Criterion 3:

MAINTENANCE OF FOREST ECOSYSTEM HEALTH AND VITALITY

Montréal Process Criterion 3 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 7.1-7.4 (USDA FS 2010d)

The importance of maintaining forest ecosystem health and vitality

Forest ecosystem health depends on stable forest composition and structure and on sustainable ecosystem processes. Forest disturbances that push an ecosystem beyond the range of conditions considered normal can upset the balance among processes, exacerbate forest health problems, and increase mortality beyond historical norms. Sometimes forest ecosystems respond to disturbances by returning to the normal range of conditions. At other times, however, the ecosystem is so altered that it follows a new trajectory—occasionally without historical precedent or known capability for resiliency—producing uncharacteristic changes in forest health and associated processes that may threaten the human, plant, or animal populations that depend on forests. The following sections describe forest health in northern landscapes using indicators based on overall mortality trends and on potential impacts of specific insects and diseases.

Indicators of forest ecosystem health and vitality for northern forests

Mortality

Mortality is a natural process in a forest ecosystem. Dead trees serve valuable ecosystem functions as wildlife habitat, substrate for young

Key Findings for Criterion 3

- Mortality rates are one indicator of forest health. Current statewide mortality rates are 1 to 2 percent of total volume per year.
- The forest-type groups with the greatest percent annual mortality on a volume basis are noncommercial hardwoods, other eastern soft hardwoods, cottonwood and aspen, and other yellow pines.
- The most frequent types of tree defects are advanced decay, cracks or seams in tree boles, cankers, galls, and dead terminal branches.
- Locations where basal area mortality is expected to increase by at least 25 percent over the next 15 years are located throughout the North but are concentrated in the Northeastern States.
- Gypsy moth and emerald ash borer are entrenched invasive species causing widespread mortality.
- Other invasive insect species that have the potential to cause extensive mortality if they become established include the Asian longhorned beetle, Sirex wood wasp, and European spruce bark beetle.

FIGURE 20
Mortality as a percentage of live-tree volume on northern forest land, 2008.

plants, and sources of nutrients for the forest floor. Patterns and trends in mortality give a sense of overall forest health. Uncharacteristic increases in mortality can indicate fundamental forest health issues that may be associated with forest age, climate, insects, diseases, weather events, or other disturbance agents.

In northern forests, statewide mortality as a percentage of current live-tree volume ranged from about 0.4 to 1.5 percent annually (Miles 2010), with the exception of Minnesota at 1.9 percent (Fig. 20). These mortality rates are within the range of the values reported from prior State surveys. A lack of historical data based on consistent sampling methods limits our ability to analyze mortality trends over time.

Mortality percentages by species group for each State provide additional insight into variation across the region (Table 6). Seven species groups—other yellow pines (*Pinus* spp.), American beech (*Fagus grandifolia*), eastern noncommercial hardwoods, spruce (*Picea* spp.) and balsam fir, other eastern soft hardwoods, jack pine, and cottonwood and aspen (*Populus* spp.)—had annual mortality rates in excess of 2 percent. Because the cottonwood and aspen group is dominated by short-lived species, relatively high mortality rates are expected. High mortality rates for many of the other species groups are partly associated with insect and disease agents.

Table 6—Annual mortality of species group as a percent of volume by Northern State, 2008. To reduce uncertainties associated with small sample sizes, mortality for a species group is reported only if the group comprises at least 3 percent of a State's volume of growing stock, but the mortality totals for individual States and for the region as a whole include all species groups. States are ordered from least to greatest mortality percent for all species groups, and species groups are ordered from least to greatest mortality percent for the combined Northern States.

State and Region	All species groups	Yellow-poplar	Tupelo and blackgum	Sweetgum	Loblolly and shortleaf pine	Eastern white and red pine	Hard maple	Select white oaks	Select red oaks	Black walnut	Eastern hemlock	Other eastern softwoods	Soft maple	Hickory
Rhode Island	0.36					0.25		0.02	0.08				0.70	
Delaware	0.51	0.15	0.10	0.55	0.57			0.03					0.66	
Connecticut	0.63					1.00	0.23	0.09	0.22		1.24		0.60	0.04
Massachusetts	0.71					0.38	0.44		0.36		0.16		1.11	
New Jersey	0.77	0.26		0.67				0.22	0.37			0.93	1.33	
West Virginia	0.87	0.44					0.36	0.71	0.71				0.44	1.06
Maryland	0.90	0.43		0.22	0.40			0.61	1.02				1.00	0.61
Pennsylvania	0.92	0.28				1.19	0.94	0.44	0.39		0.91		0.67	
Indiana	1.00	0.55					0.41	0.29	0.93				1.13	0.89
Missouri	1.06				0.35			0.52	1.81	0.60		0.17		0.58
Michigan	1.08					0.32	0.37		0.42			0.61	0.46	
Ohio	1.17	0.47					0.70	0.93	0.16				0.96	0.71
New Hampshire	1.18					0.47	0.61		0.77		0.42		0.85	
Wisconsin	1.20					0.32	0.30	0.65	0.84			0.67	0.54	
Vermont	1.23					0.67	0.68		0.53		0.45		1.13	
New York	1.29					0.81	0.57		0.46		1.11		0.68	
Maine	1.38					0.58	0.79		0.07		0.23	0.80	0.77	
Illinois	1.43						0.18	0.80	2.00	1.01			0.83	0.31
Iowa	1.43							0.65	1.16	0.15			0.91	1.36
Minnesota	1.88					0.51	1.00	0.42	0.91			1.06	0.96	
Northern States	1.15	0.41	0.47	0.47	0.49	0.56	0.58	0.59	0.65	0.69	0.70	0.73	0.73	0.74

Table 6 continued

State and Region	Basswood	Other white oaks	Ash	Other red oaks	Yellow birch	Other eastern hard hardwoods	Other yellow pines	Beech	Eastern noncommercial hardwoods	Spruce and balsam fir	Other eastern soft hardwoods	Jack pine	Cottonwood and aspen
Rhode Island				0.40									
Delaware				0.88							0.77		
Connecticut			1.27	0.65		0.63							
Massachusetts			0.98	0.60		0.43					2.01		
New Jersey		0.32	1.52	1.62		0.61	0.33				2.14		
West Virginia		0.87		0.80		1.57		2.06			1.12		
Maryland		0.44		1.49							1.09		
Pennsylvania		0.77	0.87	0.40		1.51		2.11			1.31		
Indiana			1.07	0.82							2.09		2.23
Missouri		0.63		1.80							1.92		
Michigan			1.47	0.58						2.67	3.08		2.55
Ohio			1.48	0.46				1.03			2.78		1.19
New Hampshire			0.95		1.55			1.75		2.72	3.70		
Wisconsin	0.57		0.65	1.65						3.02	3.41		2.74
Vermont			0.35		0.75			3.12		2.48	2.75		
New York			1.03		1.50			2.58		2.10	2.81		3.42
Maine					0.94			4.34		2.23	2.54		2.35
Illinois			1.66	1.66		1.56					3.55		1.23
Iowa	0.88		1.12	1.09		0.59					4.25		0.80
Minnesota	0.89		0.85							3.02	3.08		3.12
Northern States	0.77	0.77	1.05	1.15	1.26	1.40	2.11	2.35	2.43	2.44	2.45	2.59	2.66

Damage on standing timber

Tree damage is sometimes an indicator of the potential for future mortality. Although not all types of tree damage (e.g., cracks or cankers) result in tree mortality, such factors can weaken a tree and predispose it toward mortality from other causes.

Statewide forest inventories conducted by the U.S. Forest Service have recorded damage on thousands of sampled trees. The bulk of trees in the North are undamaged, but some States have evidence of certain types of damage on up to 5 percent of all trees (Fig. 21). The most prominent damage types were various forms of decay, broken trees, and brooms or cracks.

Insect and disease incidence and risk

Many different insect, disease, invasive plant, and abiotic processes can impact forest ecosystems; sometimes multiple agents act simultaneously on the same forest area. Large cumulative risks can result in forest areas where insect or disease outbreaks appear imminent. Forests at risk span the entire North, but seem particularly concentrated in portions of West Virginia and Pennsylvania (Fig. 22). These are areas where one or more "biotic processes are

FIGURE 21

Percent of total volume on northern forest land by category of forest damage.

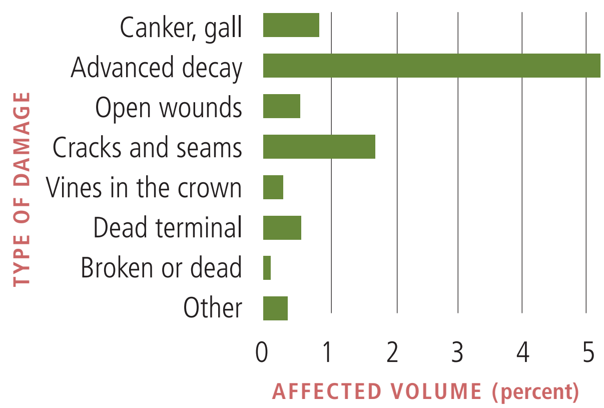
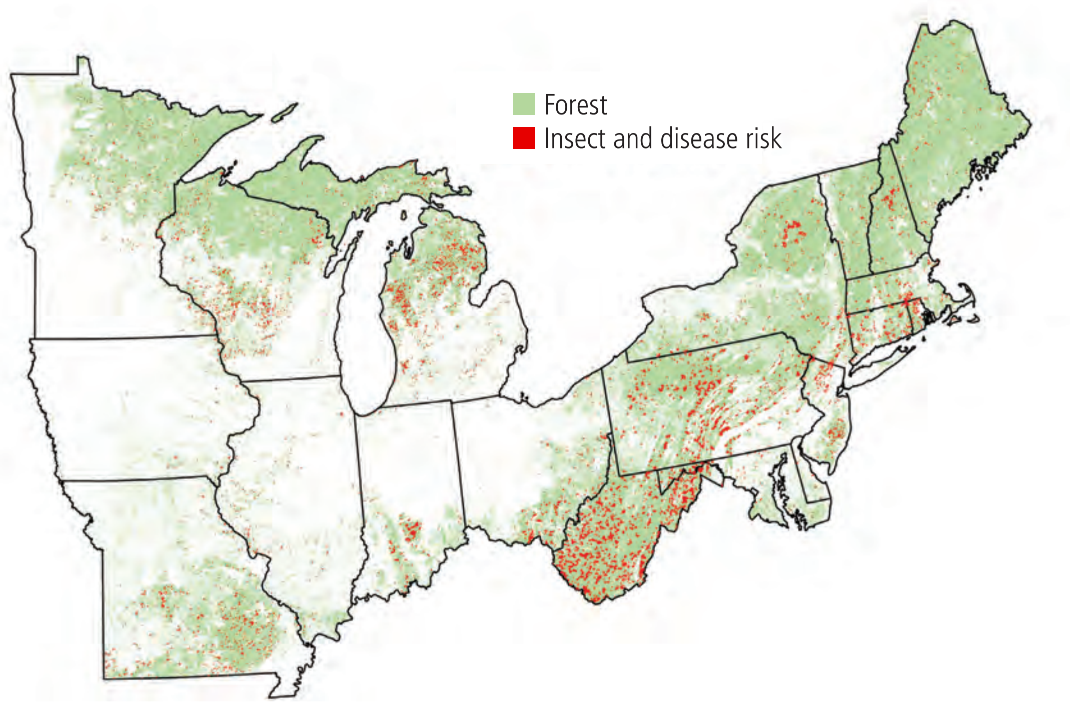


FIGURE 22

Insect and disease risk for northern forests with forest areas in red where 25 percent or more mortality (by basal area) is expected over the next 15 years. Forests at risk span the entire region, but appear particularly concentrated in portions of West Virginia and Pennsylvania. (USDA FS 2011c).



significantly out of range" (USDA Forest Service 2011e). Subsequent paragraphs examine several insect and disease agents in detail.

The Asian longhorned beetle (Fig. 23) is a vigorous, nonnative pest of maples (*Acer* spp.), birches (*Betula* spp.), elms *(Ulmus* spp.), and willows (*Salix* spp.); and it occasionally attacks ashes and poplars (*Populus* spp.). Given the prevalence of these tree species in northern forests and the many potential ports of entry through which the insect could be introduced via imported wooden pallets or shipping containers, the risk from Asian longhorned beetle is widespread (Bancroft and Smith 2001) (Fig. 23), especially for fragmented and stressed forests. Unrestrained infestation has the potential to dramatically alter forest composition, structure, and ecosystem function. The effectiveness of current Asian longhorned beetle quarantine efforts is still being evaluated.

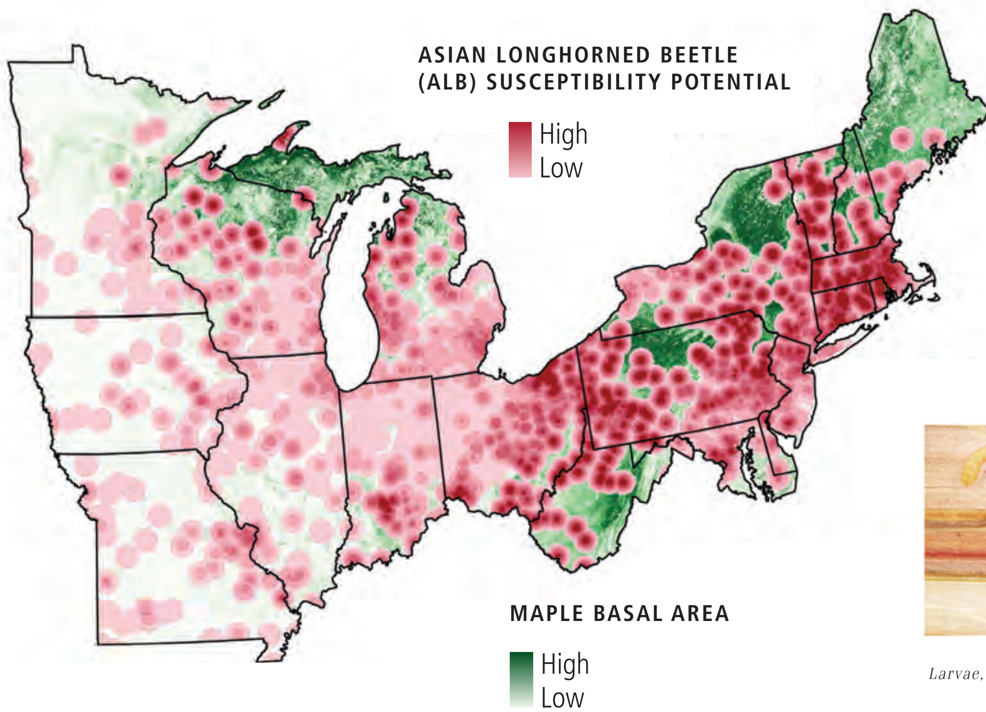


FIGURE 23

Susceptibility of northern forests to Asian longhorned beetle attack (USDA FS 2011a, 2011b).

Susceptibility potential relates to introduction and establishment where:

Introduction potential relates to:

1. Commodities associated with ALB interceptions. Associated commodities include bricks, stones, metal, and glass materials shipped (with wood packing/pallets) from countries where ALB exists.

2. Polygon ZIP code centroids that represent businesses and personnel that import and handle the commodities of interest.

Establishment potential relates to:

Mean basal area for all maple (Acer spp.), the host species for ALB, assigned to ZIP code centroids created in the introduction component as well as 30 km buffers to include the cumulative distances that ALB could possibly disperse over a 15-year period at 2 km per year (Bancroft and Smith 2001).

Larvae, Courtesy of Steven Katovich, USDA Forest Service, Bugwood.org

Adult, Courtesy of Dennis Haugen, USDA Forest Service, Bugwood.org

The emerald ash borer is a nonnative bark-boring beetle that was discovered in southeastern Michigan in 2002 and has since killed tens of millions of ash trees in forests and along streets throughout the Northern States. Figure 24 shows the spatial distribution of the northern ash resource (USDA FS 2010b) and the risk of introduction and establishment (susceptibility) when defined as a geographic function of preferred host range, urban ash trees, proximity of urban ash trees to natural forests, and past rates of phloem insect interceptions at U.S. ports of entry.

With an estimated 15 billion cubic feet of ash volume, ash species represent 5 percent of the volume of all trees in northern forests, and all ashes are susceptible to EAB attack. Due to their relative abundance of ash trees, Minnesota, Ohio, and Pennsylvania face the potential for heavy mortality from emerald ash borers. The economic impact of losing ash species is significant. For example, Treiman et al. (2008) estimated that if emerald ash borers become established statewide, Missouri's economy would lose more than $6.7 million annually. The economic impact of losing ash

Above Clockwise: 1) Second, third, and fourth stage larvae. 2) Purplish red abdomen on adult emerald ash borer. Photos courtesy of David Cappaert, Michigan State University, Bugwood.org

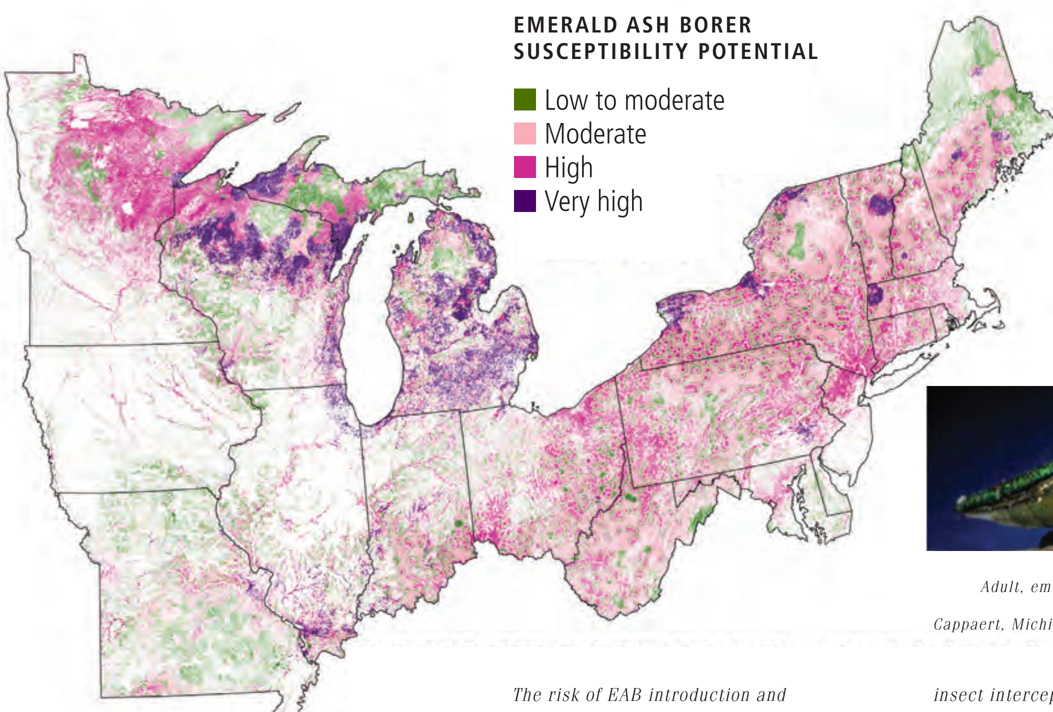


FIGURE 24

Susceptibility of northern forests to attack by emerald ash borer (USDA FS 2011a, 2011b).

The risk of EAB introduction and establishment is defined as a geographic function of: preferred host range, urban ash forests, proximity of urban ash forests to natural forests, and phloem insect interceptions at U.S. ports of entry. Susceptibility is defined as the potential for introduction and establishment, over a 15-year period, of a forest pest within a tree species or group.

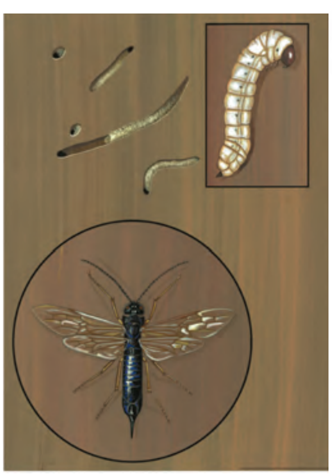
Adult, emerald ash borer, Courtesy of David Cappaert, Michigan State University, Bugwood.org street trees is harder to estimate because the losses would include aesthetic values as well as the cost of removal and replacement, loss of property values, and impact on cooling costs. Again using Missouri as an example, Treiman et al. (2008) calculated a statewide cost of $20.3 million for street tree replacement.

In 2004, the Sirex woodwasp (*Sirex noctilio*) was discovered in a New York forest. It is an invasive insect that vigorously attacks weakened and dead pine trees. It has killed up to 80 percent of the plantations trees that it has attacked in the southern hemisphere, and it threatens considerable forest land in the North where estimated susceptibility is based on forest species composition, density, and proximity to potential ports of entry (Fig. 25). Areas of forest along the eastern seaboard are particularly at risk (Haugen and Hoebeke 2005).

FIGURE 25

Susceptibility of northern forests to Sirex woodwasp. (USDA FS 2011a, 2011b).

Susceptibility is related to the introduction and establishment potential where introduction potential is determined by the locations of the ports that handle commodities with solid wood packing materials shipped from countries where Sirex wood wasp exists as well as distribution centers and markets. Establishment potential is determined by: pine basal area, presence of susceptible host, soil moisture index, and plant hardiness.



Adult, larva, and characteristic damage, Courtesy of Robert Dzwonkow, Bugwood.org

The European gypsy moth (*Lymantria dispar*) continues to devastate North American forests. Introduced in 1868, the species has spread from Boston westward to Wisconsin and southward to Virginia (Figs. 26 and 27). Although gypsy moth larvae prefer hardwoods, they may feed on several hundred different species of trees and shrubs (McManus et al. 1989). In northern forests, larvae prefer oaks, apple (*Malus spp.*), sweetgum (*Liquidambar styraciflua*), alder (*Alnus* spp.), basswood (*Tilia* spp.), birches, poplar, willow, eastern larch (*Larix laricina*), and hawthorn (*Crataegus* spp.).

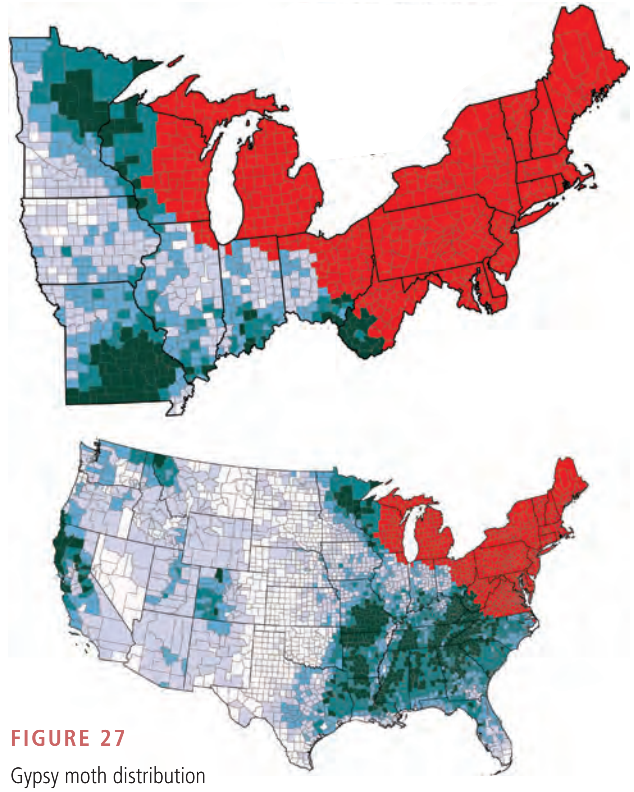
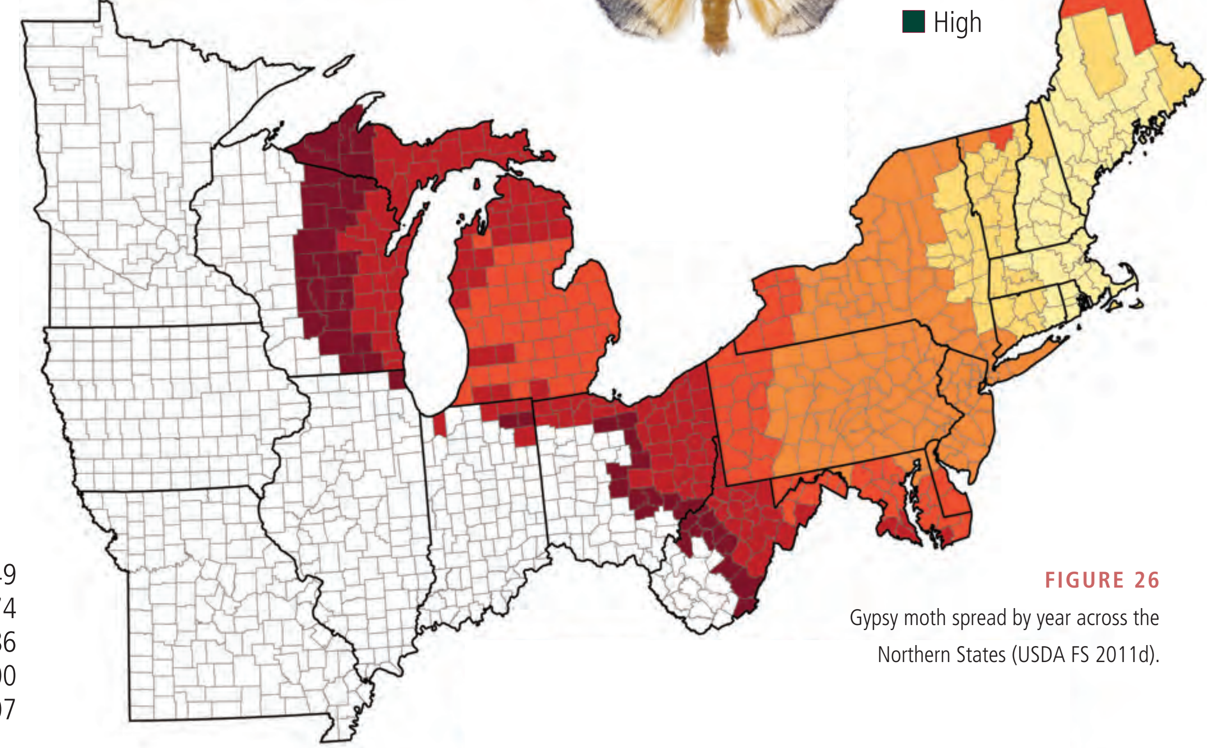


FIGURE 27

Gypsy moth distribution with future risk estimated by volume of host tree species (USDA FS 2011a).

GYPSY MOTH RISK LEVEL

- Current occupation
- Low
- 2
- 3
- 4
- High



GYPSY MOTH SPREAD

- Before 1915
- 1916 to 1949
- 1950 to 1974
- 1975 to 1986
- 1987 to 2000
- 2001 to 2007

FIGURE 26

Gypsy moth spread by year across the Northern States (USDA FS 2011d).

The list of hosts will likely expand as the insect spreads south and west. Although the invasion "front" experiences the most radical change in stand composition and tree mortality, outbreaks also recur in areas behind the front (Fig. 28). Intensive efforts to "slow the spread" through targeted treatment protocols have significantly reduced, but not stopped, the advance of this insect.

The hemlock wooly adelgid is a small aphid-like insect that feeds on the needles of eastern hemlocks (*Tsuga canadensis*) and Carolina hemlocks (*T. caroliniana*). Comprising 4 percent of all forest volume in northern forests, hemlocks fulfill critical roles within specific ecological niches (Godman and Lancaster 1990) such as provision of winter shelter and bedding for eastern white tailed deer (*Odocoileus virginianus*).

First discovered in Richmond, Virginia, the hemlock wooly adelgid has spread throughout the eastern United States since 1951 (Fig. 29), infesting anywhere from 25 percent (Morin et al. 2005) to 50 percent (USDA FS 2005) of the hemlock range. Young hemlock wooly adelgid nymphs (crawlers) can be spread by wind, on the feet of birds, or in the fur of small mammals (McClure 1990). Once settled, crawlers feed on stored starches in the twigs at the base of hemlock needles, quickly developing through the four nymph life stages and maturing in June. Hemlock decline and mortality typically occur within 4 to 10 years of infestation in the insect's northern range (3 to 6 years in its southern range). Hemlocks that are stressed by drought, poor site conditions, or attacks by other insects and diseases can decline and die more rapidly (USDA FS 2005).

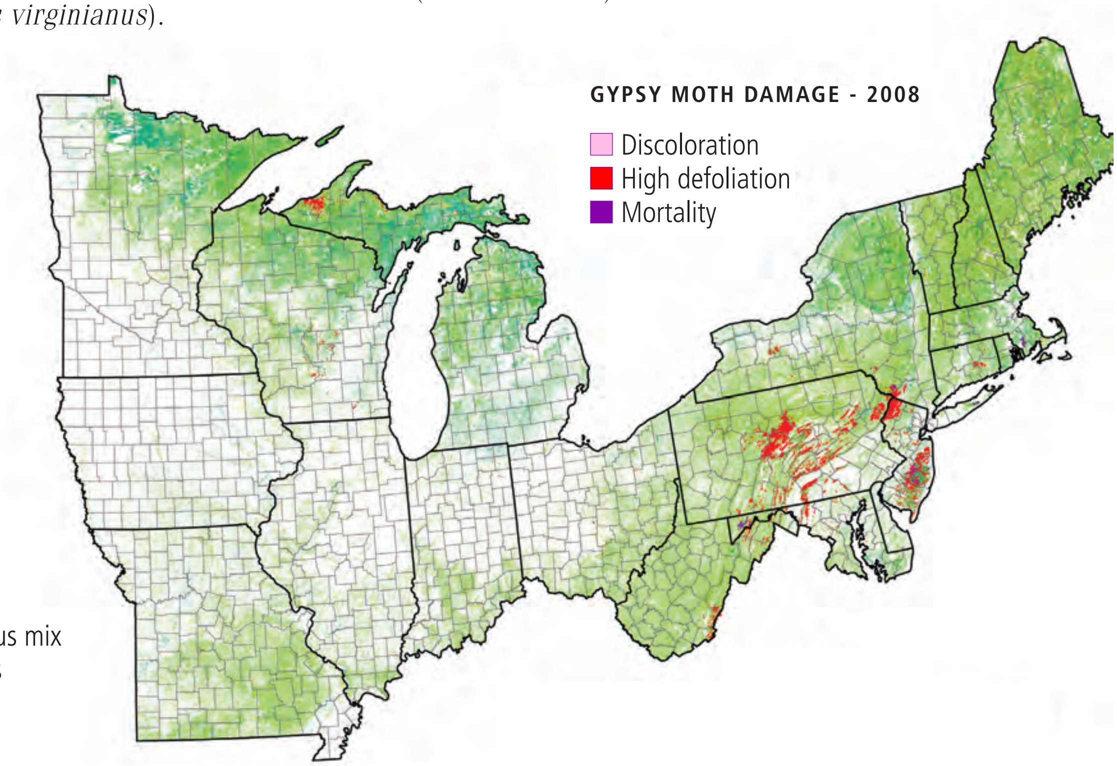


FIGURE 28

Incidence of gypsy moth defoliation behind the expanding front, 2008 (USDA FS 2011f).

FOREST

- Deciduous
- Conifer
- Conifer-deciduous mix
- Woody wetlands

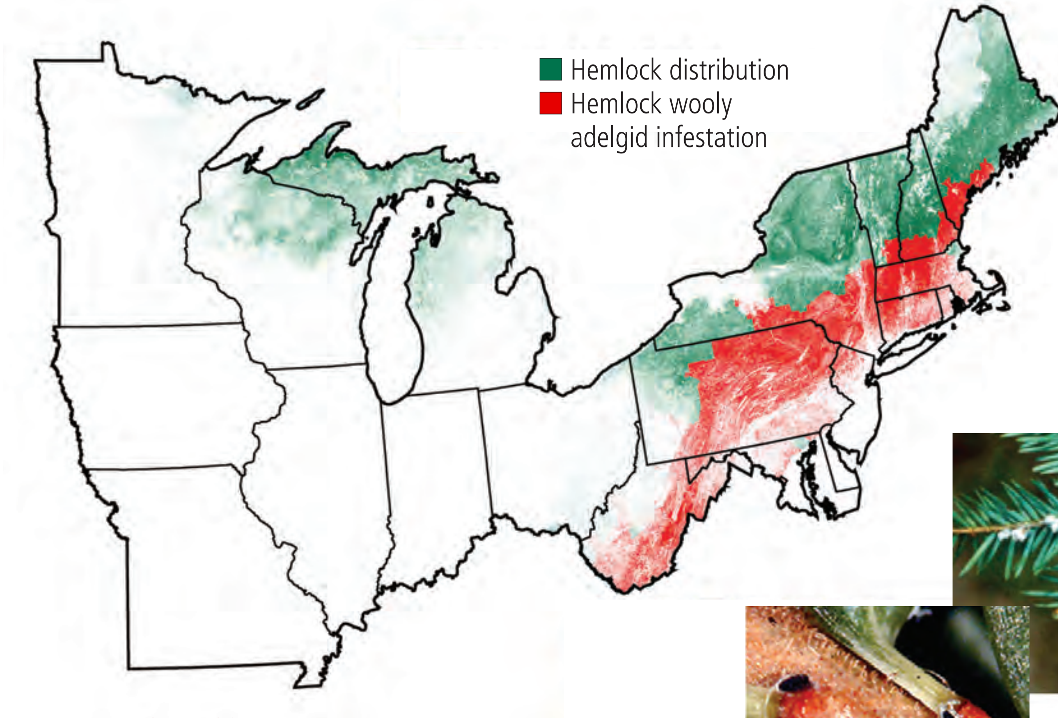


FIGURE 29

Distribution of eastern hemlock and areas infested with hemlock woolly adelgid in the Northern States; the map does not provide information below the county level and viewers should not assume 100 percent infestation in highlighted areas (source U.S. Forest Service-Northeastern Area http://na.fs.fed.us/fhp/hwa/maps/distribution.shtm).

Adelgid ovisacs

USDA Forest Service archives

Nymphs in dormancy

USDA Forest Service archives

European spruce bark beetle (*Ips typographus*), a devastating killer of spruces, is probably capable of successfully invading any of the spruces indigenous to North America. Similar to indigenous bark beetle species, the spruce bark beetle would be extremely difficult to eradicate if it became established in North America. An outbreak in Germany after World War II resulted in a loss of more than 1 billion cubic feet of spruce. Subsequent attacks have devastated spruce forests in Norway, Sweden, Germany (again), and the Czech Republic. In addition to spruces, some species of fir, pine, and larch are known to be susceptible to spruce bark beetle attacks. From 1985 to 2000, spruce bark beetles were intercepted 286 times in packing materials entering U.S. ports (Haack 2001) including Erie, PA (1993), Camden, NJ (1994) and Burns Harbor, IN (1995). This insect has a relatively high reproductive potential; because it breeds under the bark of host trees and is similar to several indigenous bark beetle species, infestations could go undetected for several years.

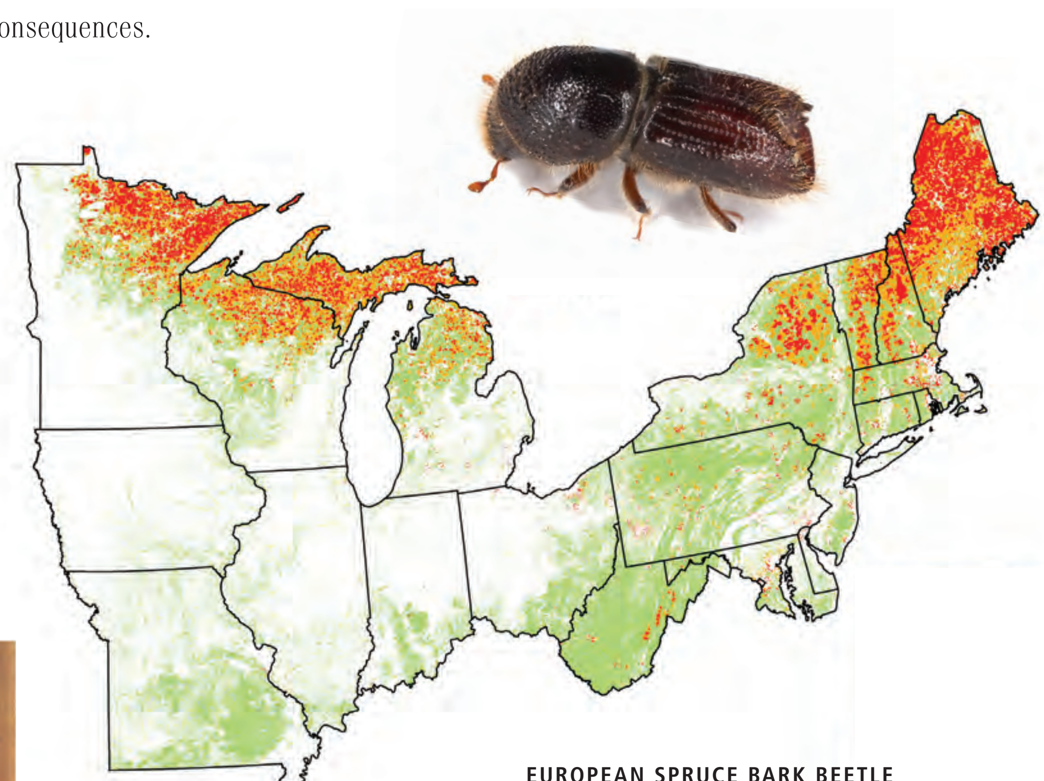
Substantial acreages of northern boreal forest are potentially susceptible to the European spruce bark beetle. Maine and Minnesota have a large spruce component, which could provide a large volume of suitable host material that would allow rapid spread in forests (Fig. 30) as well as yard and street tree plantings. Although not yet established in the United States, the European spruce bark beetle is considered a high-risk invasive species because of abundant host trees, host trees in proximity to ports of entry, and difficulty in controlling established populations. It has the potential to greatly exacerbate insect mortality in spruce-fir forests, which are already afflicted by periodic outbreaks of spruce budworm (*Choristoneura fumiferana*), that result in millions of cubic feet of lost timber with associated ecological and economic consequences.

Numerous other insects and diseases undermine the health, value, and diversity of northern forests. Some are well entrenched invasives: beech scale insect, chestnut blight, Dutch elm disease, and dogwood anthracnose. Thousand cankers disease of black walnut recently was found in Tennessee. Sudden oak death (*Phytophthora ramorum*) is a worrisome future possibility. Oak decline, hickory decline, oak tatters, tubakia leaf spot, and bacterial leaf scorch are other disease complexes of concern in northern forests.

FIGURE 30

Susceptibility of northern forests to European spruce bark beetle. The diagram shows an adult beetle, larvae, and the characteristic tree gallery (USDA FS 2011a, 2011f).

Courtesy of Robert Dzwonkow, Bugwood.org



EUROPEAN SPRUCE BARK BEETLE SUSCEPTIBILITY POTENTIAL

Low to moderate
High

Susceptibility potential relates to:
1. Establishment
2. Introduction

Establishment potential relates to:
1. Host species for European spruce bark beetle,
2. Disturbance factors (i.e., fires, lightening, winds tornadoes, avalanches, and hurricanes)
3. Urban forest

Introduction potential relates to: Ports that handle commodities and solid wood packing materials shipped from countries where European spruce bark beetle exists, distribution centers, and potential markets.