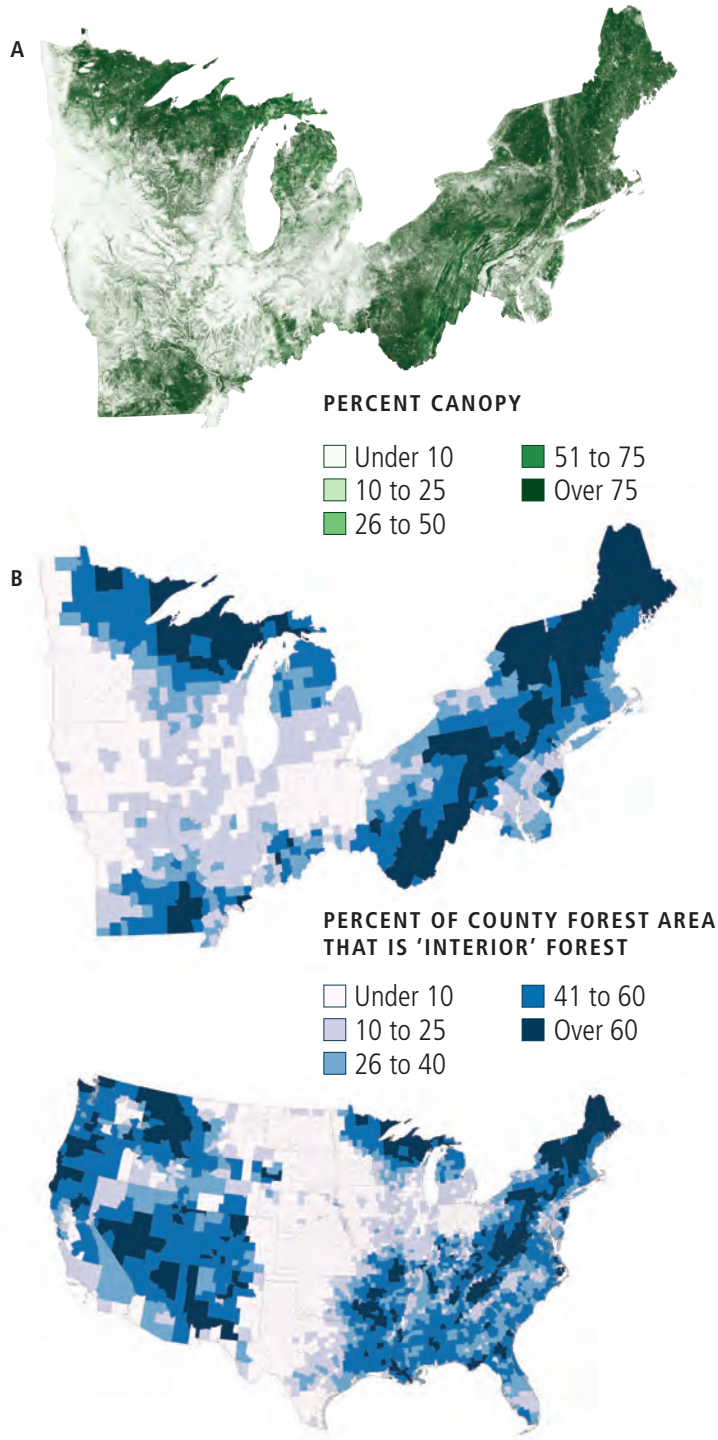
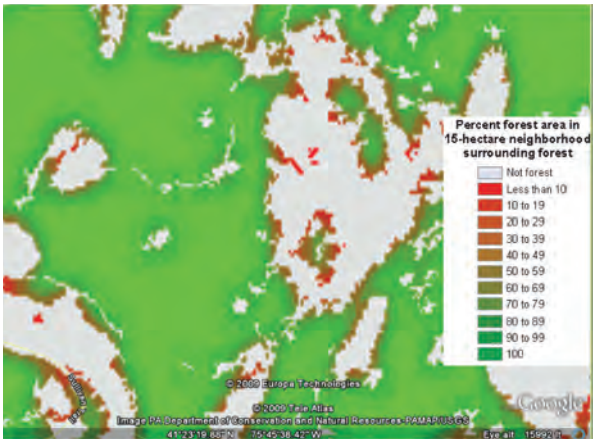


FIGURE 11

Forest area and fragmentation showing (A) forest density for the Northern States (Homer et al. 2004), and (B) fragmentation for the Northern States and the conterminous United States, with percent of interior forest measured as the percent of 40-acre blocks for each county that have at least 90 percent forest cover (source: Kurt Riitters, U.S. Forest Service; USDA FS 2011e).

A

B



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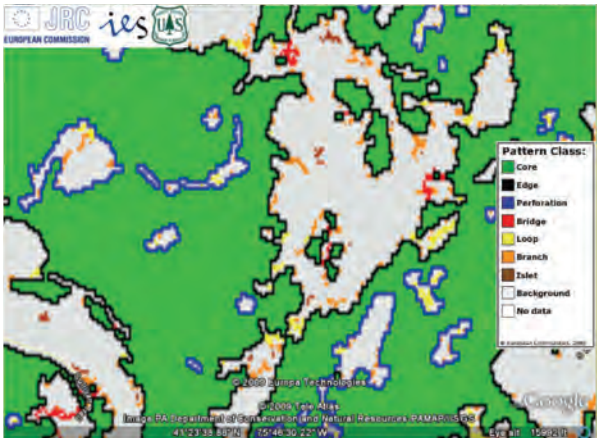

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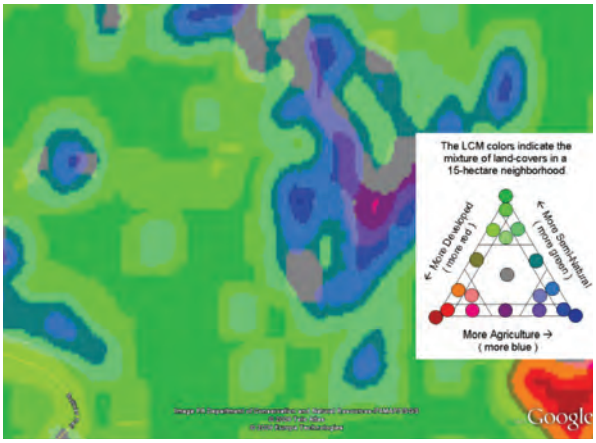


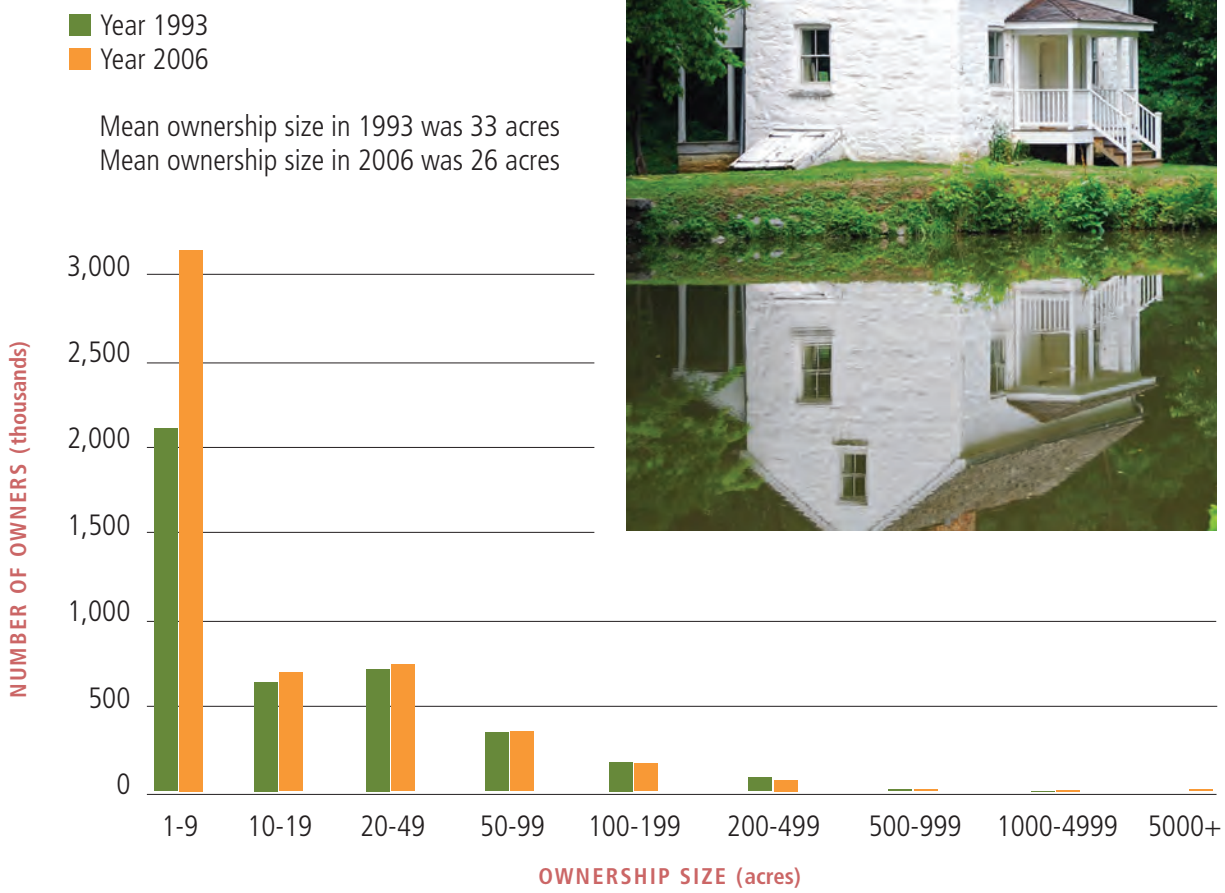
FIGURE 12

Fine scale fragmentation images from a landscape west of Scranton, PA: (A) aerial photograph of the area, (B) forest density, (C) forest fragmentation, and (D) land cover; these map layers are available for the conterminous United States and can be viewed or analyzed at large and small spatial scales [sources: Pennsylvania Department of Conservation and Natural Resources-PAMAP/USGS with additional processing by Europa Technologies©2009 and Tele Atlas©2009; Kurt Riitters; Multi-resolution Land Characteristics Consortium 2011; USGS 2010; MRLC 2011; European Commission Joint Research Centre Institute for Environment and Sustainability 2011; image processing by Peter Vogt, Institute for Environment and Sustainability; image processing by Kurt Riitters, U.S. Forest Service, using methodology by Pierre Soille, Institute for Environment and Sustainability; layer production by Kurt Riitters using methodologies of Wickham and Norton (1994) and Riitters et al. (2008)].

Parcelization occurs when forest ownerships are divided into smaller tracts. The number of private forest owners in the North increased to 5 million in 2006 from 4 million in 1993, and the average ownership size decreased from 33 to 26 acres (Fig. 13). Owners of small tracts may have different objectives and employ different management practices than those who own large tracts (Butler 2008, Gobster and Rickenbach 2004). Parcelization does not necessarily result in physical separation of forested areas, but it often results in disparate owner objectives and management practices among adjacent ownerships. This can be a barrier to building the spatial continuity in management practices needed to address broad, landscape-scale issues.

FIGURE 13

Number of private forest owners in the North by size of forest ownership, 1993 and 2006 (Birch 1996, Butler 2008).



Number and status of native forest-associated species

The number of forest-associated species is an important indicator of forest biodiversity, as is the proportion of those species that may face extinction. Natural variation in forest ecosystems across the United States creates differences in the number of forest-associated species among regions (Fig. 14). Also, the amount of available information varies from one species group to the next—much is known about the number and status of forest associated birds, mammals, and vascular plants compared insects, fungi, and microorganisms.

Northern forests support 780 known animal species (USDA FS 2010f): 85 percent have populations that are apparently secure, 13 percent are at some level of risk of future extinction, 0.8 percent are presumed extinct, and 1.2 percent are classified as "unknown status" (Fig. 15). For individual States, the proportion of species that are at risk ranges from 3 to 9 percent, and less than 1 percent of species are classified as extinct. With more research, the number of known forest-associated species will increase and the proportion of extinct or at-risk species could increase or decrease although the likelihood of extinctions appears to be smaller than the likelihood of discovering additional forest-associated species in taxonomic groups such as insects or fungi.

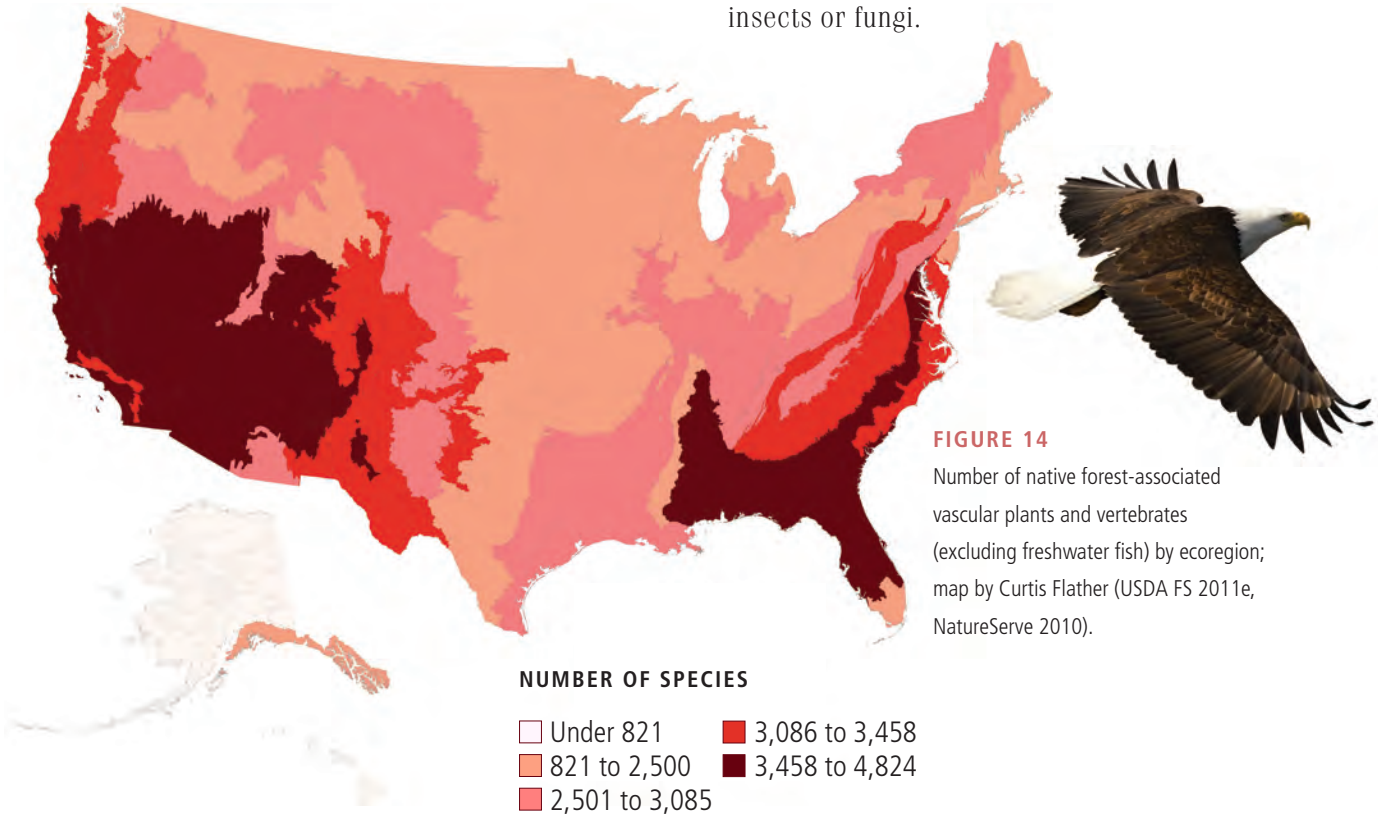


FIGURE 14
Number of native forest-associated vascular plants and vertebrates (excluding freshwater fish) by ecoregion; map by Curtis Flather (USDA FS 2011e, NatureServe 2010).

FIGURE 15

Proportion of forest-associated animals by Northern State and conservation status; species that are considered "at risk" of extinction are those classified as vulnerable, imperiled, critically imperiled, or possibly extinct (USDA FS 2010f, NatureServe 2010).

Species that are considered "at risk" are classified as vulnerable, imperiled, critically imperiled, or possibly extinct (NatureServe 2010). However, species that are not globally extinct or even at risk may still lose ground at a more local scale. Reductions in species' ranges are one way to quantify this effect. Compared with the rest of the Nation, Northern States have large numbers of extirpated (eliminated) species (Fig. 16).

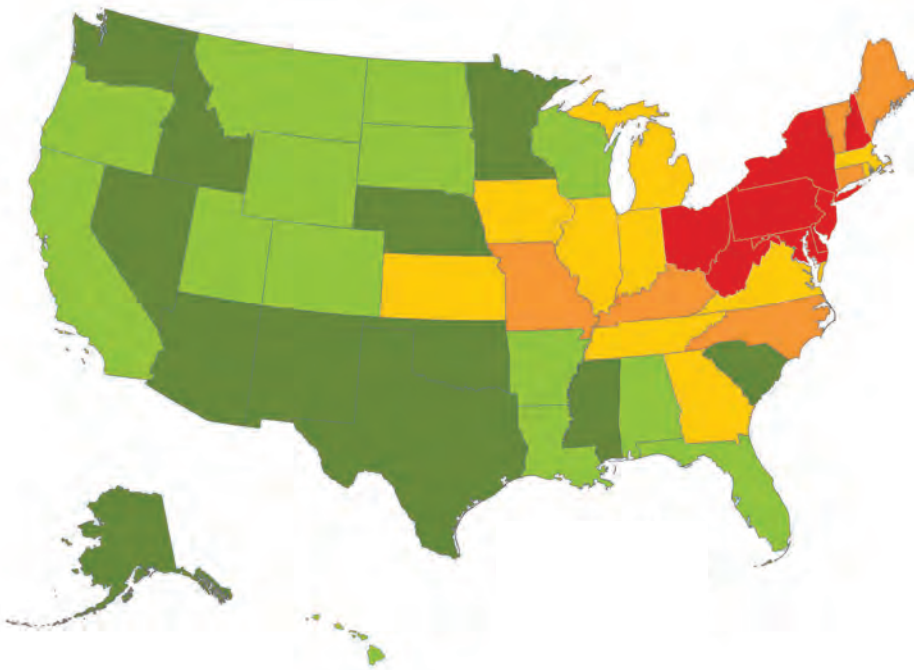


FIGURE 16

The number of forest-associated species—vascular plants, vertebrates (excluding freshwater fish), and select invertebrates—that have been extirpated within each State; map by Curtis Flather (USDA FS 2011e, NatureServe 2010.

NUMBER OF SPECIES EXTIRPATED

- Under 25
- 25 to 50
- 51 to 75
- 76 to 100
- Over 100