7. Area of forest land affected by potentially damaging agents

7.1 Tree mortality

Tree mortality, although a natural part of a developing forest, can also be an indicator of an unhealthy ecosystem. Analysis of tree mortality over time is required to understand the levels of mortality that are considered within a normal range and levels that are indicative of an unhealthy forest. Monitoring tree mortality is key to understanding the impact of biotic agents.

Total tree mortality has not changed significantly since 1996 (Figure 7.a) but certain species have experienced elevated mortality (Table 7.a). For instance, paper birch, balsam fir, elm, aspen, jack pine and black spruce have experienced mortality rates far above the average for all species. The exact cause of this mortality is not clear. It is likely that many factors have influenced the health of these species including the limits of biological age, drought, insects and diseases and potentially an increase in the winter temperatures.

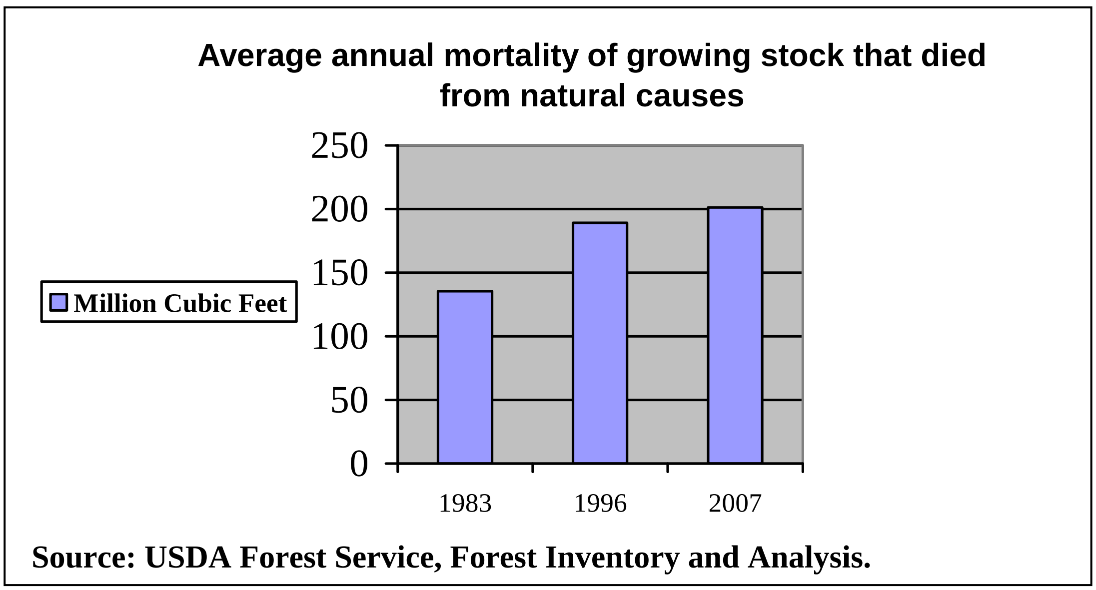


Figure 7.a: Average annual mortality of growing stock that died from natural causes in 1983, 1996, and 2007
Source: FIA, 2007

Table 7.a: Mortality, gross growth and ratio of mortality to gross growth 1996-2007

Species	Annual Mortality (million cft)	Annual Gross Growth (million cth)	Ratio of mortality to gross growth
Paper Birch	17.0	18.0	97%
Balsam Fir	19.0	26.0	75%
Elm	20.0	29.0	70%
Aspen	54.0	123.0	44%
Jack Pine	6.0	12.0	49%
Spruce	5.0	16.0	33%
Yellow Birch	2.0	6.0	34%
Red Oaks	23.0	90.0	25%
White Oaks	6.0	30.0	20%
White Pine	7.0	60.0	12%

Ash	7.0	51.0	14%
Hemlock	2.0	10.0	21%
Basswood	4.0	30.0	14%
Soft Maple	9.0	85.0	11%
Hard Maple	5.0	62.0	8%
Hickory	2.0	11.0	19%
Red Pine	2.0	70.0	3%
Total[2]	**201**	**793**	**25.4%**
Source: USDA Forest Service, Forest Inventory and Analysis			

Urban forest tree mortality and health

The statewide assessment of urban forest health began in 2002 with a national urban forest health monitoring program pilot carried out in partnership with the USDA Forest Service. As this was baseline data, mortality and health trends are not yet available. However, the data provides indicators of the current health of Wisconsin's urban forests.

Crown measurements evaluate the growth and vigor of the crown, as a whole, of each tree. Crown dieback is demonstrative of tree health and is defined as recent mortality of small branches and twigs in the upper and outer portion of the tree's crown. Both hardwood and conifer trees with crown dieback greater than 25 % may be in decline. Over 95% of urban trees have a dieback less than 25 % (Cumming, et al. 2007). Crown density is an estimate of the crown condition of each tree relative to its potential, by determining the percentage of light blocked by branches and foliage. Crown density reflects gaps in the crown that may have been caused by declining tree health. For hardwoods and conifers, density estimates less than 30 percent generally indicate the tree is in poor health. The majority of Wisconsin's urban trees (90%) exhibits a crown density greater than or equal to 30% (Cumming, et al. 2007).

[2] Totals include all species. There are minor species (i.e. hickory, cottonwood) that are not included in the table.

Damage indicators of urban forest health
At least one type of damage appeared on 19 percent of all trees sampled in urban plots. Species showing the greatest amount of damage included *Fraxinus americana*, *Acer negundo*, *Populus tremuloides*, *Picea glauca*, and *Acer platanoides*.

Table 7.b: Most common types of urban damage and frequency of damage type among trees with urban damage

Urban damage type	**Frequency**
Stem decay	23%
Other human damage	11%
Butt rot	10%
Hypoxylon canker	10%
Included bark	10%
Poor pruning	10%

(Source: Cumming, et al. 2007)

Forest health monitoring damage indicators do not fully capture information about damage types and agents found in urban areas. Of all the urban trees sampled, 9 percent showed some type of urban damage. The most common urban damage encountered was stem decay (Table 7.b). Wood decay is a serious concern in urban areas, since its presence increases the potential for tree failure. The specific cause of decay or initiating factors has not been identified.

Overall the trees in Wisconsin's urban forest are healthy and vigorous. However, specific stressors could have significant future impact on urban tree health and mortality. Two are most notable: 1) emerald ash borer poses a mortal risk to 20% of urban trees and 2) the prevalence of butt and stem decay is likely to result in substantial urban tree removal because of the potential public safety impact and also tree loss due to storms.

7.2 Catastrophic events

In Wisconsin, catastrophic events affecting forests include flooding, tornadoes, or storms that produce high speed winds (>100 mph). This type of event occurs annually on a small scale, affecting localized groups of trees. Large-scale impacts (>5,000 acres of forest land affected) occur less frequently.

Impacts of flooding are variable depending on the length of time trees are subjected to saturated soil, age of tree and depth of water. Seedlings and saplings are more susceptible to flooding than older trees; conifers are more susceptible to adverse impact than hardwoods. Some species such as silver maple, green ash and willow tolerate saturated soils for several weeks without noticeable impact. Tracking flooding events has become more important in the last decade as climate change begins to influence weather events that cause damage to trees. Monitoring trends will provide information needed for forest managers to reduce the impact of flooding through species selection and management.

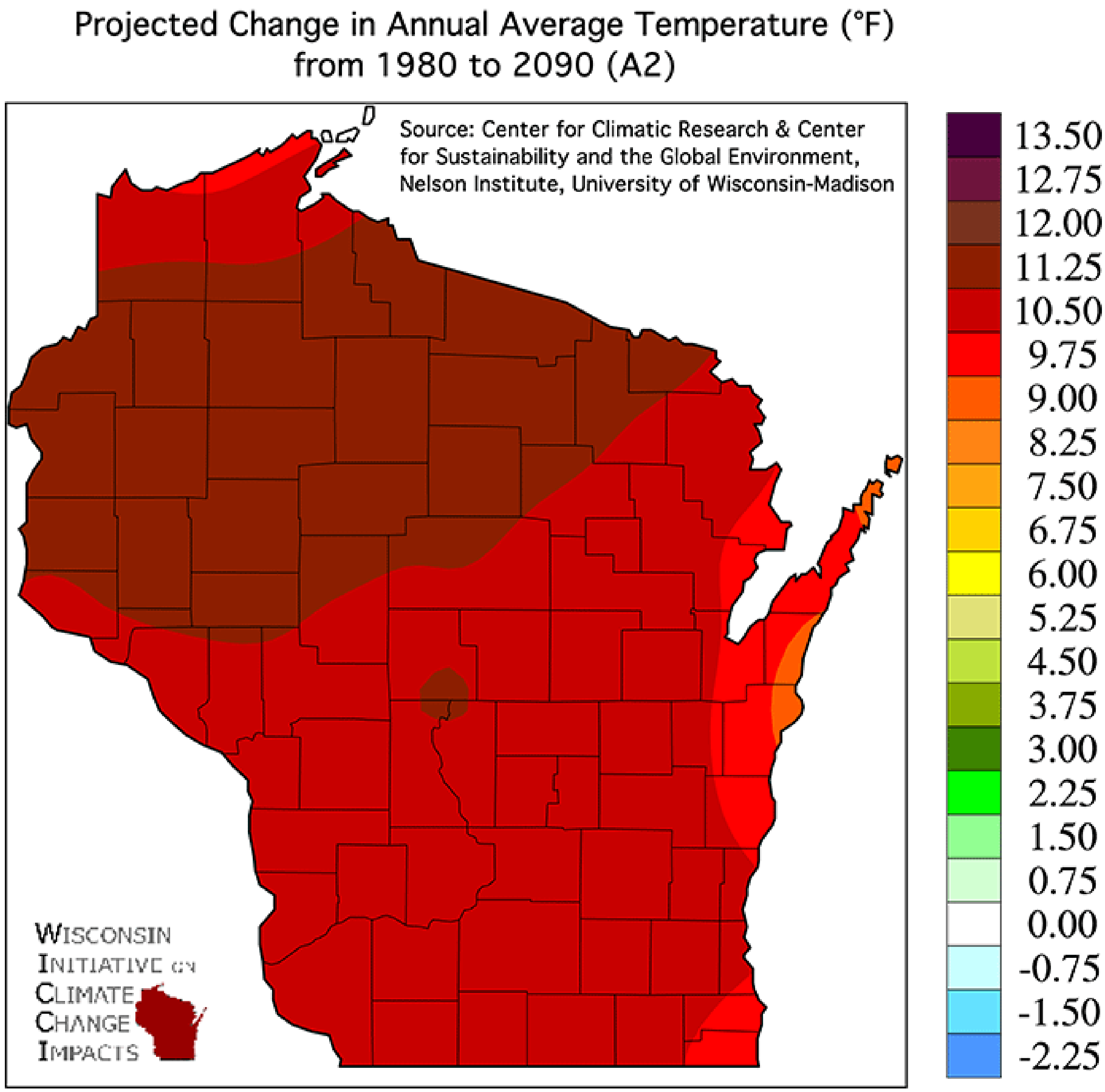
High winds cause damage to trees including uprooting and stem breakage. Forest stands that are uprooted are often very challenging to reforest given the extreme level of site disturbance.

Timber types can be dramatically changed from late to early succession. If salvage is delayed, the economic value of affected stands is decreased or lost due to timber stain and decay. Stem breakage creates large wounds (>50 square inches) that lead to stain, decay and degrade in wood quality.

Catastrophic events such as flooding and high winds are tracked through state and national databases. Data on the extent of these events and in some cases, the impact, have been collected and summarized in the annual report of the forest health protection program yet no standards have been implemented for documenting these events. Methodology for capturing the impact of catastrophic events on Wisconsin's forests in more consistent format should be developed and implemented.

7.3 Climate

Climate models endorsed by the Intergovernmental Panel on Climate Change (IPCC) show a continuing upward trend in warming. Without actions for intervention, average temperatures are projected to rise between 2 and 6 degrees Celsius by 2100 (IPCC, 4th assessment). To put this into context, a 2 degree warming is expected to have irreversible impacts on natural systems, including a 30 percent increase in plant and animal extinctions (IPCC, 4th assessment). These same models have been downscaled to the state level and produce similar results but with more variability across the state, as shown in Map 7.a.



Map 7.a: Modeled changes in annual average temperature
Source: Vimont et al, in review

It is also is important to note that these changes are already occurring over the past thirty years. Figure 7.b below shows that the frost free period in the state has been on the rise since the early 1990s. Figure 7.c shows the Palmer Drought Severity Index, which is a good indicator of drought. In the last decade, Wisconsin experienced three consecutive years of drought in central and northern areas. This is also consistent with Map 7.b

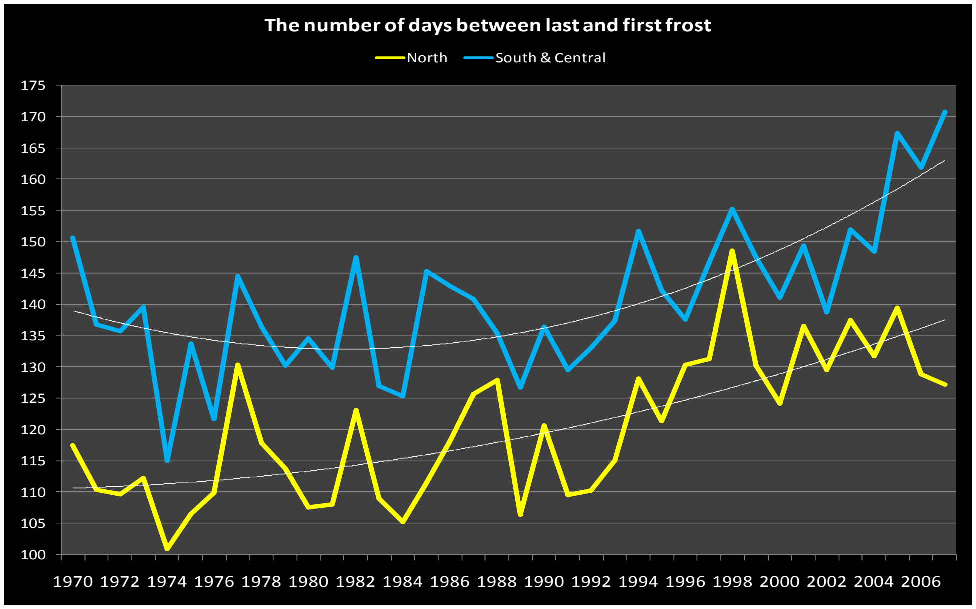


Figure 7.b: Number of days between last and first frost in northern and southern Wisconsin from 1970 to 2005
Source: Wisconsin State Climatologist

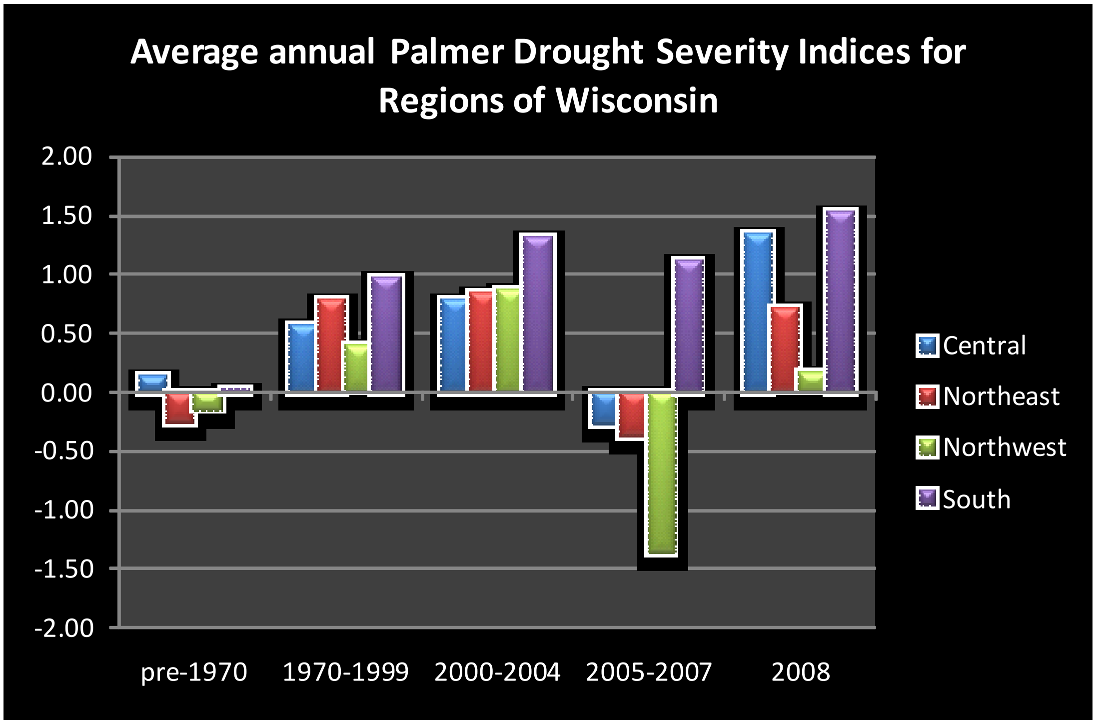
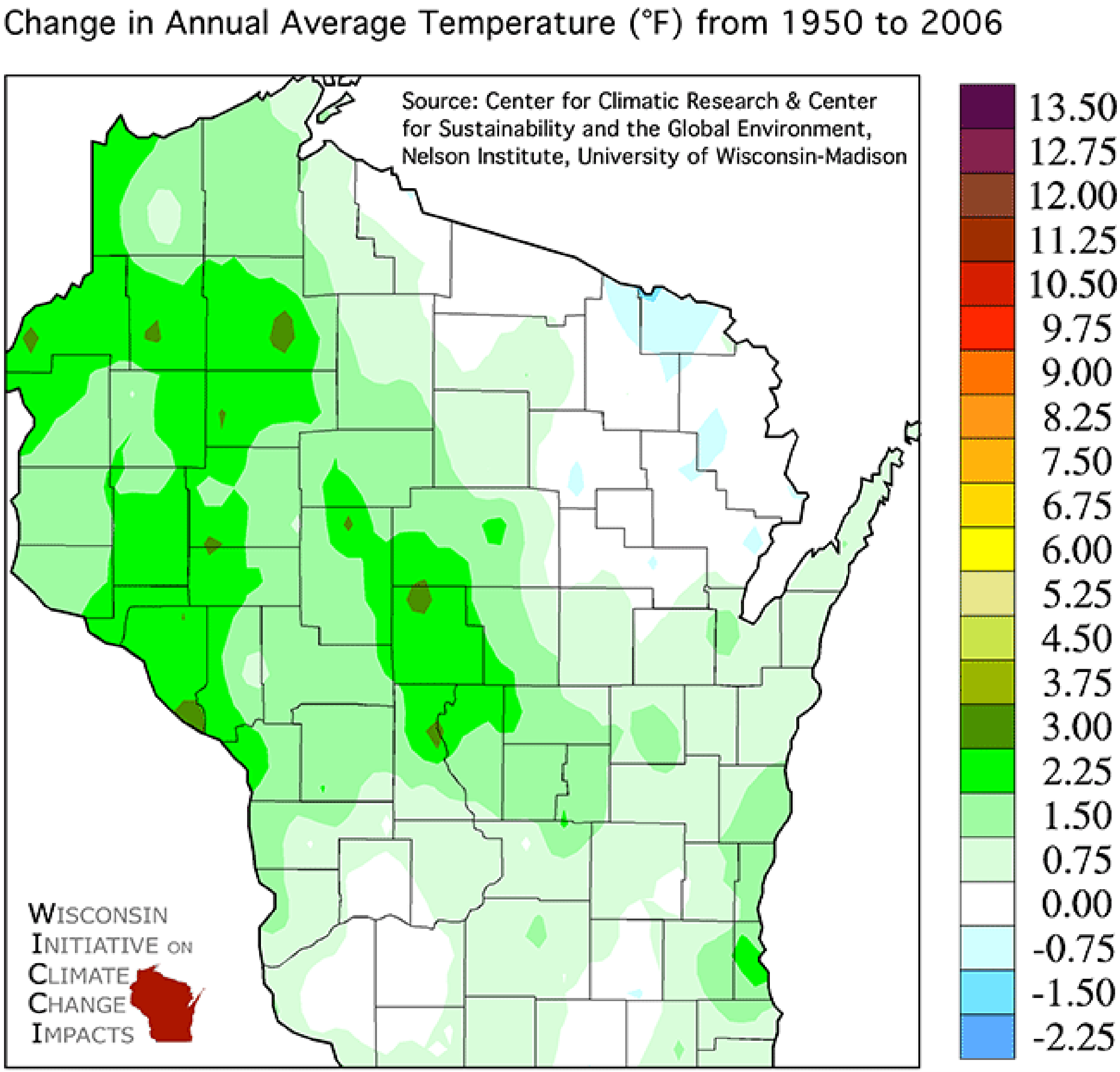


Figure 7.c: Average annual Palmer Drought Severity Indices for Regions of Wisconsin.
Source: Wisconsin State Climatologist



Map 7.b: Observed changes in annual average temperature
Source: Kucharik, in review

Based on observed and modeled climate change, forest ecosystems in the state will be subject to summer droughts, less snow cover and milder winter temperatures, and increases in extreme precipitation events (Lorenz, in review), (Kucharik, in review). These changing temperatures will push species beyond their adaptability limits, inducing heat and moisture stress. These environmental stressors will lessen population resilience to pest and disease outbreaks in northern forest types.

Forest composition in the northern half of the state could be the most affected by climate change. Wisconsin's forests occupy a unique position in the Great Lakes region as many of its tree species exist on the edge of their natural ranges. For example, red pine is at its southern limit, black walnut at its northern limit and American beech at its western limit. Range edges are likely to expand or contract as temperature and precipitation changes, and so some of these species could be pushed outside of their genetic limits and others afforded a more favorable growing environment.

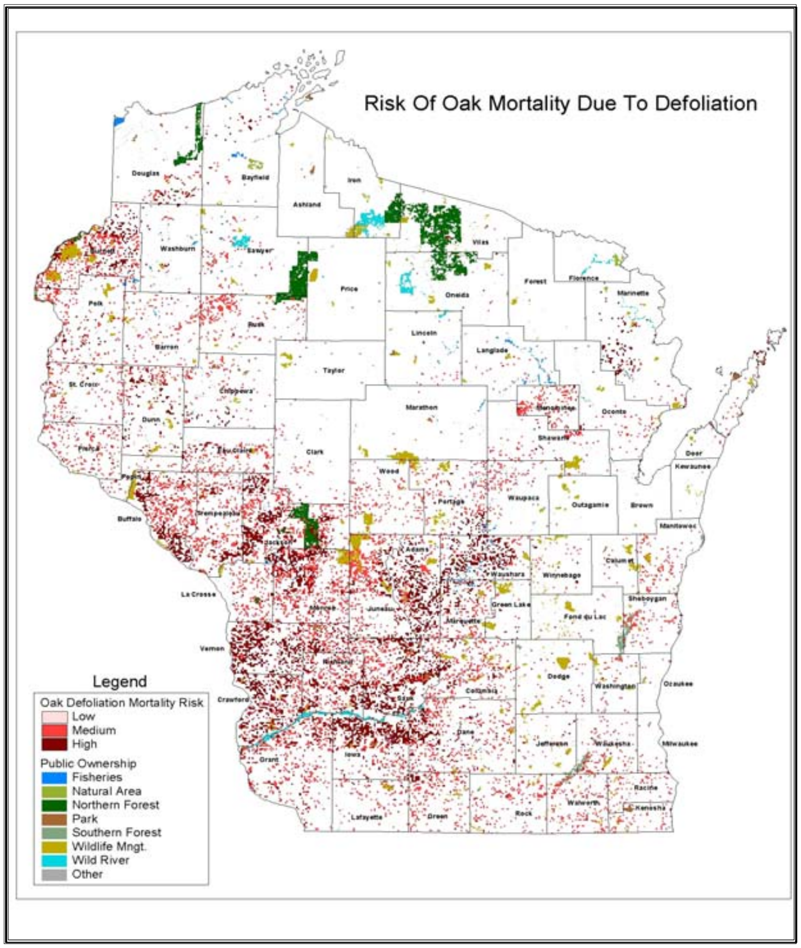
Wisconsin’s natural resources, including forests have been and will continue to be affected by a changing climate (US Climate Change Science Program, US Dept. of Commerce, NOAA 2009). Selected species including paper birch, balsam fir, elm, aspen, jack pine and black spruce have experienced mortality rates far above the average for all species due in part to insects, diseases and climate factors. The direct role of climate change on these mortality rates is not known, yet these species are considered most susceptible to climate change that includes warmer winter temperatures and drier growing seasons. Climate change scenarios from NOAA and WICCI support a continuation of decline and mortality of these species at a rate higher than the average for all tree species.

7.4 Insects and Diseases

Insects and diseases play a variety of roles in the forest ecosystem. At low levels, they kill suppressed, unhealthy trees, contributing to the natural process of forest succession and development and nutrient cycling. Natural cycles with periodic outbreaks and waves of mortality and succession do occur. Several native insects have been documented to reach outbreak levels where large numbers (>5,000) of acres are affected for several years before the insect’s population collapses. Pest cycles can increase tree mortality to a level that negatively affects forest stand stocking levels, clean water, wildlife habitat, and raw material for wood products, creating an unsustainable forest. Monitoring the incidence, severity, impact and location of forest insect and disease populations provides the information needed to focus mitigation strategies and broadens our knowledge on the influence these organisms play on forest ecosystems.

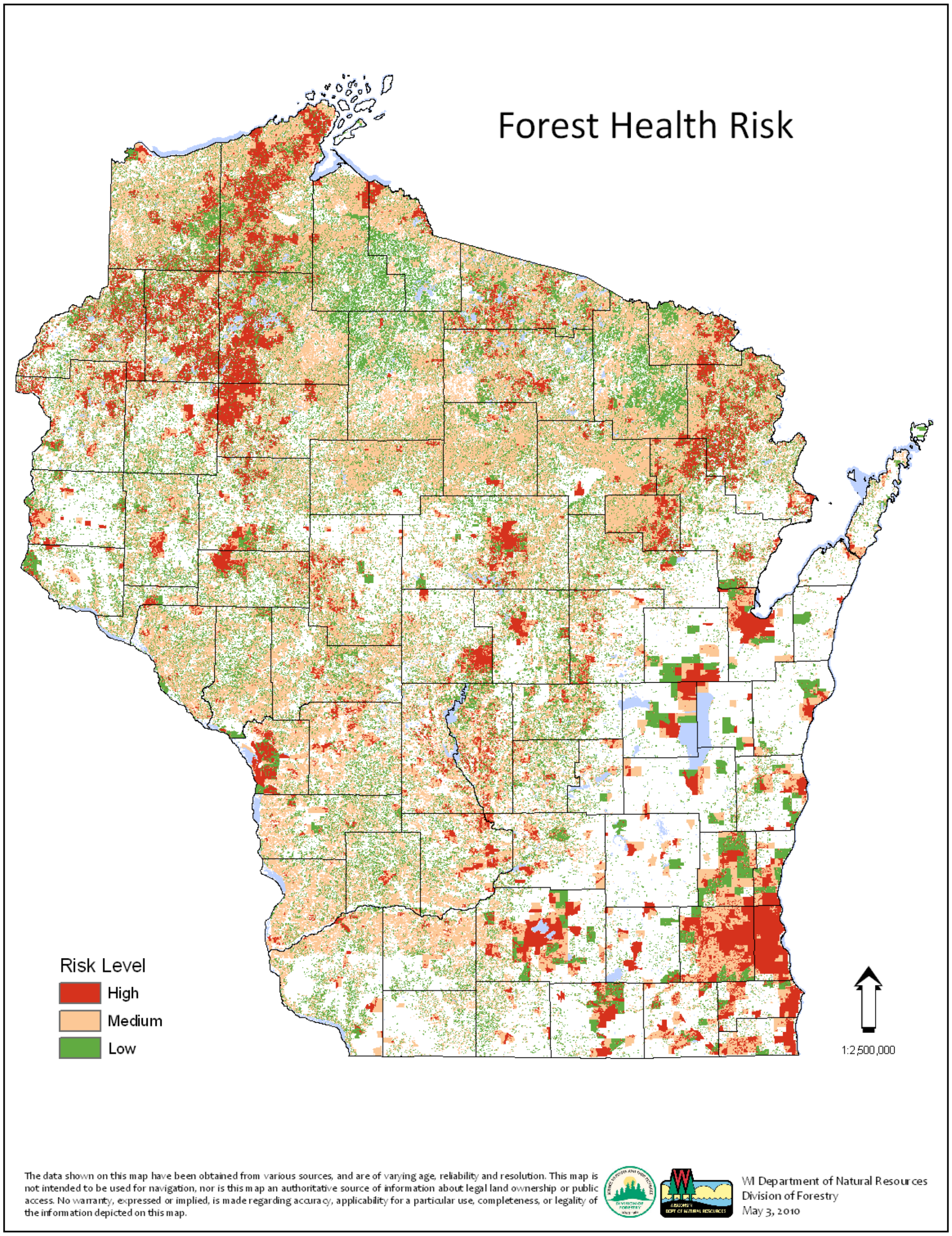
<u>Future Risk</u>

Threats from exotic insects and diseases have increased significantly since 2002. If successfully established, exotics can kill native tree species more quickly than native pests due to the lack of host resistance and biological controls. The hemlock woolly adelgid is known to be present in western Michigan; gypsy moth populations are building in central and southern Wisconsin and within the last year, the emerald ash borer and beech bark disease were found in the state. Recent detections of sirex woodwasp outside of port areas in the United States have raised concerns because this insect has the potential to cause significant mortality of pines. The emerald ash borer has the potential to eliminate ash from the forest environment. There are limited options for reducing the impact of these exotic species yet a focused effort on management activities that reduce the forest’s susceptibility to mortality should be a top priority for Wisconsin’s land managers. Map 7.c illustrates areas of the state that are at risk for oak mortality from defoliation by the gypsy moth and other oak defoliators. Identifying areas at risk is an excellent tool for forest managers to use when prioritizing areas for mitigation. Risk assessments and maps can also provide valuable information for locating early detection surveys.



Map 7.c: Future risk of mortality to oak due to defoliation by gypsy moth and other summer defoliators
Source: DNR, 2009

Wisconsin's forests are at risk of mortality by both native and exotic insects and diseases. Map 7.d illustrates areas at various levels of risk of experiencing 25% or more tree mortality over 15 years from a combination of pests. Native forest insects and diseases contributing to risk of mortality include forest tent caterpillar, oak wilt, jack pine budworm, Diplodia shoot blight and canker, red pine pocket mortality and pine bark beetle. Exotic insects and diseases contributing to risk of mortality include gypsy moth, hemlock woolly adelgid, beech bark disease, sudden oak death and emerald ash borer.



Map 7.d: Areas at low, moderate, and high levels of risk for experiencing 25% or more tree mortality over 15 years due to native and exotic insects and diseases
Source: DNR, 2009

Diseases that kill forest trees have long played an important role in forest succession, reducing tree density in overstocked stands, creating openings in the canopy that encourage successful regeneration and providing down woody material. In some cases, trees diseases can cause such high levels of mortality that a species may be reduced to only a few individuals on a site or statewide. Butternut canker, caused by the fungus *Sirococcus clavigignenti-juglandacearum*, has infected more than 95% of Wisconsin's butternut trees, significantly limiting the presence of this species. Oak wilt, caused by the fungus *Ceratocystis fagacearum*, is widespread in southern Wisconsin where red and black oak in both rural and forest settings are at risk from infection and mortality. The ecological impact of oak wilt has not been determined but efforts are underway to assess the impact of this disease. Annosum root rot, caused by the fungus, *Heterobasidium annosum*, is a significant threat to the health of pine plantations. Both oak wilt and annosum root rot can cause high levels of mortality within a forest stand; preventative measures have been developed for both of these diseases. Implementing these measures is critical to limiting their impact. Development of policy and guidance related to management of forest diseases provides an important link between scientifically-tested management practices and implementation of those practices.

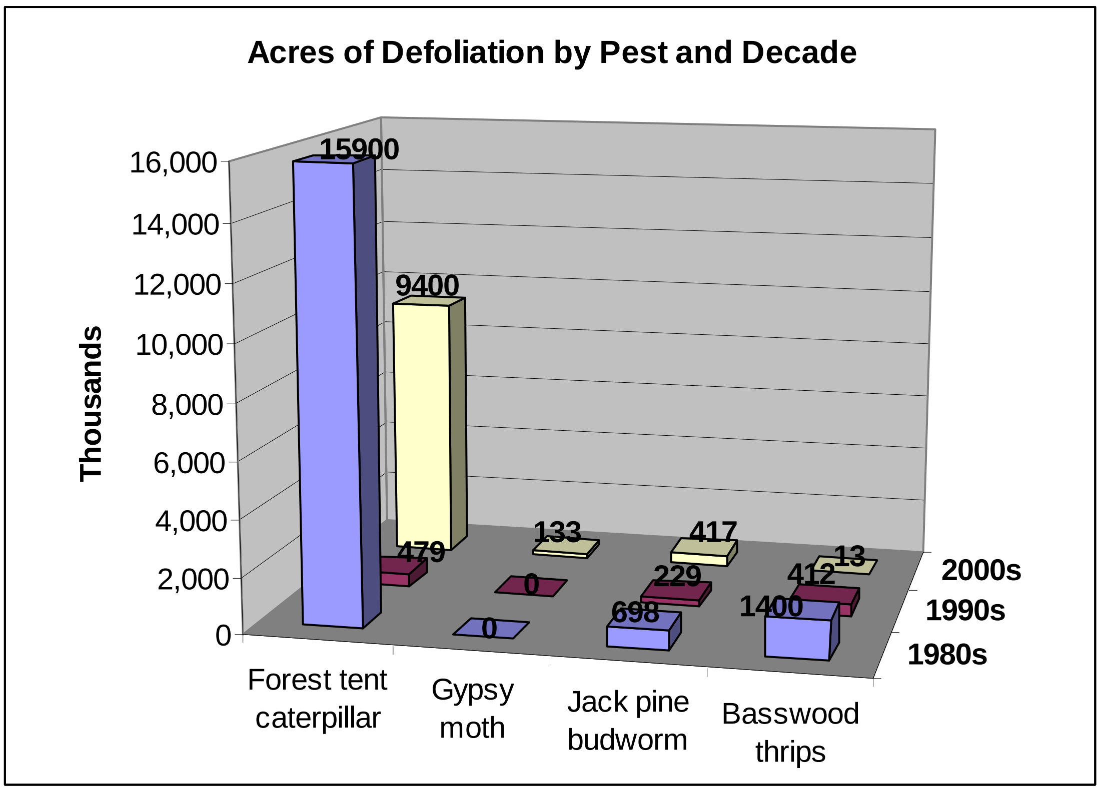
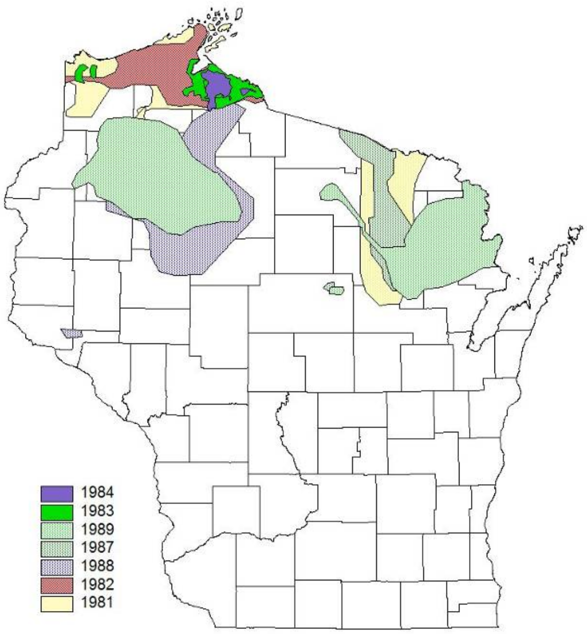
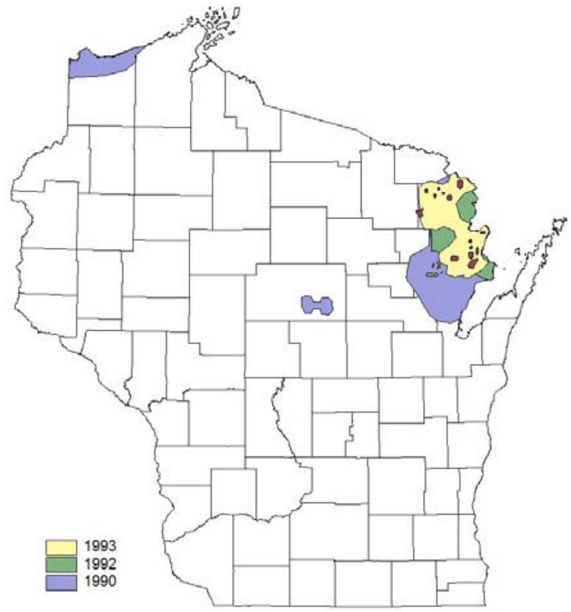


Figure 7.d: Acres of forest land defoliated by forest tent caterpillar, jack pine budworm, basswood thrips and gypsy moth by decade. (DNR, 2009)

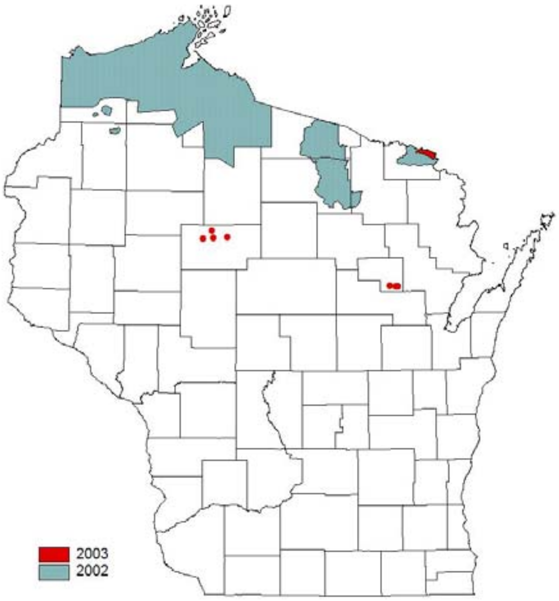
The forest tent caterpillar, *Malacosoma disstria*, is a native insect that feeds primarily on oak and aspen in northern Wisconsin. Feeding typically occurs early enough in the summer for trees to produce a second compliment of leaves. Extensive areas of Wisconsin's forests have been defoliated by this insect, with outbreaks typically lasting 3 years. The number of years between outbreaks varies widely (Map 7.e, 7.f, and 7.g). When defoliated trees refoliate, a reduction in stored carbohydrates occurs. This stress, combined with drought, disease such as Armillaria root disease or other defoliators can lead to tree mortality. Factors contributing to the collapse of populations of the forest tent caterpillar include cool, moist weather during caterpillar development, availability of host material and parasitism by Sarcophaga aldrichi.



Map 7.e Area of forest land defoliated by the forest tent caterpillar in the 1980's
Source: DNR, 2009

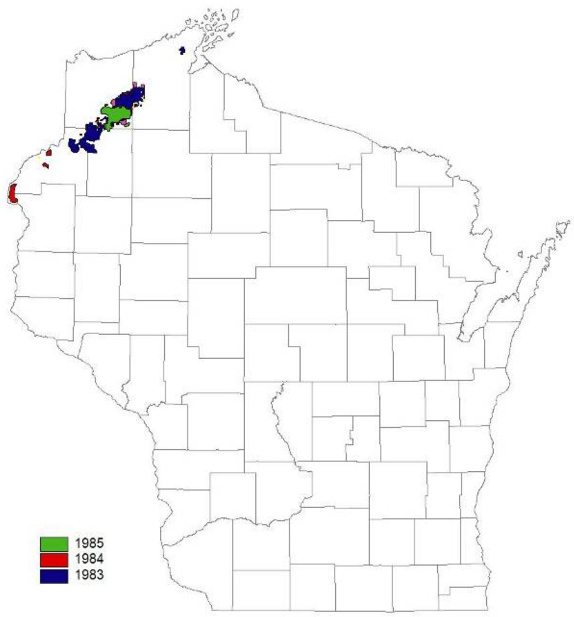


Map 7.f Area of forest land defoliated by the forest tent caterpillar in the 1990's
Source: DNR, 2009

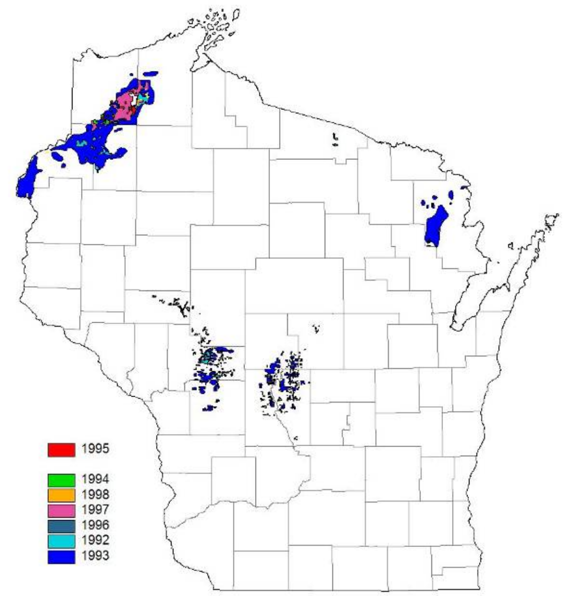


Map 7.g Area of forest land defoliated by the forest tent caterpillar in the 2000's
Source: DNR, 2009

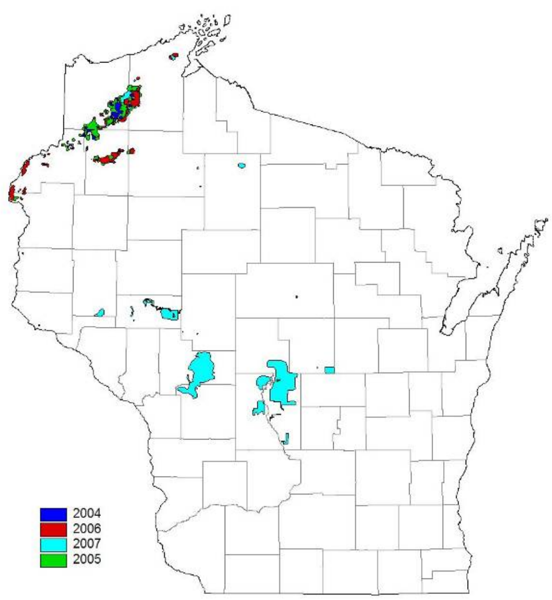
The jack pine budworm, *Choristoneura pinus*,is a native insect and is the most important defoliator of jack pine. Areas of defoliation have been documented since the mid-1950's (Map 7.f, 7.g, and 7.h). Since 1954, there have been 5 outbreaks where defoliation was extensive. Approximately half of the Northwest Sands ecological landscape and 10% of the Northeast Sand and Central Sand Plains ecological landscapes were defoliated in the 1990's. The severity of injury from budworm feeding is uneven across the landscape from year to year. Resulting tree mortality depends not only on the amount of foliage consumed but also the number of sequential years of feeding. Like the forest tent caterpillar, factors contributing to the collapse of populations of the jack pine budworm include cool, moist weather during caterpillar development, availability of host material and parasitism by several species of insects.



Map 7.h Area of forest land defoliated by the jack pine budworm during the 1980's
Source: DNR, 2009

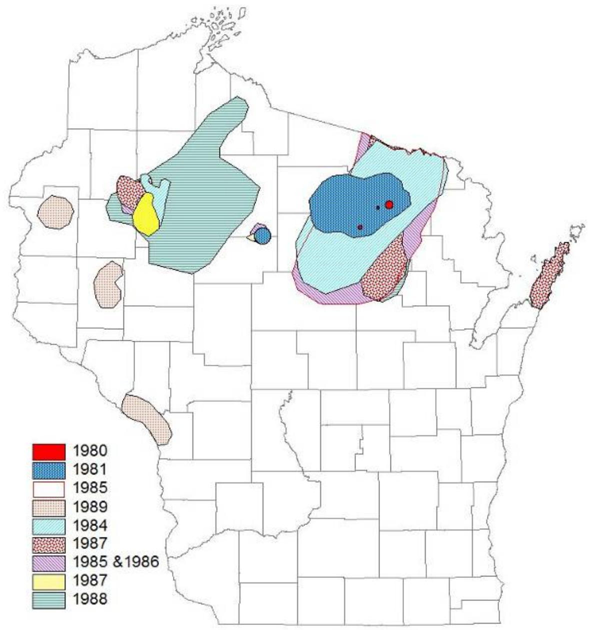


Map 7.i Area of forest land defoliated by the jack pine budworm during the 1990's
Source: DNR, 2009

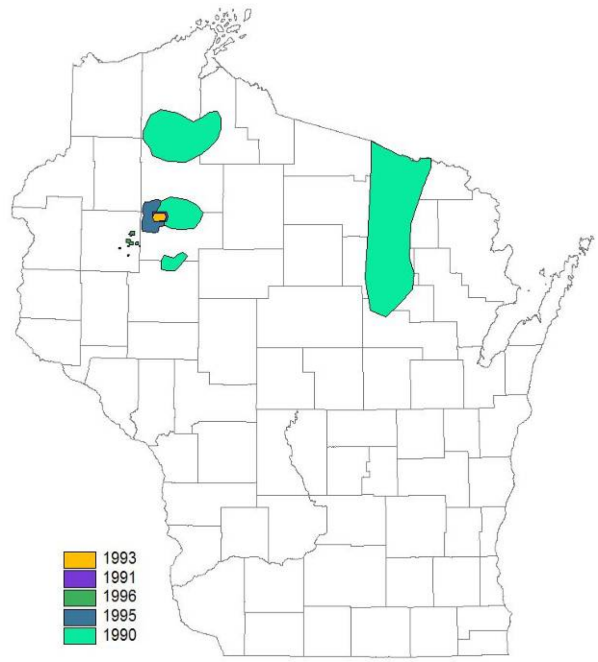


Map 7.j Area of forest land defoliated by the jack pine budworm during the 2000's
Source: DNR, 2009

The introduced basswood thrips, *Thrips calcaratus,* defoliates American basswood in early spring as the leaves are beginning to unfold from the bud. Affected trees may have leaves that are stunted and discolored. Heavy feeding in sequential years can cause a decrease in radial growth. This exotic insect is native to Europe and was first observed in Wisconsin in the late 1980's. Information related to factors that cause a collapse in the thrips population is not known.



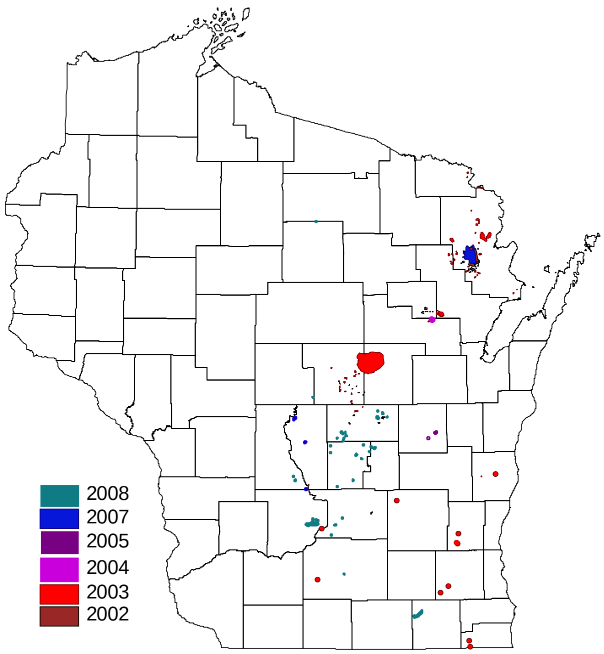
Map 7.k Area of forest land defoliated by basswood thrips during the 1980's
Source: DNR, 2009



Map 7.l Area of forest land defoliated by basswood thrips during the 1990's
Source: DNR, 2009

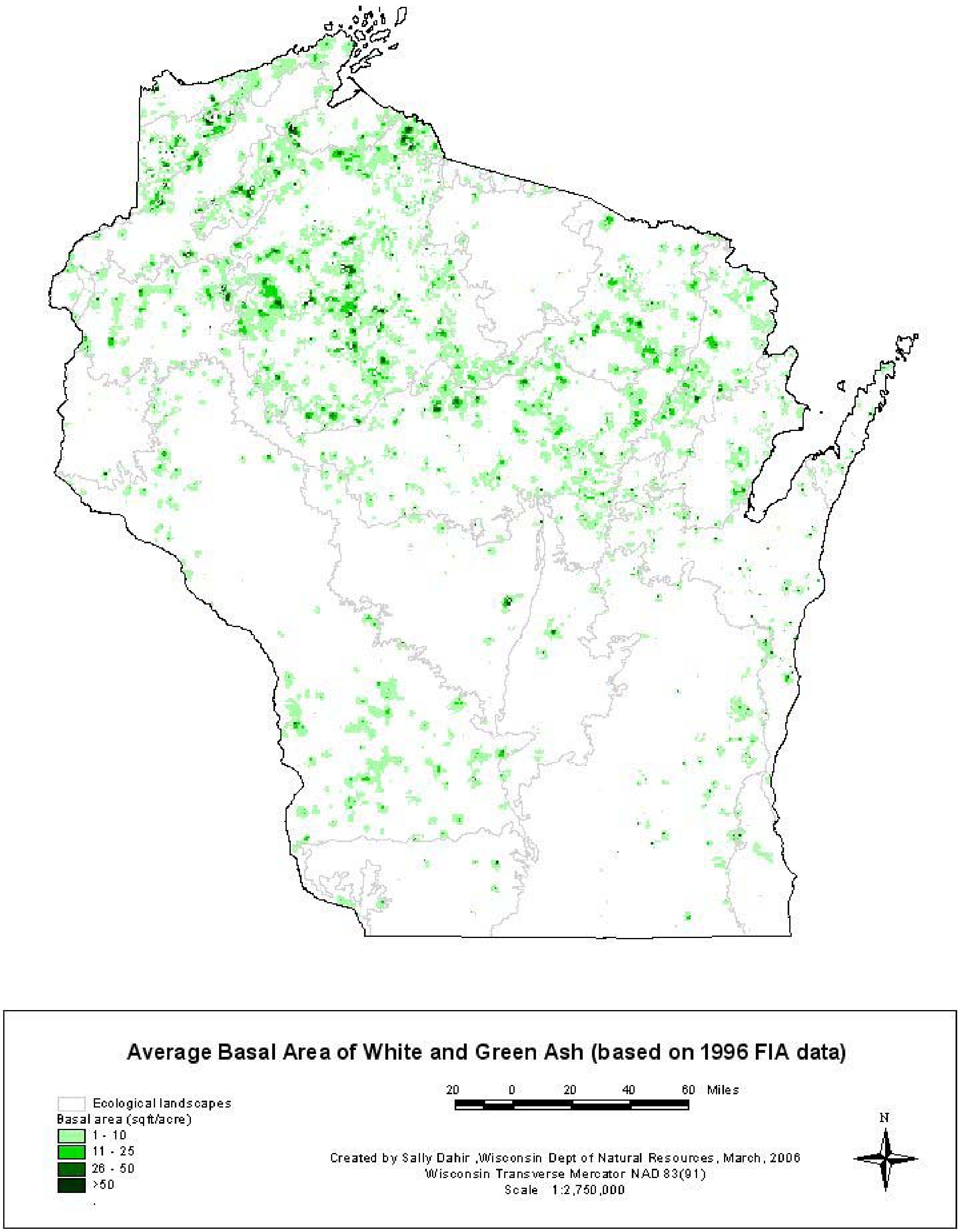
Map 7.m Area of forest land defoliated by basswood thrips during the 2000's
Source: DNR, 2009

The European gypsy moth, *Lymantria dispar*, is an exotic insect that has been known to be in Wisconsin since the 1990's and is currently spreading from east to west across the state. The gypsy moth will feed on over 200 species of trees but the most significant impact of feeding is expected to occur to all of Wisconsin's native oak species. Radial growth loss is the most common impact of feeding by the gypsy moth. Seedlings, and trees that are stressed by drought, defoliation by other insects and any other factors that induce stress, are most susceptible to incurring dieback and eventual mortality. Factors contributing to the collapse of populations of the gypsy moth include cool, moist weather during caterpillar development, availability of host material, predation and parasitism by several species of insects and infection of caterpillars by fungi.

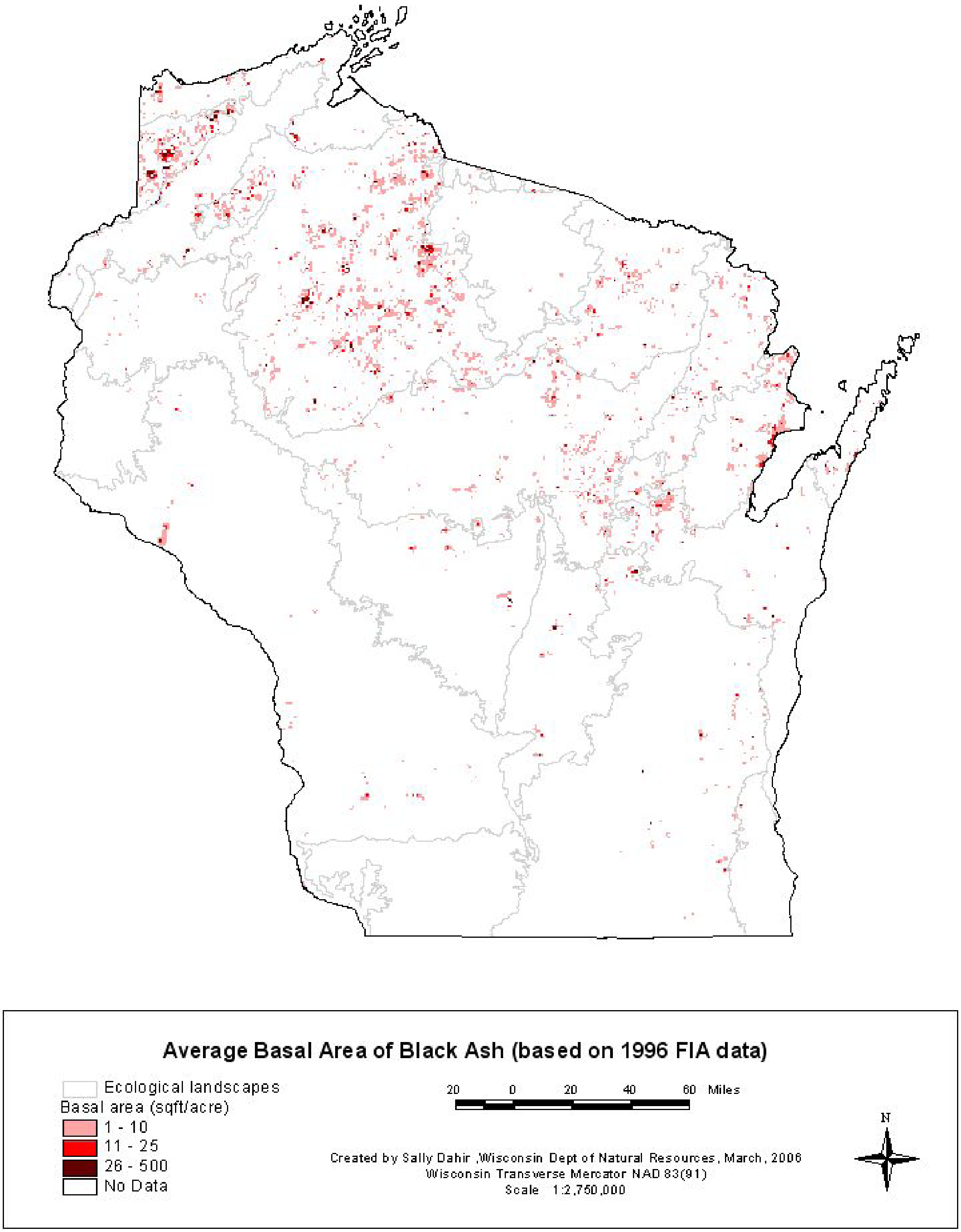


Map 7.n: Area of forest land defoliated by the gypsy moth, 2002 – 2008
Source: DNR, 2009

The emerald ash borer (EAB), *Agrilus planipennis*, is an exotic insect that was first observed in Wisconsin in 2008. EAB is native to eastern Russia, northern China, Japan, and Korea. As of August 2009, EAB was found in Vernon, Crawford, Kenosha, and Brown counties. Unfortunately, new EAB locations are continually being found. For the most up-to-date information, see [Wisconsin's Emerald Ash Borer Information Source](http://www.emeraldashborer.wi.gov/) (http://www.emeraldashborer.wi.gov/). There are over 700 million ash trees (>1" in diameter) in Wisconsin's forests. Approximately 5.2 million urban trees, about 20% of all trees in Wisconsin's cities and villages, are ash. Some communities report ash components as high as 55% of all public trees. Once emerald ash borer is in an area, options for minimizing tree mortality are limited. A lack of effective early-detection tools contributes to this problem. Pursuing strategies to reduce the impact of EAB before it becomes established can help minimize the cost of removing, processing and utilizing large volumes of dead and dying ash.



Map 7.o: Average basal area of white and green ash
Source: FIA, 2006



Map 7.p: Average basal area of black ash
Source: FIA, 1996

White and green ashes are a component of several timber types including northern hardwoods, central hardwoods and bottomland hardwoods (Map 7.o). Black ash is a significant component of ash swamps in northern Wisconsin. (Map 7.p) The widespread distribution of ash in urban and rural forests will require extensive planning and funding of activities that reduce the impact of EAB through treatment with pesticides or removal and replacement of ash in urban settings or reduction in ash density in rural forests.

The density of ash in forest lands varies widely with approximately 65% of forest land with ash having <20% of the basal area as ash. Forests having >20% of the basal area as ash may be impacted to a level that sustainability is threatened without intervention with activities that encourage regeneration of non-ash species. Of particular concern are lowland, wet mesic and mesic sites where regeneration practices are not well developed and the number of tree species that grown on these sites is more limited than drier sites.

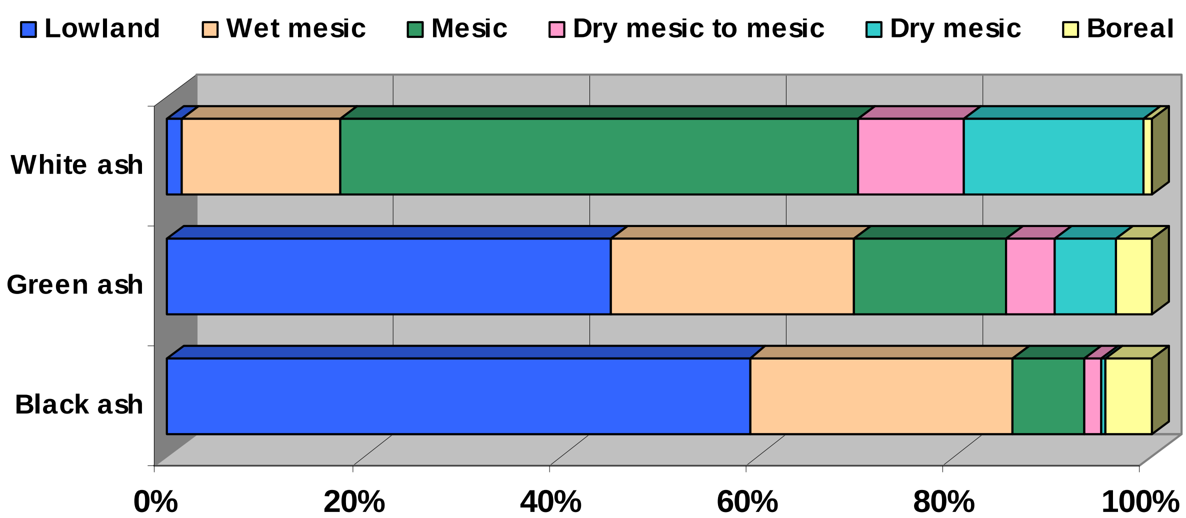


Figure 7.d: Percent of acreage by habitat type for FIA plots with a relative density of 10% or more
Source: FIA, 2007

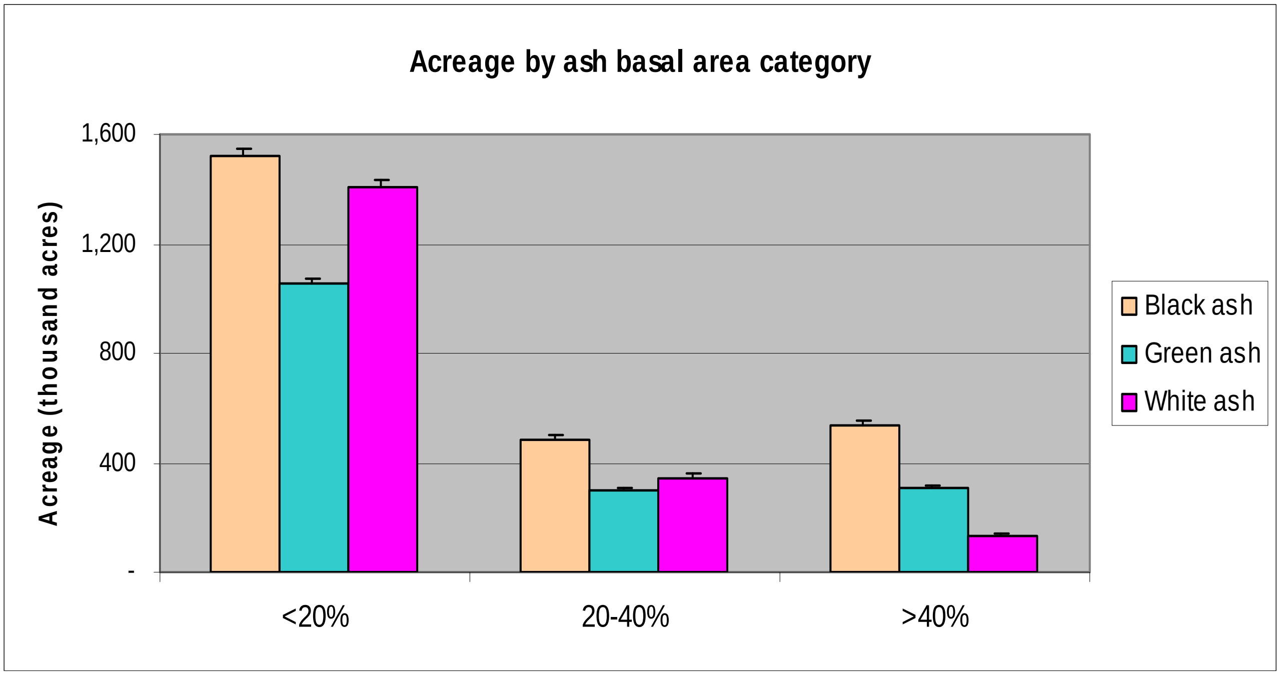


Figure 7.e: Number (in thousands) of acres of black, white and green ash by three basal area categories

Source: FIA, 2007

7.5 Invasive Plants

Invasive plants, both exotic and native, have been recognized as a threat to forest sustainability and are clearly an emerging issue in forestry. Aggressive non-native species are impacting forest regeneration in many parts of the state, and potentially harmful species continue to arrive. As the exchange of products and people continues unabated around the world, there is an increasing awareness that non-native, invasive plants are causing serious problems wherever they are found. Called by some the "least reversible" of all human impacts, exotic invasive species invasions can cause great harm to the environment, economies, human health, and aesthetics. Such invasions threaten biological diversity by producing population declines of native species, as well as altering key ecosystem processes like hydrology, nitrogen fixation, and the fire regime (White and Brittion, 1997).

Humans play a large part in accelerating the spread of invasive plants in forested communities and their detrimental effect on sustainability. Common threats and issues include the globalization of our society and increased pressure on land which causes disturbance, continual introduction of species, man caused spread, and spread by nature.

Despite a fair amount of research by scholars, land managers and other interested individuals, there is little information that quantifies the ecological and/or economic effects of these plants. In spite of this, it is useful to consider the anecdotal, qualitative, and scattered measures of quantitative information that these studies offer. Most studies attempt to illustrate how invasive plants affect forest regeneration, species richness, biodiversity, ecosystem processes, and nest predation.

The DNR, Division of Forestry underwent a study in 2005 on invasive plants in forests. The results identified several species that are of greatest impact to Wisconsin's forests. These include garlic mustard, buckthorns, Eurasian bush honeysuckles, reed canary grass, Japanese barberry, black locust, multiflora rose, dame's rocket, autumn olive, Japanese knotweed, leafy spurge, spotted knapweed, and Oriental bittersweet. Specifically, ash, beech and hemlock are at risk of experiencing a high level of mortality from exotic pests.

Invasive plant inventory data has been gathered for many years in Wisconsin and by many different sources. While this is beneficial and critical in assessing threats and trends, the data is generally not complete and is not consolidated into one location to best utilize the data.

The following inventory data is ongoing:
1- FIA has been collecting invasive woody and shrub data each year since 2000 in a complete 5 year cycle. In the future, these efforts will be expanded to include some herbaceous plant data. FIA data are available from the USFS through a web-based system. FIA data can be used to look at statewide trends; there are not enough plots in the state to draw conclusions about an area land base that is smaller than the state.

2- In 2006 and 2007, DNR, Division of Forestry conducted an assessment of invasive plants at specific locations on state-owned forests. Locations included heavily traveled and used areas such as: trail heads, trails, roads, campsites, etc. This data is available from the DNR website. Inventory will continue in varied amounts at the state-owned forests to supplement the existing data.

3- The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) have been conducting inventories and gathering data for the entire state for many years and is currently the best resource for statewide invasive plant inventory data. GLIFWC data are available from GLIFWC through a web-based system.

4- There are many other organizations and agencies involved in an attempt to collaborate and consolidate invasive plant inventory data. In particular, the National Institute of Invasive Species Science (NIISS) is taking the lead on developing a website application that will be able to link all of the other databases in Wisconsin. These include: DNR, Invasive Plants Association of Wisconsin (IPAW), UW-Herbarium, and the several Cooperative Weed Management Areas (CWMA). NIISS and the UW-Herbarium data are also available through web-based systems.

There is no consistent, common dataset to accurately assess the distribution and therefore the threat of invasive plant species. However, the NIISS application is intended to be the link between the many databases that exist. Wisconsin's Sustainabilty Framework ranked this data need as one of the critical gaps in knowledge (See Data Gaps Appendix H). The GLIFWC database is the most comprehensive database to date. The DNR, Division of Forestry is also going to be conducting inventories on a more regular basis; however, it will not be a statistically viable inventory. The purpose of these inventories is to have a place based inventory that will inform everyday activities and bolster the existing inventory.

The following figures illustrate the differences between data sets. The first example (Figure 7.f) is pulled from the UW-Herbarium website for Japanese Knotweed (*Polygonum cuspidatum)* distribution. The second and third maps are from the GLIFWC (Figure 7.g) and NIISS (Figure 7.h) website, respectively. The first and second indicates that 23 counties contain *Polygonum cuspidatum* while the third shows 33 counties. Furthermore, the DNR is in the process of writing an administrative rule to classify invasive species and during this process of gathering public input, staff gathered as much distribution data for certain species as they could in order to better classify the species. For *Polygonum cuspidatum,* survey information indicated that 44 of the 72 counties have occurrences of this species as opposed to the 23 and 33 indicated in the distribution maps above. The 2004 FIA Invasive Pilot survey did not find any plots in the ten counties that were part of the survey. Due to the lack of consistency and accuracy of the data that is available makes analyzing the extent and condition of invasive species extremely difficult and unreliable.

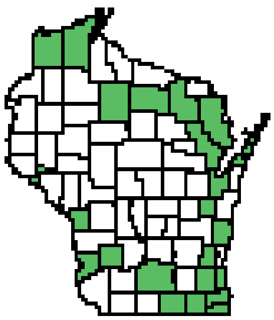


Figure 7.f: UW Herbarium website for *Polygonum cuspidatum* distribution
Source: http://wisplants.uwsp.edu/scripts/Detail.asp?spcode=POLCUS, 2007

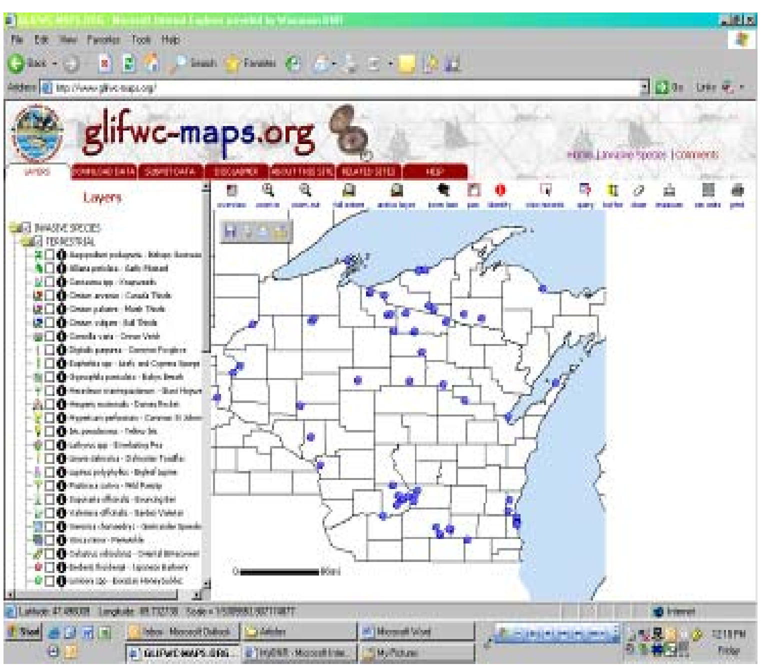


Figure 7.g GLIFWC website for *Polygonum cuspidatum* distribution
Source: http://www.glifwc.org/invasives/Fallopia_spp/id.html, 2009

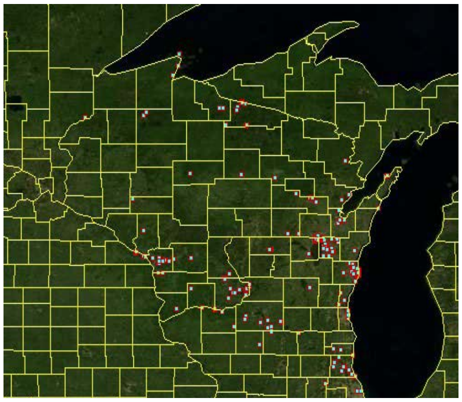


Figure 7.h: NIISS website for *Polygonum cuspidatum* distribution
Source: http://www.niiss.org/, 2010

Despite the increasing spread of invasive plants and new species entering the state, there are many opportunities to minimize their spread and introduction. One such strength is the Wisconsin Council of Forestry sponsored development of Best Management Practices for Invasive Species, focusing on four separate, but parallel tracks: Forestry, Recreation, Urban Forestry and Right-of-ways. Another growing opportunity is cooperative weed management areas (CWMA) such as the Northwoods CWMA (http://www.northwoodscwma.org/). These groups mobilize many partners to conduct work on the ground as well as educational and outreach material.

The DNR has also implemented an Early Detection Rapid Response Program to attempt to identify and control the species that are not yet in the state or are in low numbers such that control is feasible. The early detection program is becoming more established each year and along with the proposed rule, the reporting of species that are not yet here or are not yet common in the state will become more common. This will allow us to more accurately assess threats and prioritize management efforts. Another DNR initiative is an administrative rule to limit the introduction, possession, transfer and transport of invasive species.