Forest Ecosystem Health

The forest community health information listed below is not all encompassing given the broad array of both native and invasive diseases and pests affecting the forest communities of the Nantahala and Pisgah National Forests. Table 1 below, lists many of the relevant native and non-native threats to the forest ecosystems in NC. Those threats that have had a large impact on forest ecosystems or are emergent threats are described in more detail below. More information about these and other threats may be found at http://www.fs.fed.us/foresthealth/management/index.shtml

Table 1: Nantahala and Pisgah Forest Threats Summary

Threat *(Bold = more information)*	Native or Invasive	Species Affected	Impact Scale on Target Species[¥]
Annosus Root Rot	Native	White Pine[β]	Localized
Anthracnose	Non-native	F. Dogwood, A. sycamore, B. Walnut	Widespread
Armillaria Root Rot	Native	Many	Scattered
Asian Longhorned Beetle	Non-Native	Maples	Localized
Balsam Wooly Adelgid	Non-Native	Frasier Fir	Widespread
Beech Bark Disease	Non-Native	American Beech	Widespread
Butternut Canker	Non-Native	Butternut	Widespread
Chestnut Blight	Non-Native	A. Chestnut and Scarlet Oak	Widespread
Didymo	Non-Native	Cold Water Organisms	Localized
Elm Spanworm	Native	Ash, Hickory, Walnut, Oak, Others	Scattered
Emerald Ash Borer	Non-Native	Ash Species	Widespread
Forest Tent Caterpillar	Native	Oaks, Maples, Blackgum	Scattered
Gray's Lily Disease	Native ?	Gray Lily	Scattered
Gypsy Moth	Non-Native	Oaks, Maples, Many Others	Scattered
Hemlock Woolly Adelgid	Non-Native	Eastern and Carolina Hemlocks	Widespread
Laurel Wilt	Non-Native	Laurace Family	Localized
Littleleaf Disease	Native	Shortleaf Pine[δ]	Widespread[δ]
Oak Decline	Native	N. Red, Scarlet, Black, White, Chestnut	Scattered
Oak Wilt	Non-Native	Red Oak Group	Localized
Red Oak Borer	Native	Red Oak Group > White Oak Group	Scattered
Sapstreak Disease	Native	Sugar Maple, Tulip poplar	Localized
Sirex Woodwasp	Non-Native	Many NA Pine Species	Scattered
Southern Pine Beetle	Native	Southern Pines	Widespread
Spruce Budworm	Native	Red Spruce, other conifers	Scattered
Sudden Oak Death	Non-Native	Red oak Group, Rhodo, Vaccinium spp	Localized
Thousand Cankers Disease	Non-Native	Black Walnut	Localized
White Nose Syndrome	Non-Native	Five Eastern Bat Species inc. Indiana	Localized
W. Pine Blister Rust	Non-native	E. White Pine	Localized
White-Pine Weevil	Native	E. White Pine	Widespread

[β] The disease is not prevalent in other S. pine species even though they are susceptible in other regions of the SE.

[δ] Rarely occurs on Virginia and pitch pines. Rarely occurs in the NC Mountains.

[¥] Target Species Impact Scale: Widespread>Scattered>Localized

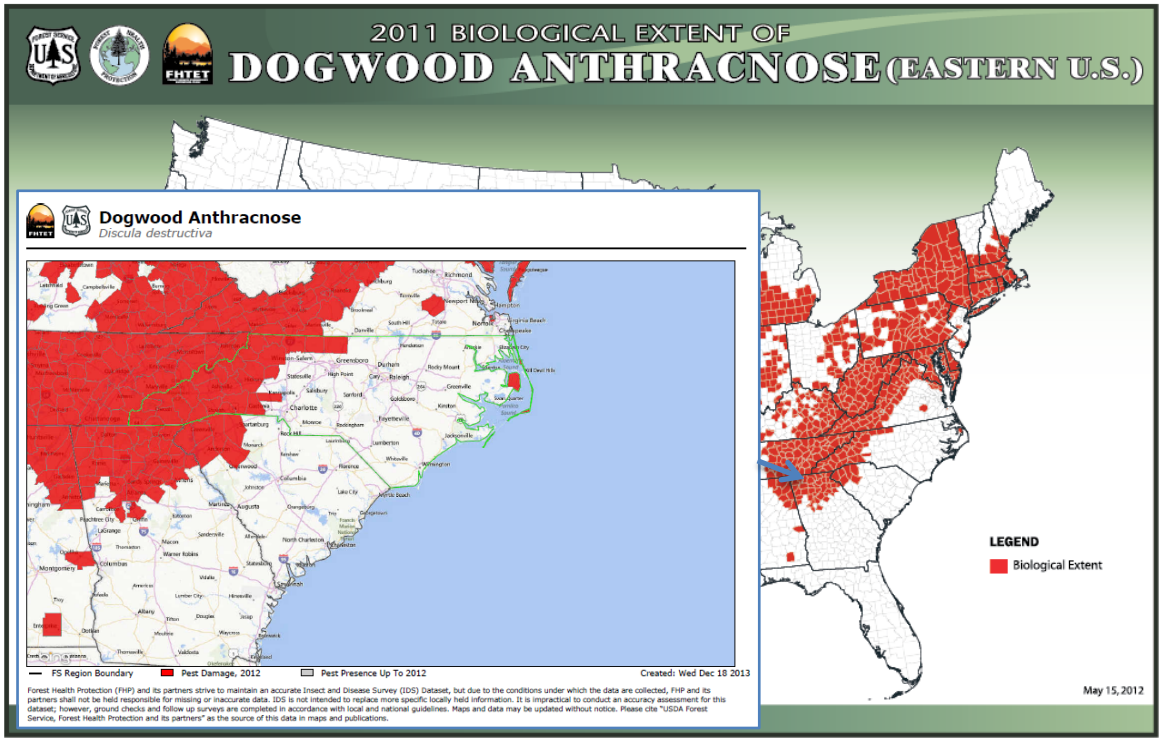
Disease or Pest: **Anthracnose**

Background: Generally termed anthracnose, this genus of fungi cause leaf diseases on hardwood trees in eastern North America (Manion 1991).

Pathology: Anthracnose fungi take advantage of cool moist conditions in the spring to infect the foliage of several eastern tree species. Infection usually causes the death of tissue on infected leaves, and in extreme cases will cause cankers and mortality on twigs and branches (Skelly et al. 1990).

Forest Community Impacts: The effects of these attacks are felt the strongest on flowering dogwood, black walnut, American sycamore and species of the white oak group (Berry 1998, Skelly et al. 1990). Anthracnose is also known to attack oaks, maples, horse chestnut, with hickory and ash to a lesser extent (Skelly et al. 1990). In many instances, the health of the tree will improve with dryer and warmer weather conditions. In certain cases of stressed trees and multiple defoliations, mortality may occur.

Nantahala and Pisgah NF Distribution: Of the forest tree species that are susceptible to anthracnose in western NC, flowering dogwood may be the most at risk. Flowering dogwood is an important source of soft mast for many species of wildlife and a desirable spring flowering understory tree. The dogwood anthracnose fungus was introduced into western North Carolina in the 1980s. From the period 1984 to 2006, the volume of flowering dogwood declined by 48 percent. In the Smokies, dogwood mortality ranged from 69 to 92 percent depending on forest community type and elevation (Holzmueller et al. 2006). It is expected that dogwoods will be largely eliminated above 3,000 feet. Trees in full sun exposure and/or below 3,000 feet are expected to sustain lower levels of damage.



Disease or Pest: **Asian Longhorn Beetle**

Background: Endemic to China, the Asian Longhorn Beetle (*Anoplophora glabripennis*) has been found in portions of the Northeastern US since the late- 1990s (Sawyer and Panagakos 2009). To date, populations have been identified in urban areas within NY, IL, NJ, MA and OH (Haack et al. 2010; Ohio 2012).

Pathology: Asian Longhorn Beetle larva feed on the phloem and sapwood of host tree species. The adults feed on the bark and cambium of twigs and branches (Ludwig et al. 2002; Poland et al. 2001). North American longhorn beetles are more commonly known to attack dead and dying trees (Roden et al. 2009). Unaided spread rates of 1 to 1.4 miles have occurred in 5 to 7 years (Sawyer and Panagakos 2009).

Forest Community Impacts: Primarily considered a threat to the Acer genus (maples), tests indicate that Asian Longhorn Beetle will attack birches, elms, poplars, willows, oaks, ashes cherries, and locust (Roden et al. 2009; Ludwig et al. 2002; Poland et al. 2001).

Nantahala and Pisgah NF Distribution: There are no known populations of Asian Longhorn Beetle within the Nantahala and Pisgah National Forests. The nearest known infestation is in southwest Ohio along the border with Kentucky. However, given the wide range of host species that Asian Longhorn Beetle prefers, the impact of widespread infestations could be great (personal communication P. Merten).

Disease or Pest: **Balsam Woolly Adelgid**

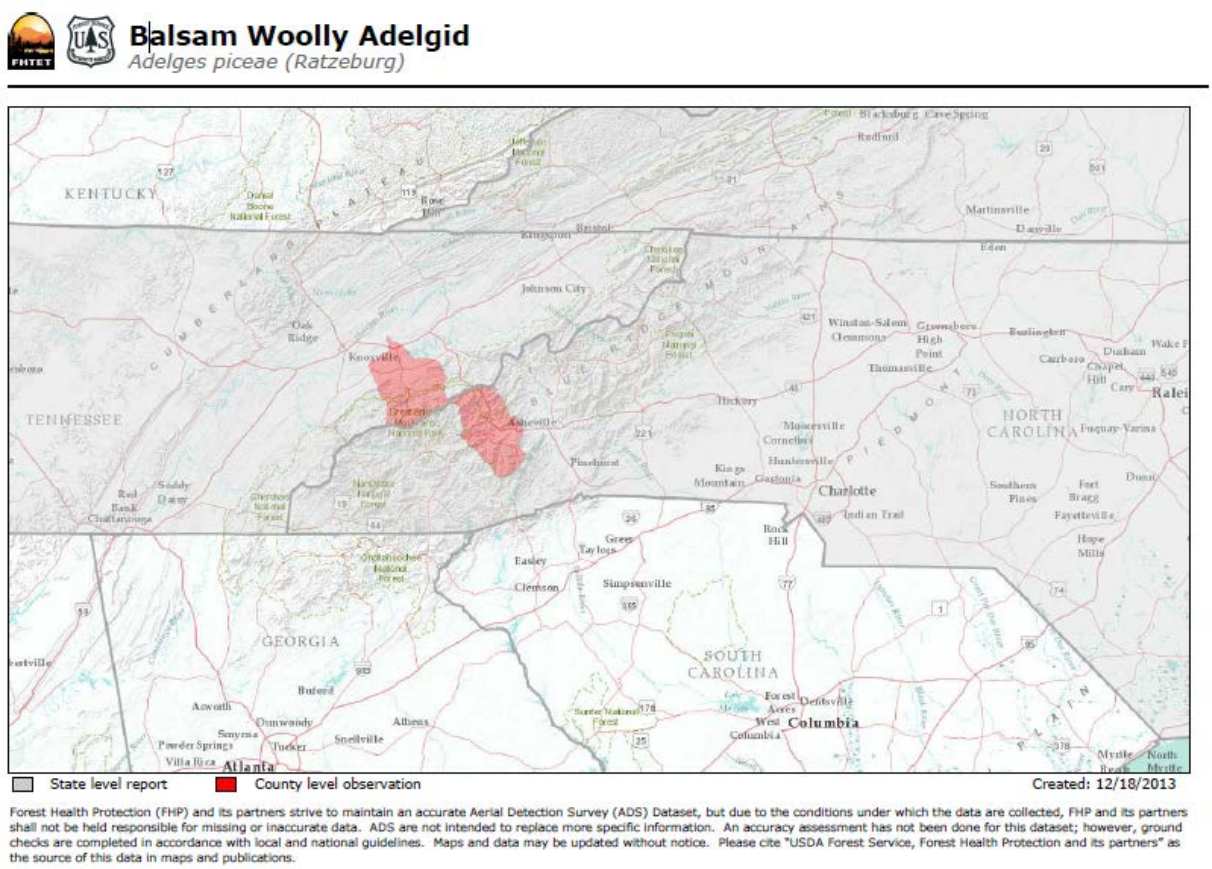
Background: Balsam Woolly Adelgid (*Adelges piceaeis*) an exotic insect believed to be from central Europe (Hain et al. 1991).This exotic pest was first identified as impacting fir in Mt. Mitchell State Park, NC in 1955. However, it was thought to have entered North America around 1900 (Hain et al. 1991). Balsam Woolly Adelgid moved South through the remaining spruce-fir forest infesting all communities by the late 1960's (Smith and Nicholas 1999). During the height of its infestation in western North Carolina (1965), mature fir mortality was estimated to be close to 2.5 million trees (Amman 1966).

Pathology: The adelgid feeds on sap from Frasier fir attaching the bark. Serious infestations cause severe crown dieback and eventual mortality. Infestation by Balsam Woolly Adelgid results in a change in the type of wood the tree produces and associated decreases in water transport (Hain et al. 1991).

Forest Community Impacts: Stands dominated with greater than 50% Fraser fir cover decreased by close to 80% between 1954 and 1988 (McManamay et al. 2010). Seedlings and saplings are not subject to attack at levels that cause serious harm. Mature trees die one to eight years after infestation (Amman 1966). Consequently, developing stand structures appear to have the same species composition as the disturbed forests but the trees are of smaller size classes (Lusk et al. 2010, Bowers and

Bruck 2010). Smaller trees of spruce and fir are capable of reaching maturity where fir is commonly killed again by Balsam Woolly Adelgid after one to two years of successful seed production (Lusk et al. 2010, Nowacki et al. 2010, Rhea, personal communication).

Nantahala and Pisgah NF Distribution: Balsam Woolly Adelgid is present throughout the spruce fir ecozone in western North Carolina. The insect appears to be operating in a patchy distribution as smaller groups of fir grow to sizes that permit infestation (Lusk et al. 2010, Bowers and Bruck 2010, Rhea, personal communication, White and Walker unpublished data). This is not occurring in a uniform manner across the ecozone. There is research indicating that Fraser fir is not following a regeneration-mortality trajectory in parts of the ecozone (McManamay et al. 2010). Currently Balsam Woolly Adelgid is most active within high elevations of Haywood County, NC.



Disease or Pest: **Beech Bark Disease**

Background: The non-native beech scale insect (*Cryptococcus fagisuga*) and canker fungus (*Neonectria faginata*) were introduced to North American through Halifax, Nova Scotia, around 1890. The disease has slowly moved south and west through the northeastern US at conservative spread rates of nine miles/year (Morin et al. 2007). Infestations by the scale insect first appeared in the high elevations of northern hardwood forests and beech gaps of western North Carolina in the early 1990s. These jumps in the population from the continuous advancing front are hypothesized to be related to accidental transport of infected beech material by humans (Morin et al. 2007).

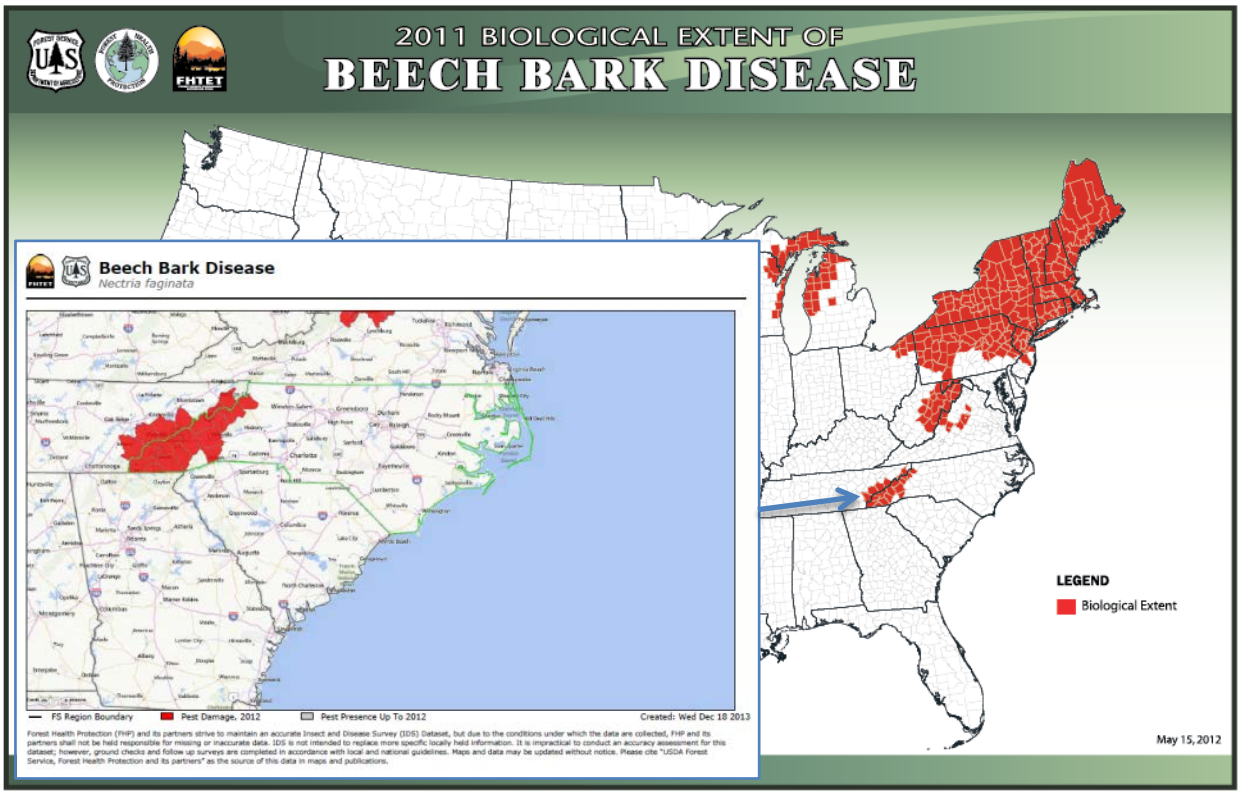
Pathology: Beech bark disease occurs when the bark and cambium of the beech tree is invaded and killed by the canker fungi after being fed on by the beech scale.

Forest Community Impacts: Beech bark disease dynamics alter a forest community in three phases.

(1) The advancing front where the scale insect has recently invaded a healthy beech community;

(2) The killing front, which is typically 3 to 5 years after the advancing front when mortality begins to occur from the fungal invasion;

(3) The aftermath forest, where community species and structural distributions start to occur and the disease becomes endemic (Houston 1994).



Throughout the three phases of Beech bark disease the beech tree may suffer high rates of mortality and loss of larger sized trees in the community (80 to more than 95% mortality) (Houston 2004; MacKenzie 2004). Due to beech's ability to sprout (and sucker) and its clonal habits, a structural shift occurs as the density of midstory sized beech dominates local forest conditions (MacKenzie 2004). These "beech thickets" reduce understory light levels resulting in reduced herbaceous diversity and limited tree species regeneration. These conditions also perpetuate the scale and fungal populations as beech is continually re-invaded killed and sprouts (Morin et al. 2007).

Nantahala and Pisgah NF Distribution: Virtually all high-elevation beech stands and beech gaps in Western North Carolina are extensively impacted by beech bark disease. In many locations, the species and structural shifts have already occurred. Across the landscape, the component of American beech is limited to small clonal clumps or stands of scattered individuals.

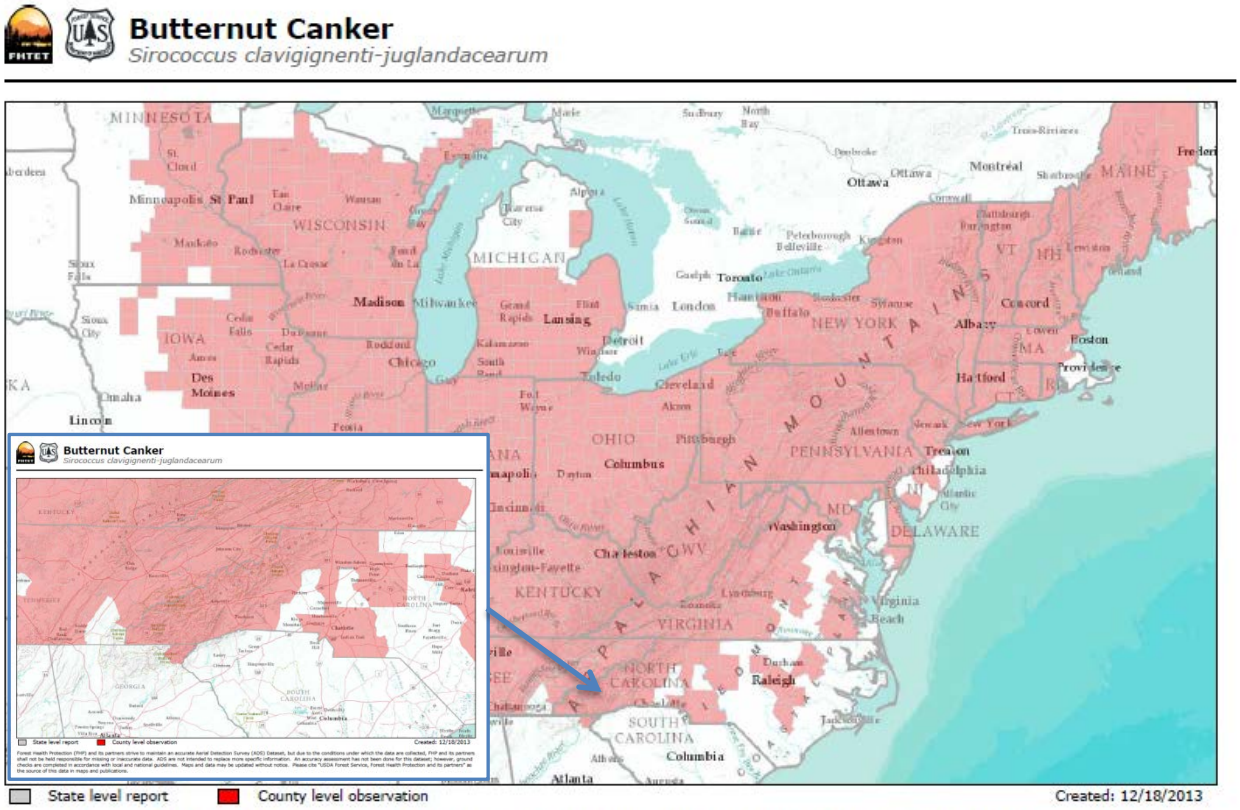
Disease or Pest: **Butternut Canker**

Background: Butternut canker (*Sirococcus clavigigenti-juglandacearum*) was first identified in southwestern Wisconsin in 1967. It is now threatening butternut trees throughout its range (Ostry et al. 1996). Other species from the Juglans family are susceptible but have much higher rates of survival (Schultz 2003).

Pathology: The fungus infects the tree through leaf scars and other small wounds, resulting in dieback in upper portions of the tree. Insects and wildlife will also transport the disease. Rainfall moves the infection to the main stem resulting in cankers that girdle and kill the tree (Ostry et al. 1996). Trees of all ages are susceptible (Schultz 2003).

Forest Community Impacts: Mortality has approached 80% for butternut across its range(Ostry et al. 1996) with at least 77% dead in the Southeastern US by 1995 (Schlarbaum et al. 1997). There is the great potential for loss of genetic and biological diversity with the decline of butternut in eastern forests.

Nantahala and Pisgah NF Distribution: Butternut is typically found in low abundance throughout mid and lower elevation forest communities. However, the species was reported as essentially extirpated by the late 1970s in North Carolina (Anderson and LaMadeleine 1978). In the mid-1990s the southern region of the Forest Service joined a coalition to identify butternut populations in the field, complete resistance screening, and plant progeny tests (Schlarbaum et al. 1997). Some of this work has occurred on the Nantahala and Pisgah NFs. The Nantahala & Pisgah NFs lists butternut as a sensitive species.



Disease or Pest: **Chestnut Blight**

Background: The fungus that causes chestnut blight (*Cryphonectria parasitica*) was introduced into North America in New York in 1904 spreading across the range of chestnut in less than 50 years (Diller 1965).

Pathology: The fungus infects the bark of the tree through wounds. forming a canker that girdles the tree at the site of infection. Cankers on the stem will girdle the entire tree.The fungus does not infect the portion of the tree below ground (Diller 1965).

Forest Community Impacts: The fungus that causes chestnut blight also damages chinkapin species and may also be found on maples, hickory, sumac, and scarlet oak (Diller 1965). The loss of the American chestnut has drastically changed the composition of the second growth forests that were developing in western North Carolina after the large-scale timbering that occurred from the late 1800's to the mid-1900's. The loss of the species gave rise to the oak dominated forests of today. Chestnut sprouts from the original 100+ year old root systems are still found in the forest. Many of these sprouts have sibling sprouts standing nearby that have died from the blight as a testament to the fungus's continued presence.

Nantahala and Pisgah NF Distribution: Chestnut blight reached the mountains of North Carolina in the mid-1920s (Diller 1965). The forests present in the Nantahala and Pisgah at that time contained between 30 and 60% chestnut (Wang et al. 2013,

McNabb personal communication). Today many of the acres that contained American chestnut at the time of the blight still contain remnant root systems and small above ground sprouts. Since 2009, the Nantahala and Pisgah NFs, in agreement with the Southern Research Station, The University of Tennessee, and the American Chestnut Foundation (TACF), have been implementing test plantings on small acres of National Forest lands to test the blight resistance. More information on restoration efforts may be found at http://www.fs.fed.us/r8/chestnut/index.php.

Disease or Pest: **Didymo**

Background: Didymo (*Didymosphenia geminate*), commonly referred to as rock snot, is a unique and very large freshwater benthic diatom native to Europe. It was present in Canada in the late 1800s, but did not begin to cause problems until the early 1990s. It was present in the rivers of the Western U.S. by 2004, and it was first discovered east of the Mississippi River in 2005, in Tennessee (USDA 2012).

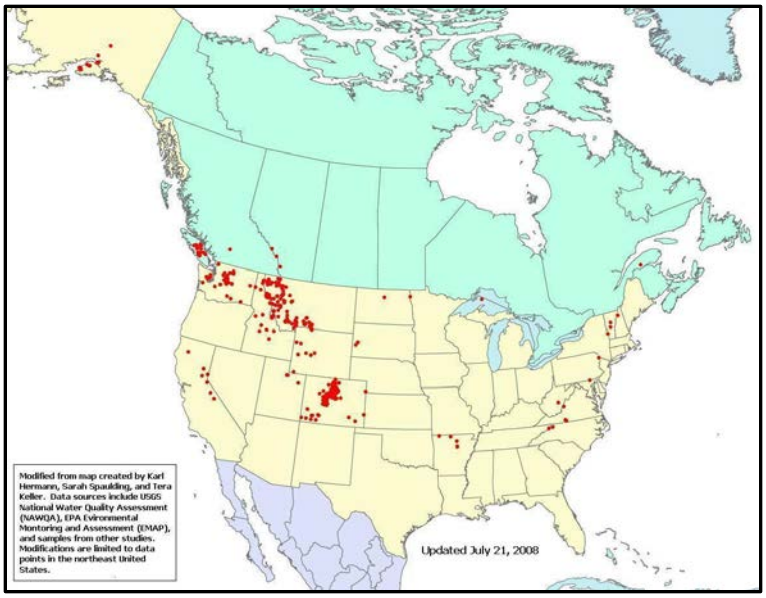
The individual diatoms are microscopic, however, they have a stalk that separates into two branches when the cells divide, such that one diatom becomes entangled in the next as they grow. This eventually leads to the development of mats of diatoms which spread across the stream bottom. The mats are strong and resistant to degradation. They are not slimy. Instead, they feel fibrous like wet cotton wool. They are pale yellow-brown to white in color (USFWS 2012).

Pathology: The local pattern of distribution suggests that it is being spread by recreational anglers. The diatom is so small that it can be spread in a drop of water. The management control for human transfers is to (1) check all gear and remove all visible clumps; (2) clean all gear by soaking and scrubbing for at least one minute in either 140°F hot water or 5% solution dishwashing detergent (1 cup detergent per 1 gallon water) - Felt soled boots require a 30-40 minute soaking; and, (3) Dry all gear thoroughly - it must be completely dried and then dried again for another 48 hours before use. If neither recommended cleaning nor drying is possible, restrict use of gear to a single water body and use different gear for infested areas.

Forest Community Impacts: Mats of didymo can result in dense algal blooms that block sunlight and disrupt ecological processes, causing a decline in native plant and animal life. Except for the aesthetic appearance of the infested river and general safety hazard for anglers and other river users (slippery rocks), there does not seem to be a negative impact to the trout or other fish populations living in infested streams in Norway, Quebec, Scotland, Finland, Iceland or France because a viable food source remains present. (USFWS 2012).

This diatom prefers cold, oligotrophic streams with stable flows, hard/stable substrates, Ca >2 mg/l and a high nitrogen to phosphorous ratio. It can attach to plants. It is rarely found in lakes. It needs a lot of light and thrives under increased ultraviolet conditions. Floods seem to provide a natural control (USFWS 2012).

Nantahala and Pisgah NF Distribution: Didymo is not known to occur in North Carolina. In 2008 and 2009, the National Forests in North Carolina, Great Smoky Mountains National Park, and North Carolina Wildlife Resources Commission reviewed available stream chemistry data to evaluate the risk of introduction into North Carolina waters since anglers routinely cross to and from waters in infected states. While this risk was determined to be low to moderate, it is possible that if introduced, didymo could survive in some waters on the forest. Angler access areas are now posted with decontamination protocols.



Disease or Pest: **Emerald Ash Borer**

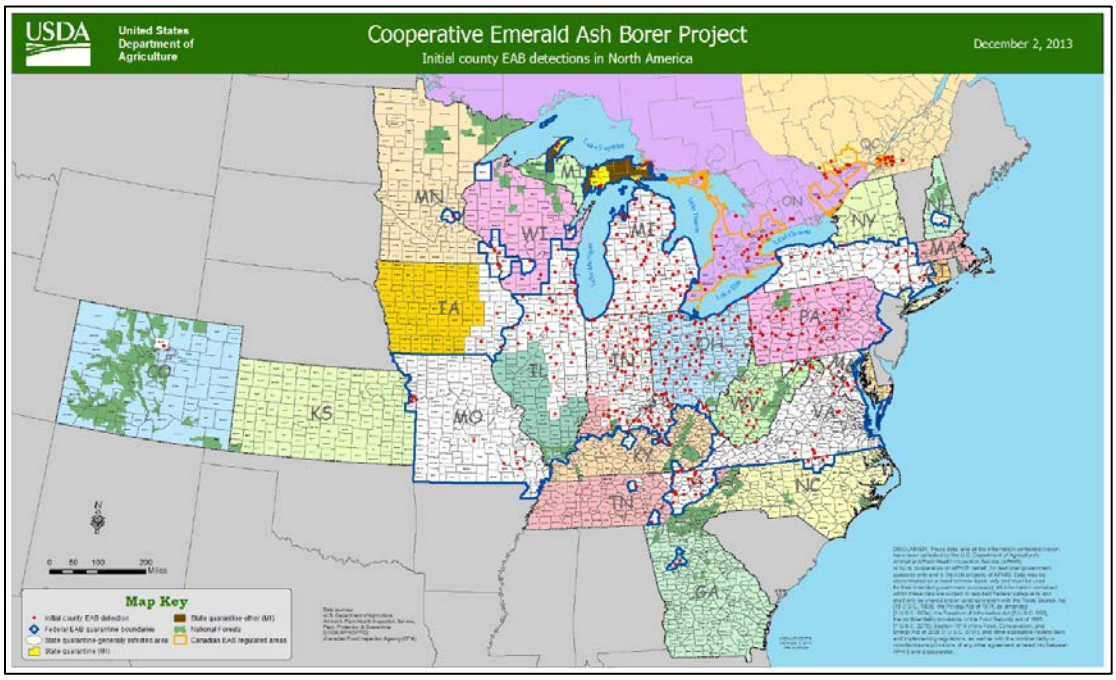
Background: Accidentally introduced into Michigan near Detroit in the early 1990's (Poland et al., 2010), as of December 2013 this exotic insect from Asia (*Agrilus planipennis*) is now found in 21 states. Similar to other forest pests, emerald ash borer is easily dispersed by humans transporting ash products such as firewood or logs creating a pattern of outlier pockets of infestation that combine with the adult female's natural rate of spread (Mercader 2011).

Pathology: Emerald ash borer is a phloem feeding beetle that specializes on the ash species. Adult females deposit their eggs on the bark and after hatching the insect burrows under the bark creating galleries, ultimately girdling the tree (Petrice and Haack 2011; Mercader 2011). After infestation, mortality of mature ash trees will exceed 96% within six years (Knight et al. 2010). Emerald ash borer represents a serious threat to North American ash species (Pugh et al. 2011).

Forest Community Impacts: High levels of mortality in ash species create gaps and openings in the forest canopy. Ash trees will regenerate and grow to the seedling and sapling sizes (until roughly 1 inch in DBH) when they are attacked by baseline levels of the emerald ash borer that are now present in the forest. The density of ash in the forest does not correlate to the rate of infestation with scattered ash trees being attacked at similar rates as dense stands of ash (Knight et al. 2010; Petrice and Haack 2011).

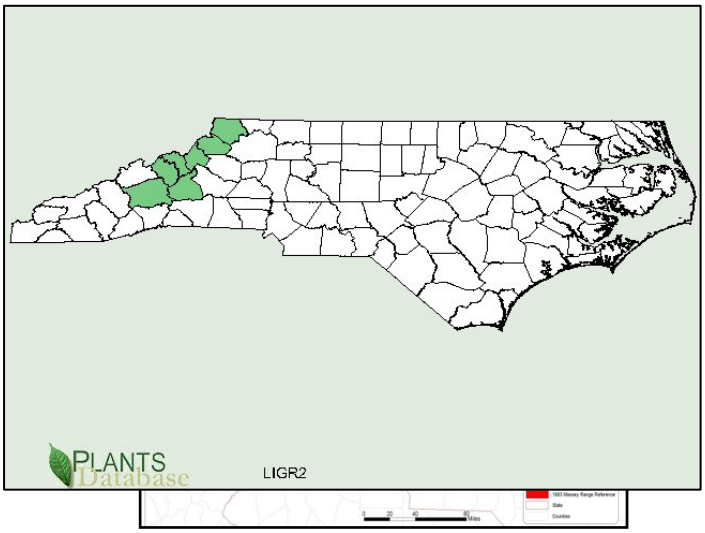
Emerald ash borer adult females appear capable of finding small populations of ash trees across a landscape as the availability of ash trees decline within existing population centers (Mercader 2011).

Nantahala and Pisgah NF Distribution: Ash species are present on the Nantahala and Pisgah NFs as a scattered component within several forest types and ecologic communities. With emerald ash borer able to locate and attack scattered pockets or individual trees, the species as a whole is at risk of serious decline. Though not located on the Nantahala and Pisgah NFs, emerald ash borer is present in counties immediately to the west in Tennessee. Emerald ash borer is present in the north central portions of North Carolina.



Disease or Pest: **Gray's Lily Disease**

Background: Gray's Lily is a perennial herb that is endemic to balds, bogs, seeps, streams and forest openings at mid to high elevations in North Carolina, Tennessee and Virginia. It was first identified in 1879. This lily is threatened by vegetative succession, suppression of wildfire, overgrazing, mowing, and overharvesting. Most recently is the presence of a fungus that infects and kills the plant prior to reproductive maturity.



Forest Community Impacts: Gray's lily is federally listed as a threatened species. Continued pressure from the above mentioned threats, especially the fungal pathogen, may lead to accelerated reduction in this species' limited abundance.

Nantahala and Pisgah NF Distribution: In North Carolina, Gray's lily is found on Roan Mountain in Mitchell and Avery County. Long Hope Valley in Ashe County, North Carolina possesses the largest known populations of this species. The Gray's lily is currently on the Regional Forester's sensitive species list.

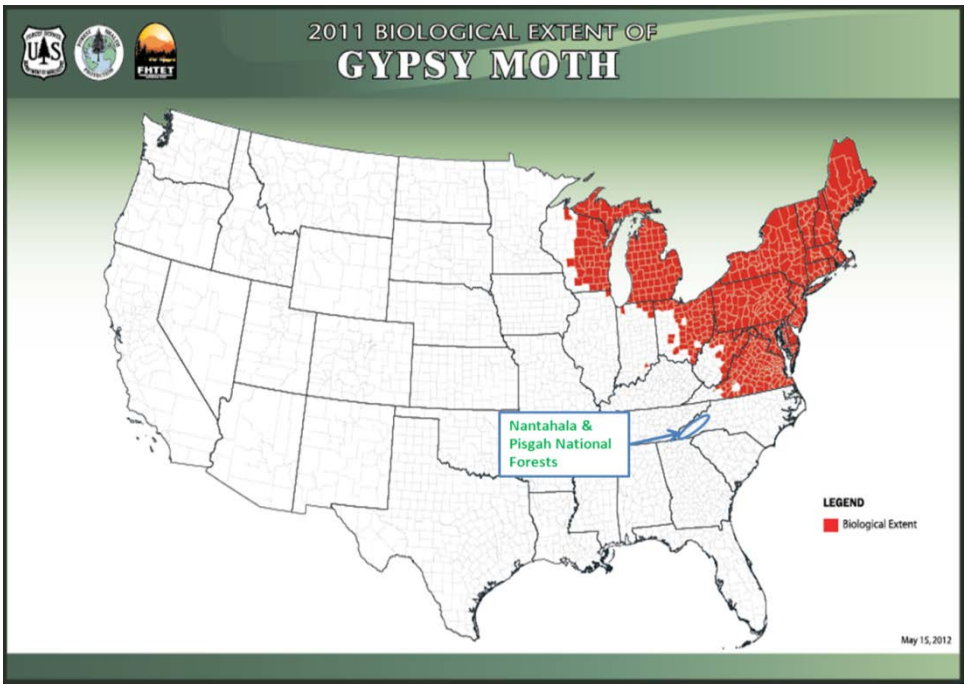
Disease or Pest: **Gypsy Moth**

Background: The gypsy moth (*Lymantria dispar ssp.)* was introduced into the U.S. in 1869 (McManus et al. 1989). The insect is now permanently established in 17 states.

Pathology: The caterpillar life stage consumes the foliage of desirable tree species. Populations very quickly reach epidemic levels causing widespread defoliation. Dense gypsy moth populations may last for two to four years (McManus et al. 1989). Outbreaks generally occur between eight to ten years (Tobin et al. 2012). Movement of the species occurs when the larva "balloon" from infested trees to nearby trees or egg masses are transported by humans (Tobin et al. 2012).

Forest Community Impacts: Gypsy moths feed on a wide variety of trees, shrubs, and vines, but prefer all oak species, apple, beech, birch, basswood, and willow. Multiple defoliations of forest tree species may result in mortality of stressed trees. Other trees may become vulnerable to other killing agents. In oak species, defoliation by gypsy moth may lead into an oak decline scenario.

Nantahala and Pisgah NF Distribution: Although gypsy moth is not yet permanently established in Nantahala and Pisgah NF counties, there have been numerous instances of human-mediated introductions of this pest over the past 10-15 years. A few of these introductions developed into small, isolated pockets of infestation that were subsequently eradicated. Additionally, the USDA Forest Service is implementing a program to "slow the spread", which will delay the establishment of gypsy moth in



Western North Carolina. The entire state of North Carolina has been monitored for gypsy moth since 1982. 2011 trapping results show the majority of advancing gypsy moths caught in northern North Carolina. Of the 18 counties in Western North Carolina NFS lands, four had gypsy moths trapped in 2011: Burke, Caldwell, Watauga and Clay.

Disease or Pest: **Hemlock Woolly Adelgid**

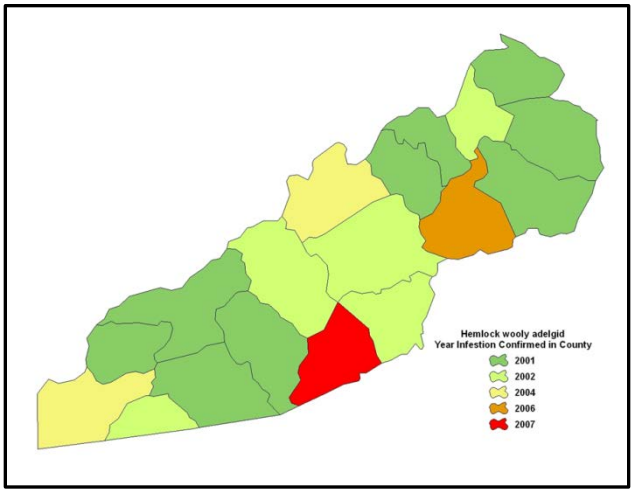
Background: First identified in Virginia in 1951, this small aphid-like insect (*Adelges tsugae*) covers over half the range of eastern hemlock species (FHP 2005).

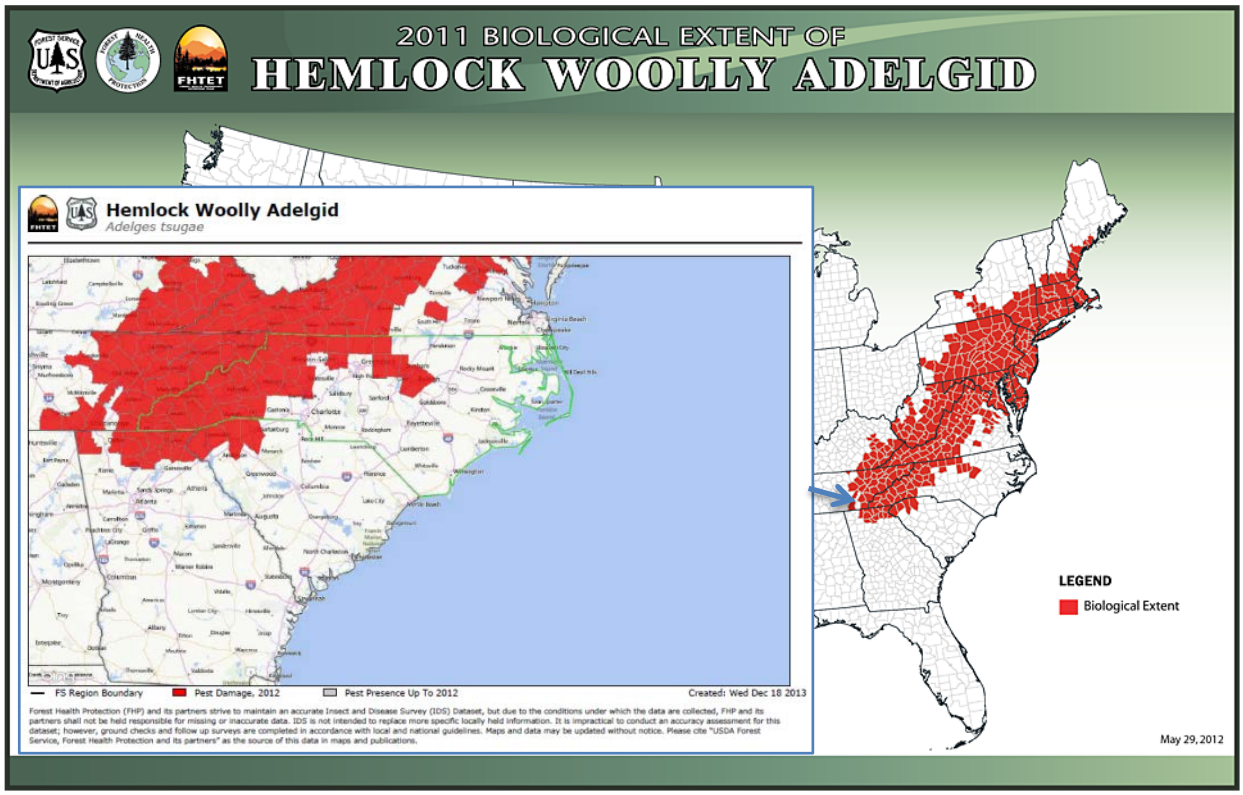
Pathology: Hemlock woolly adelgid feeds by inserting a feeding tube into the host tree at the base of the needle. They feed on the tree's stored starches. Wind and animals result in hemlock woolly adelgid's most common mode of dispersal though humans frequently aid long distance dispersal (FHP 2005). Mortality of infected hemlock trees averages greater than 90% (Mayer 2002).

Forest Community Impacts: Hemlock woolly adelgid directly effects both eastern and Carolina hemlock. Decline and mortality usually takes four to 10 years but has been found to occur faster in the southern US (FHP 2005). Loss of hemlock forests near streams poses a threat to aquatic species adapted to those types of stream communities, potentially including brook trout. Streams draining hemlock forests had higher species richness than similar hardwood forest drains (Snyder et al. 2005).

In 2002, Forest Inventory and Analysis data indicated that western North Carolina contained over 95 million hemlocks one inch or greater in diameter, of which approximately 32 million, or about one third, were on National Forest System lands (USDA-FS 2004, appendix C). At mortality rates greater than 90%, the Nantahala and Pisgah NFs could potentially lose (or has already lost) 28 million hemlock trees.

Nantahala and Pisgah NF Distribution: Hemlock woolly adelgid has been present in western North Carolina for more than a decade. It was first found on the forests in 2001 and mortality had started to develop by 2004. The adelgid now infests the entire native range of both eastern and Carolina hemlocks in the state (FHP 2005). The Nantahala and Pisgah NFs have been treating both eastern and Carolina hemlocks for hemlock woolly adelgid since 2005 using both chemical treatments and release of biological predators. The Nantahala and Pisgah NFs have roughly 2,500 acres of hemlock currently under treatment with insecticides or biological control.





Disease or Pest: **Laurel Wilt**

Background: Laurel wilt was first noticed in the US near Savannah Georgia in 2002.

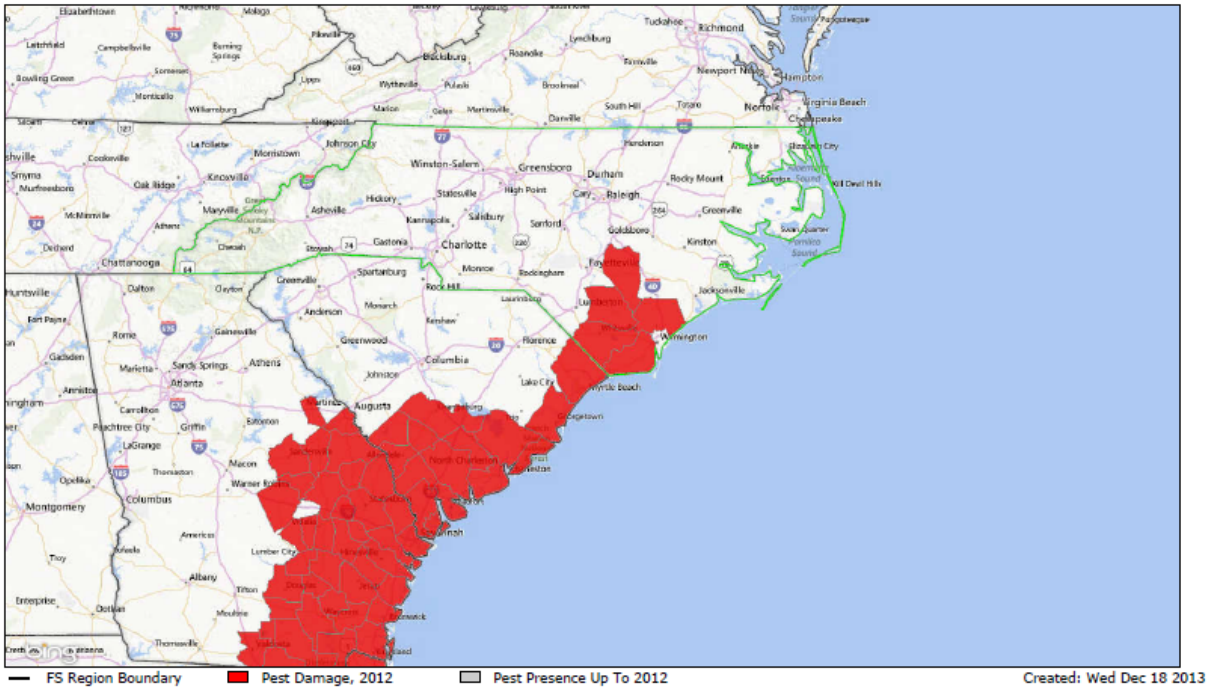
Pathology: Laurel wilt is caused by an exotic Ambrosia beetle/fungus combination from Asia (*Xyleborus glabratus/Raffaelea lauricola*). The fungus is deposited into the host species during the female beetle's search for suitable egg laying sites. The fungus then enters the trees' vascular system causing wilt, dieback, and ultimately death (Gramling 2010).

Forest Community Impacts: The Redbay Ambrosia Beetle attacks all species within the Lauraceae family (Mayfield et al. 2008). The beetle's rate of spread has been estimated at 34 miles/year (Koch and Smith 2008) and human aided distribution is suspected. Mortality rates within host species are high (Fraedrich et al. 2008) and have been documented as high as 95% in redbay (NCDOF 2011).

Nantahala and Pisgah NF Distribution: Though not currently known to be present on the Nantahala and Pisgah NFs, this disease is present within several counties in eastern NC in 2011, as well as SC, FL, and GA (NC 2011).The most widely distributed species in the Lauraceae family across the Nantahala and Pisgah NFs is Sassafras.

It is a common but minor component in many of the forest communities. Other species with documented susceptibility include Northern spicebush, pondberry, bog spicebush, pondspice. Loss of these species may have far reaching effects including effects to the Spicebush swallowtail (Gramling 2010). Until a recent infestation of sassafras in Alabama, only redbay had been affected.

Laurel Wilt
Raffaelea lauricola



Forest Health Protection (FHP) and its partners strive to maintain an accurate Insect and Disease Survey (IDS) Dataset, but due to the conditions under which the data are collected, FHP and its partners shall not be held responsible for missing or inaccurate data. IDS is not intended to replace more specific locally held information. It is impractical to conduct an accuracy assessment for this dataset; however, ground checks and follow up surveys are completed in accordance with local and national guidelines. Maps and data may be updated without notice. Please cite "USDA Forest Service, Forest Health Protection and its partners" as the source of this data in maps and publications.

Disease or Pest: **Oak Decline**

Background: Oak decline is a complex interaction between climatic stress, physical site conditions, pests, pathogens and tree age that result in the slow decline and death of individual or groups of oak trees (Kessler and Houston 1989, Manion 1991). Oak decline has occurred throughout the range of oaks (Wargo et al. 1983).

Pathology: Oak decline operates in three progressive levels. First includes the limits on growth and health of the physical site, such as soil nutrients, soil depth or texture (predisposing factors) (Manion 1991). Outwardly appearing, healthy oak trees are then stressed by one or more inciting factors such as late spring frosts, successive droughts, waterlogged soils, defoliating insects, and diseases such as gypsy moth or anthracnose (Kessler and Houston 1989, Manion 1991). The tree's root reserves are they used by

the tree to recover from the stress, weakening the root system leading to infection by armillaria root rot (*Armillaria mellea*) or attack by wood boring insects like two-lined chestnut borer or red oak borer (mortality causing organisms) (Kessler and Houston 1989, Oak et al. 2004). This decline process takes several years (2 to 5) to progress to the death of the tree.

Forest Community Impacts: Oak decline affects all oak species. There is some indication that species within the red oak group are affected more than those in the white oak group (Oak et al. 2004). Often the scale of the decline is related to the scale of the initial stressor and the population size of armillaria and the two-lined chestnut borer. Oak decline can be expressed as individual tree declines to scattered groups of trees across the landscape.

Nantahala and Pisgah NF Distribution: Within the Nantahala and Pisgah NFs, oak species are among the most dominant trees. Roughly 70% of Nantahala and Pisgah system lands currently have an oak overstory or oak overstory component. From the period of 1984 to 1997 the incidence of oak decline in North Carolina increased from roughly 10% to greater than 19%. Western North Carolina was noted as having a high density of forest inventory and analysis plots with oak decline present (Oak et al. 2004).

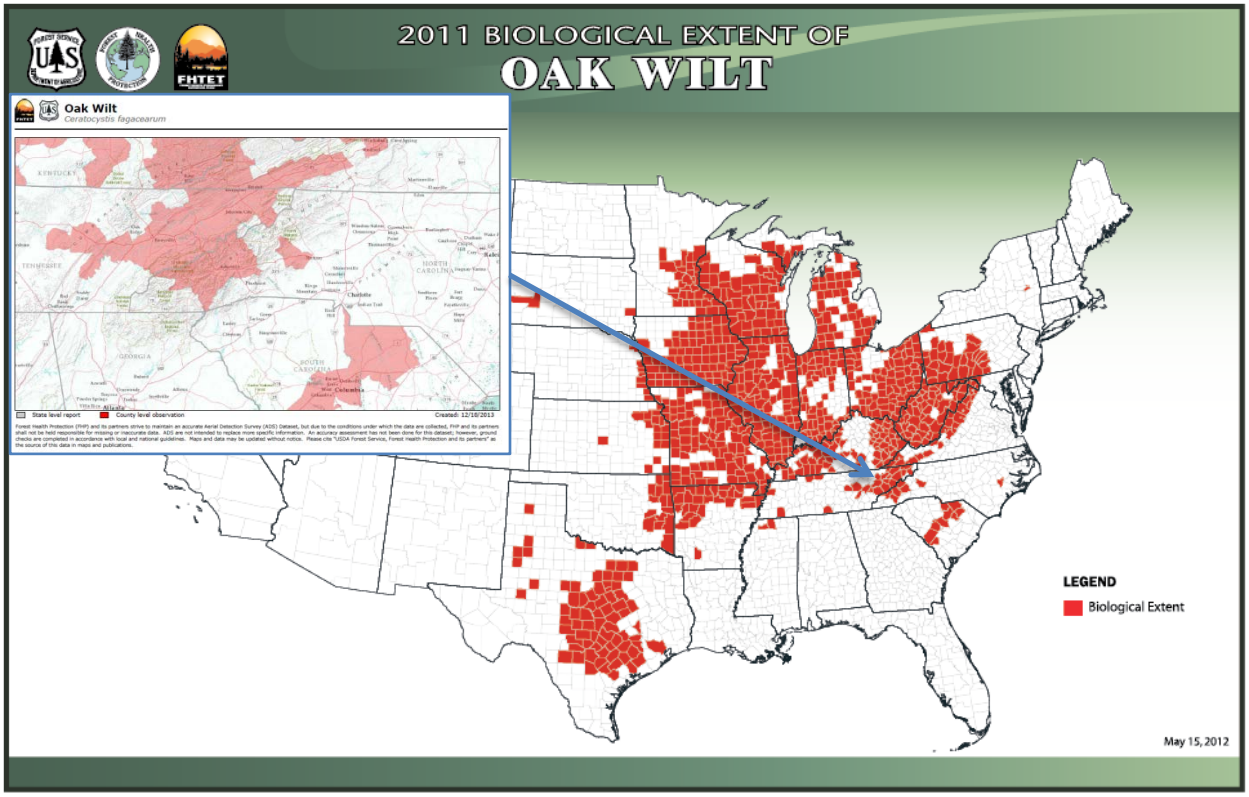
Disease or Pest: **Oak Wilt**

Background: First identified in 1944, oak wilt is caused by a fungus suspected to be exotic to the eastern US (*Ceratocystis fagacearum*). It is thought to have arrived in North America in the early 1900's (O'Brien et al. 2010, Koch et al. 2010).

Pathology: Oak wilt spreads through natural root grafts that occur between trees or through sap and bark beetle colonization of physical wounds. The fungus leading to wilting and death compromises the infected tree's vascular system. In the red oak group, this progression is rapid (several weeks to months) while the white oaks may take years to succumb. Live oaks are intermediate in their rate of mortality (O'Brien et al. 2010, Juzwik et al. 2011). Human spread of infected tree materials is a source of new infections (Koch et al. 2010).

Forest Community Impacts: Oak wilt is one of the most serious diseases to affect oak species in the eastern US (O'Brien et al. 2010, Koch et al. 2010). Out of the three eastern oak groups, red oaks are the most susceptible to the disease, with both white oaks and live oaks showing some level of physiological resistance (O'Brien et al. 2010; Koch et al. 2010, Juzwik et al. 2011).

Nantahala and Pisgah NF Distribution: Oak wilt is rather slow to spread (Juzwik et al. 2011). Oak wilt has been identified as present within counties of the Nantahala and Pisgah NFs.



Disease or Pest: **Sirex Woodwasp**

Background: The wasp (*Sirex noctilio*) is native to Europe, Asia and North Africa where it exists as a secondary pest.

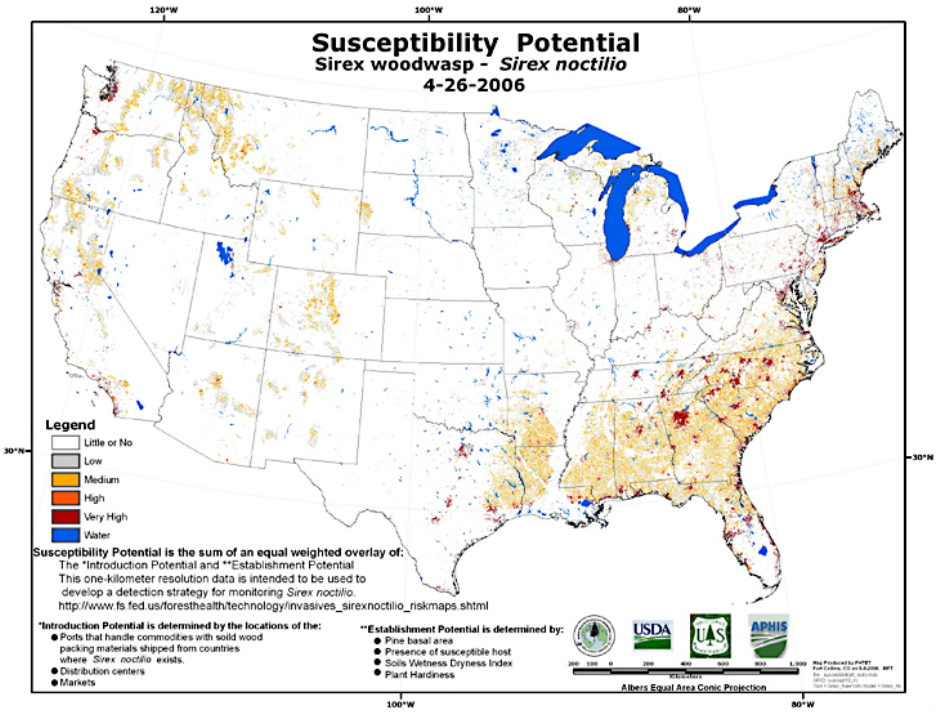
Pathology: The female wasps drill their ovipositors into the outer sapwood to inject a symbiotic fungus (*Amylostereum areolatum*), toxic mucus, and eggs. The fungus and mucus act together to kill the tree. The larval wasps feed on the fungus as they tunnel through the wood.

Forest Community Impacts: This insect has the potential to cause significant mortality in pine species. Infestations in South American pine plantations containing loblolly pine resulted in up to 80% tree mortality (Haugen and Hoebeke 2005). Many North American pine species are known to be susceptible (Pears and Wallin 2011; NYS_DEC 2012). The wasp attacks living pines regardless of tree health.

Nantahala and Pisgah Distribution: Though not currently known to be present in North Carolina or other areas south of Pennsylvania, modeling of rates of spread predict the wasp could be present in VA and NC in the next 10 years without human aided movement. Losses in southern pine could reach 275 million dollars (USDA-FS 2012).

Movement of the insect is likely through wood packing material and infested pine logs (Evans-Goldner and Bunce 2009).

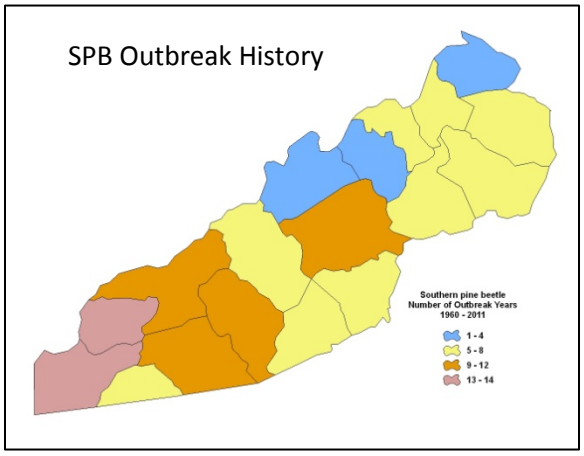
Roughly 25% of the forest communities on the Nantahala and Pisgah NFs have a conifer component. Densities of pine basal area range from close to 100% in white pine plantations and Virginia pine stands to scattered shortleaf pine in low elevation mesic oak pine woodlands. Several species of pine, like table mountain pine, are already threatened in their habitat due to fire suppression. Over the whole landscape within the National Forests, susceptibility is predicted to be low. This pest will likely have the greatest impacts in the ecozones where pine is present in higher densities (pine oak heath, shortleaf pine, and white pine plantations).



Disease or Pest: **Southern Pine Beetle**

Background: The southern pine beetle (*Dendroctonus frontalis*) is one of the most destructive pests of pines in the southern United States, Mexico, and Central America. This insect killed approximately 4.5 million board feet of pine timber from 1973 through 1977 in the southern United States. The beetle occurs from Pennsylvania to Texas and from New Mexico and Arizona to Honduras (Hain et al. 2011).

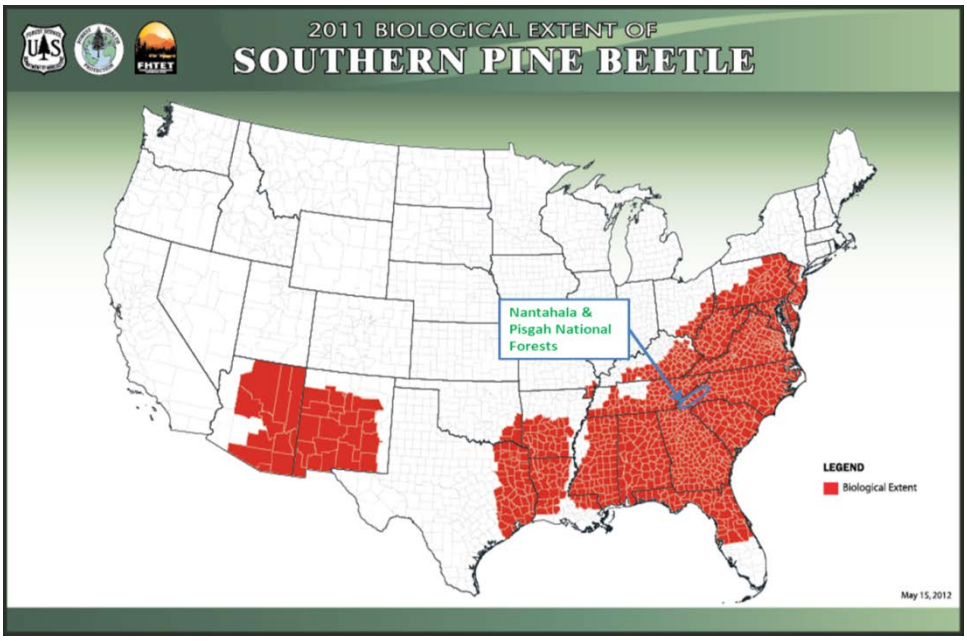
Pathology: Female beetles bore into the inner bark and cambium of host tree species. Using pheromone attractants mating males and other adults build the population in the host. Beetles also infect the tree with blue stain fungus. The galleries and fungus combine to girdle the tree (Clarke and Nowak 2009).



Forest Community Impacts: Within the Nantahala and Pisgah NFs, southern pine beetles can attack and kill all species of pines, but prefers shortleaf, Virginia, and pitch pines. Under extreme outbreak conditions, southern pine beetles are also capable of attacking and killing white pine, spruce and hemlock (Clarke and Nowak, 2009). Within pine communities, infestations of southern pine beetles will lead to heavy mortality of the pine overstory and release of the existing midstory and understory. In mixed pine/hardwood stands, smaller gaps may occur as overstory trees succumb. Reductions in pine basal area and reduction of species abundance may occur as forests lose their pine component.

Nantahala and Pisgah NFs Distribution: The southern pine beetle has been North Carolina's most significant forest insect pest. From 1999 through 2002, the beetle killed at least $84 million worth of timber in North Carolina. Most of the mortality during this outbreak was in the mountains and western piedmont areas (Birt 2011).

The Nantahala and Pisgah NFs contain roughly 113,665 acres (11%) of forest community types susceptible to southern pine beetles (USDA-FS, 2001). Between 1960 and 2000, the western counties of North Carolina have had 15 years where southern pine beetle populations reached epidemic levels in some part of the landscape. The mid-1970's and early 2000's saw widespread epidemic populations and significant southern pine species mortality (Birt 2011).



Disease or Pest: **Sudden Oak Death**

Background: Sudden oak death was identified in California and Oregon in 1995 (O'Brien et al. 2002).

Pathology: This disease is caused by a fungus (*Phytophthora ramorum*). Infection results in a "bleeding" canker on the stem of red oak species and leaf spots and dieback on other species (O'Brien et al. 2002; Gottschalk et al. 2003).

Forest Community Impacts: Many oak species in the red oak group are susceptible including northern red oak, which is highly susceptible. Other forest plant species that are susceptible include *Vaccinium* species and *Rhododendron* species (O'Brien et al. 2002).

Nantahala and Pisgah NFs Distribution: Currently sudden oak death is only affecting oaks on the west coast of the US, however transportation of infected plant material poses a grave risk to the oak forests present on the Nantahala and Pisgah NFs if sudden oak death became established within the eastern forest hardwoods (O'Brien et al. 2002; Gottschalk et al. 2003; Koch and Smith 2008). The fungus has been detected within water courses in four southeastern states including North Carolina (NCFS 2011). The closest location to the Nantahala and Pisgah NFs is in Northeastern Georgia (Chastagner et al. 2010). The fungus is currently not known to be affecting oak trees in the eastern US.

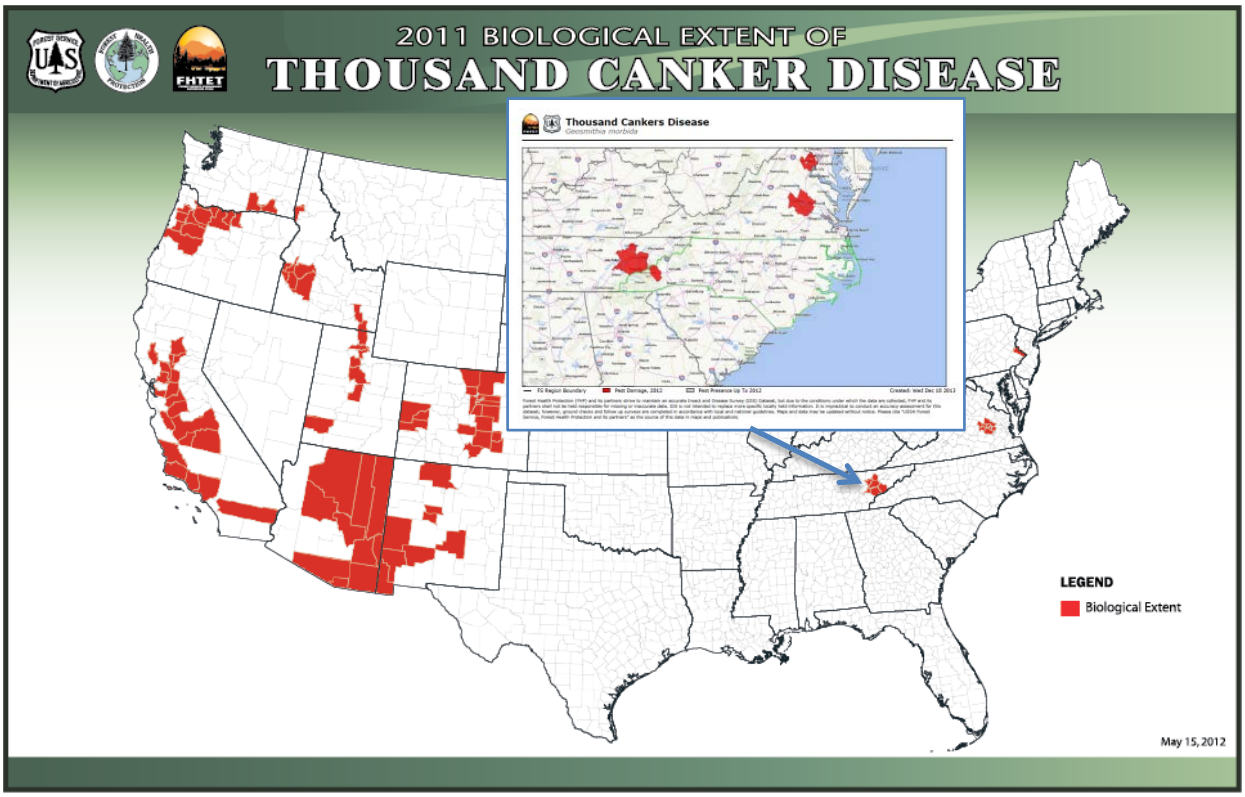
Disease or Pest: **Thousand Cankers Disease**

Background: Thousand cankers disease was identified in eastern Tennessee in 2010, and Virginia and Pennsylvania in 2011 (Seybold et al. 2011; Tiserat and Cranshaw 2012). It is suspected to have been present in the western US for more than a decade (Newton and Fowler 2009). Infected trees usually die within three years (Tiserat and Cranshaw 2012).

Pathology: Caused by a fungus in the genus Geosmithia, this disease is currently distributed by a bark beetle native to the western North America (*Pityophthorus juglandis*) (Newton and Fowler 2009; Seybold et al. 2011). The disease kills walnut species as the bark beetle bores thousands of holes in the tree, which each serve as infection sites causing wilt, dieback and eventual mortality. It is suspected that human movement of walnut wood products is contributing to the spread of this disease (Newton and Fowler 2009).

Forest Community Impacts: Within the Nantahala and Pisgah NFs, the susceptible eastern host species is black walnut (Newton and Fowler 2009). Butternut does not appear as susceptible.

Nantahala and Pisgah Distribution: Though black walnut appears as a relatively minor component within the forested landscape of the Nantahala and Pisgah NFs, it does exist. Its hard mast is important for wildlife species especially with the presence of other diseases affecting many of the hard mast producing species in the S. Appalachian forests. Thousand cankers disease is present in North Carolina in Haywood County. It is currently not know to be on National Forest System lands.



Disease or Pest: **White-nose Syndrome**

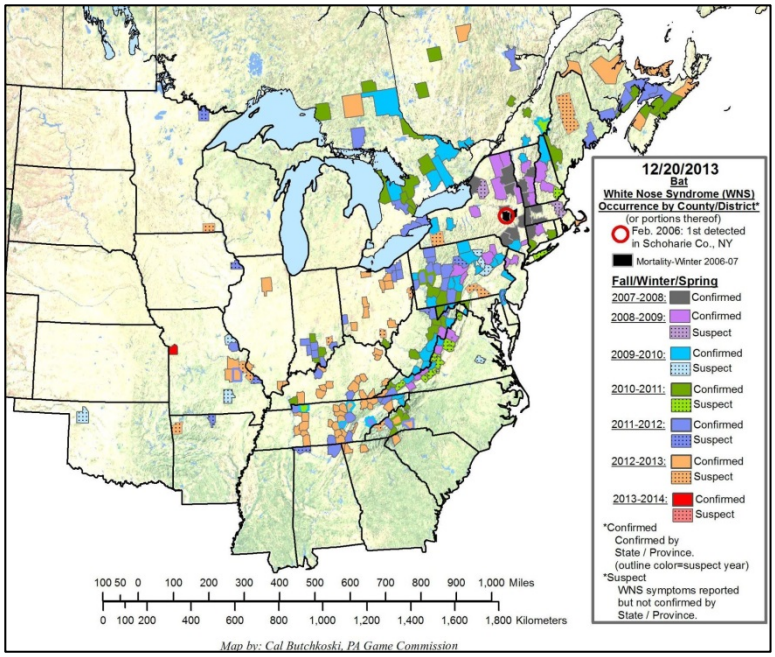
Background: White-nose Syndrome is a disease caused by a non-native, cold-loving fungus (*Geomyces destructans*) found in caves. The name of the disease refers to the white fungal growth found on the noses of infected bats. It was first discovered in New York in 2006, where evidence showed that up to half of the wintering bat population was killed. Since then, it is estimated that white-nose syndrome has killed more than 5.7 million bats in eastern North America. The fungus is currently affecting hibernating bat species in 16 states and four Canadian provinces.

Pathology: *Geomyces destructans* is native to European caves, where it evolved with native bat species, allowing them to develop resistance. The fungus is transferred cave to cave by contaminated equipment and clothing used by both researchers and recreationists if it is not properly disinfected. It is hypothesized that this method may have been what brought the fungus to the United States. The fungus also spreads among infected bats.

Forest Community Impacts: Little brown bats, once a common bat in the area, are sustaining the largest number of deaths. Some caves infected with white nose syndrome are experiencing 90-100% bat mortality. Currently, five other hibernating bat species are affected by the fungus: big brown bat, northern long-eared bat, tri-colored bat, eastern small-footed bat and the endangered Indiana bat. The disease is spreading

rapidly and has the potential to infect at least half of the bat species found in North America.

Research has shown that white-nose syndrome infected bats are emerging from hibernation as often as every 3-4 days, as opposed to the "normal" every 10-20 days. The fungus damages the connective tissues, muscles and skin of the bats while also disrupting their physiological functions. The bats wake up dehydrated and hungry during the cold winters when there are no insects to eat. It is estimated that 90% of infected bats perish from starvation.



Nantahala and Pisgah NFs Distribution: Presently, white-nose syndrome is known from seven counties in North Carolina containing the Nantahala Pisgah NFs.

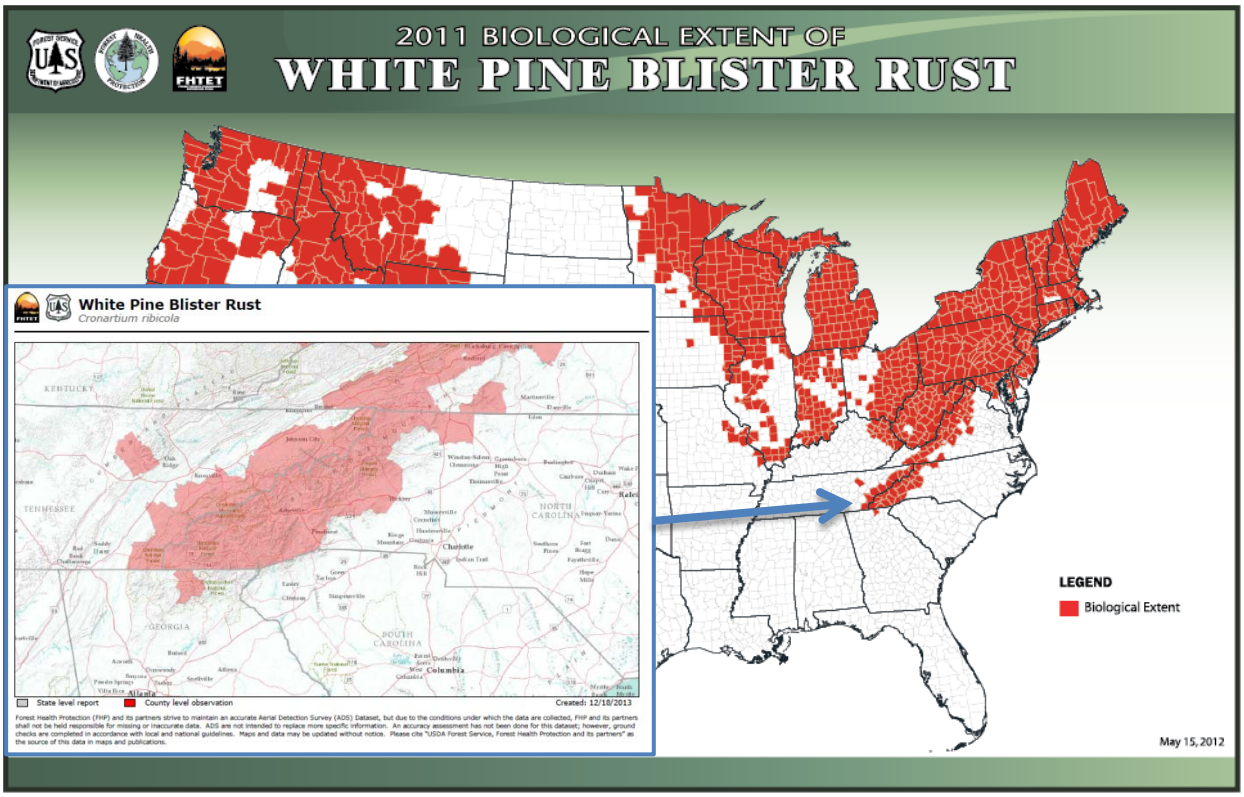
Disease or Pest: **White Pine Blister Rust** Background: First identified in North America during the turn of the 20th century, white pine blister rust has spread to the extent of both eastern and western white pines (Miller et al. 1959). The Forest Service and State Forestry Services started an extensive Ribes eradication program that lasted through the 1970's. Neither this program nor efforts to breed resistance into eastern white pine were overwhelmingly successful (Manion 1991).

Pathology: The complex disease cycle associated with the rust fungus (*Cronartium ribicola*) causing white pine blister rust affects most five-needle pines. To complete the cycle of infection the fungus must alternate parts of its life cycle on both the white pine and the shrub genus Ribes (Manion 1991). Cankers produced on the branches of infected white pine eventually spread to the cambium and in combination with the formation of new cankers, will eventually girdle the tree. Transfer of the rust between Ribes and eastern white pine occurs in the fall under cool temperatures with high humidity (Miller et al. 1959, Van Arsdel 1972). Temperatures greater than 95 degrees F are fatal to the rust (Van Arsdel 1972).

Forest Community Impacts: Very few white pine trees are resistant to white pine blister rust. Many areas of the US contain non-infected trees because the environmental conditions are not favorable for the disease (Van Arsdel 1972). Where the disease proliferates, eastern white pine is reduced or damaged. This disease can be particularly damaging in plantations.

Nantahala and Pisgah NFs Distribution: The incidence of white pine blister rust is low in the mountains of the Nantahala and Pisgah NFs. White pine blister rust was reported as

reaching western North Carolina between 1943 and 1958 (Miller et al. 1959). A combination of factors including early fall temperatures commonly above the thermal limit for the fungus, lower incidence of Ribes in the forest, and arrival of the optimum temperatures and humidity after leaf fall for the species likely limit its proliferation in the mountains of North Carolina (Van Arsdel 1972).



Citations

Amman, G. D. 1966. A study of the native predators of the balsal woolly adelgid, Chermes Piceae Ratz. (Homoptera: Chermidae), in North Carolina. PhD Dissertation. Univ. Michigan. 226 pages.

Anderson, R. L. and L. A. LaMadeleine. 1978. The Distribution of Butternut Decline in the

Eastern United States. USDA Forest Service. Northeastern Area State & Private

Forestry. Survey Report S-3-78. Pp. 1-5.

Berry, F. H. 1998. Anthracnose Diseases of Eastern Hardwoods. USDA-FS Forest Insect and Disease Leaflet 133. 1 page.

Birt, A. 2011. Regional Population Dynamics. In R. N. Coulson and K.D. Klepzig eds. *Southern Pine Beetle II*. USDA-FS SRS GTR 140. Asheville, NC, 28804. pp. 109-128.

Hain, F. P., R. G. Hollingsworth, F. H. Arthur, F. Sanchez, and R. K. Ross. 1991. Adelgid host interactions with special reference to the balsam woolly adelgid in North America. In. Baranchikov, Y.N., Mattson, W.J., Hain, F.P., and Payne, T.L, eds. 1991. Forest Insect Guilds: Patterns of Interaction with Host Trees. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-153.

Bowers, T. A. and R. i. Bruck. 2010. Evidence of montane spruce-fir recovery on the high peaks and ridges of the Black Mountains, North Carolina: recent trends, 1986-2003. In. J. S. Rentch, and T. M. Schuler eds. Proceedings from the conference on the ecology and management of high-elevation forests in the central and southern Appalachian Mountains. 2009 May 14-15; Slatyfork, WV. Gen. Tech. Rep. NRS-P-64. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 242 p..

Chastagner, G., S. Oak, D. Omdal, A. Ramsey-Kroll, K. Coats, Y. Valachovic, C. Lee, J. Hwang, S. Jeffers, M. Elliott. 2010. Spread of P. ramorum from nurseries into waterways-implications for pathogen establishment in new areas. In: Frankel, Susan J.; Kliejunas, John T.; Palmieri, Katharine M. 2010. Proceedings of the Sudden Oak Death Fourth Science Symposium. Gen. Tech. Rep. PSW-GTR-229. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. pp. 22-28.

Clarke, S. R., J. T. Nowak. 2009. Southern Pine Beetle. Forest Insect & Disease Leaflet 49. USDA-FS PNW. Portland, OR. 8 pages.

Diller, J. D. 1965. Chestnut Blight. USD-FS Forest Pest Leaflet 94. 7 pages

Evans-Goldner, L. and L. K. Bunce. 2009. *United States Sirex woodwasp program update*. In: McManus, Katherine A; Gottschalk, Kurt W., eds. Proceedings. 19th U.S. Department of Agriculture interagency research forum on invasive species 2008; 2008 January 8-11; Annapolis, MD. Gen. Tech. Rep. NRS-P-36. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 21.

Fraedrich, S.W., T.C. Harrington, R.J. Rabaglia, M.D. Ulyshen, A.E. Mayfi eld III, J.L. Hanula, J.M. Eickwort, and D.R. Miller. 2008. A fungal symbiont of the Redbay Ambrosia Beetle causes

a lethal wilt in Redbay and other Lauraceae in the southeastern United States. Plant Disease 92:215–224.

Gramling, J. M. 2010. *Potential effects of laurel wilt on the flora of North America*. Southeastern Naturalist, 9(4):827-836.

Gottschalk, K. W., R. S. Morin, and A. M. Liebhold. 2003. Potential susceptibility of eastern forests to sudden oak death, Phytophthora ramorum. In: Fosbroke, Sandra L.C.; Gottschalk, Kurt W., eds. Proceedings, U.S. Department of Agriculture interagency research forum on gypsy moth and other invasive species 2002; 2002 January 15-18; Annapolis, MD. Gen. Tech. Rep. NE-300. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 32.

Haack, R. A., F. Hérard,, J. Sun,, J. J. Turgeon. 2010. Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: a worldwide perspective. Annual Review of Entomology. 55: 521-546.

Hain, F. P., A. J. Duehl, M. J. Gardner and T. L. Payne. 2011. Natural History of Southern Pine Beetle. In R. N. Coulson and K.D. Klepzig eds. *Southern Pine Beetle II*. USDA-FS SRS GTR 140. Asheville, NC, 28804. pp. 109-128.

Haugen, D.A. and E.R. Hoebeke. 2005. *Pest Alert: Sirex woodwasp—Sirex noctilio F. (Hymenoptera: Siricidae)*. USDA Forest Service, Northeastern Area. NA-PR-05-07.

Haugen, D. A. 2007. S*irex woodwasp: biology, ecology and management*. In: Gottschalk, Kurt W., ed. Proceedings, 17th U.S. Department of Agriculture interagency research forum on gypsy moth and other invasive species 2006; Gen. Tech. Rep. NRS-P-10. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 48-49.

Holzmueller, E. J., S. Jose and M.l A. Jenkins. 2006. The effect of Fire on Flowering dogwood stand dynamics in Great Smokey Mountains National Park. In. K. F.Connor, ed. Proceedings of the 13th biennial southern silvicultural research conference. GTR SRS–92. Asheville, NC: USDA-FS, SRS. 640 p.

Houston, D.R. 1994. Major new tree disease epidemics: beech bark disease. Annu. Rev. Phytopathol. 32: 75-87.

Houston, D. R., B. D. Rubin, M. J. Twery, and J. R. Steinman. 2005. Spatial and Temporal Development of Beech Bark Disease in the Northeastern United States. In. Evans, C. A., J. A. Lucas, and M. J. Twery eds. Beech Bark Disease: Proceedings of the Beech Bark Disease Symposium. Saranac Lake, NY June 16-17, 2004. USDA-FS, NRS GTR NE-331.

Kessler, K. J. Jr., D. R. Houston. 1989. Oak Decline. In: F. B Clark, tech. ed.; J. G. Hutchinson, ed. Central Hardwood Notes. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.: Note 8.12..

Knight, K. S., R. P. Long, J. Rebbeck, D. A. Herms, J. Cardina, C. P. Herms, K. J. K. Gandhi, A. Smith, K. C. Costilow, L. C. Long, D. L. Cappaert. 2010. Effects of emerald ash borer (Agrilus planipennis) on forest ecosystems. In: K. A. McManus, K. W. Gottschalk, eds. Proceedings. 20th U.S. Department of Agriculture interagency research forum on invasive species 2009;

January 13-16, 2009; Annapolis, MD. Gen. Tech. Rep. NRS-P-51. Newtown Square, PA: USDA-FS NRS: 82.

Koch, F.H., and W.D. Smith. 2008. Spatio-temporal analysis of *Xyleborus glabratus* (Coleoptera: Circulionidae: Scolytinae) invasion in eastern US forests. Environmental Entomology 37(2):442–452.

Koch, F. H. and W. D. Smith, 2008. Mapping sudden oak death risk nationally using host, climate, and pathways data. In: Frankel, Susan J.; Kliejunas, John T.; Palmieri, Katharine M., tech. coords. 2008. Proceedings of the sudden oak death third science symposium. Gen. Tech. Rep. PSW-GTR-214. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. pp. 279-287

Juzwik, J., D. N. Appel, W. L MacDonald, S. Burks. 2011. Challenges and successes in managing oak wilt in the United States. Plant Disease. 95(8): 888-900.

Ludwig, S. W., L. Lazarus, D. G. McCullough, K. Hoover, S. Montero, and J. C. Sellmer. 2002. Methods to evaluate host tree suitability to the Aisian Longhorn Beetle, Anoplophora glabripennis. Journal of Environmental Horticulture. 20: 175-180.

Lusk, L., M. Mutel, E. S. Walker, and F. Levey. 2010. Forest change in high-elevation forests of Mt. Mitchell, North Carolina: re-census and analysis of data collected over 40 years. In. J. S. Rentch, and T. M. Schuler eds. Proceedings from the conference on the ecology and management of high-elevation forests in the central and southern Appalachian Mountains. 2009 May 14-15; Slatyfork, WV. Gen. Tech. Rep. NRS-P-64. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 242 p..

MacKenzie, M. 2005. Survival of the Fittest: Beach Bark Disease-Resistant Beech Will Leave More Offspring. In. Evans, C. A., J. A. Lucas, and M. J. Twery eds. Beech Bark Disease: Proceedings of the Beech Bark Disease Symposium. Saranac Lake, NY June 16-17, 2004. USDA-FS, NRS GTR NE-331.

Manion, P.D. 1991. Tree disease concepts. Second ed. Prentice-Hall, Englewood Cliffs, NJ. 328-348.

Mayfield III, A. E., J. H. Crane and J. A. Smith. 2008. Rev 2011. Laurel Wilt: A Threat to Redbay, Avocado and Related Trees in Urban and Rural Landscapes. Univ. of Florida Extension. HS1137. 6 pages.

McManamay, R. H., L. M. Resle, and J. B. Campbell. 2010. Fresier fir structure in the Black Mountains of North Carolina. In. J. S. Rentch, and T. M. Schuler eds. Proceedings from the conference on the ecology and management of high-elevation forests in the central and southern Appalachian Mountains. 2009 May 14-15; Slatyfork, WV. Gen. Tech. Rep. NRS-P-64. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 242 p..

McManus, M., N. Schneeberger, R. Reardon and G. Mason. 1989. Gypsy Moth. USDA-FS Forest Insect and Disease Leaflet 162. 14 pages.

Mercader, R. J., N. W. Siegert, •A. M. Liebhold, • D. G. McCullough. 2011. Influence of foraging behavior and host spatial distribution on the localized spread of the emerald ash borer, Agrilus planipennis. Popul Ecol (2011) 53:271–285.

Miller, D. R., J. W. Kimmey and M. E. Fowler. 1959. White Pine Blister Rust. USDA-FS Forest Pest Leaflet 36. 8 pages.

Morin, R. S., A. M. Liebhold, P. C. Tobin, K. W. Gottschalk, and E. Luzader. 2007. Spread of beech bark disease in the eastern United States and its relationship to regional forest composition. Can. J. For. Res. 37: 726-736.

NCDOF.2011. North Carolina Forest Health Highlights. NC Forest Service and USDA_FS 6 pages.

NCFS. 2011. North Carolina Forest Health Highlights 2011. http://www.ncforestservice.org

Newton, L. and G. Fowler. 2009. Pathway Assessment: Geosmithia sp. and Pityophthorus juglandis Blackman movement from the western into the eastern United States. USDA_APHIS, 50 pages.

Nowacki, G., R. Carr, and M. Van Dyck. 2010. The current status of red spruce in the eastern United States: distribution, population trends, and environmental drivers. In. J. S. Rentch, and T. M. Schuler eds. Proceedings from the conference on the ecology and management of high-elevation forests in the central and southern Appalachian Mountains. 2009 May 14-15; Slatyfork, WV. Gen. Tech. Rep. NRS-P-64. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 242 p..

NYS_DEC. 2012. Sirex Woodwasp, Sirex Woodwasp - Sirex noctilio. *http://www.dec.ny.gov/animals/7248.html*

Oak, Steven W.; Huber, Cindy M.; Sheffield, Raymond M. 1991. Incidence and impact of oak decline in Western Virginia, 1986. Resour. Bull. SE-123. Asheville, NC: U.S. Department of Agriculture, Southeastern Forest Experiment Station. 19 p..

Oak, S. W., J. R. Steinman, D. A. Starkey, and E. K. Yockey. 2004. Assessing Oak Decline Incidence and Distribution in the Southern U.S. Using Forest Inventory and Analysis Data. In. Spetich, M. A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. GTR SRS–73. Asheville, NC: USDA,-FS, SRS. 311 p.

Oak, Steven W.; Steinman, James R.; Starkey, Dale A.; Yockey, Edwin K. 2004. Assessing Oak Decline Incidence and Distribution in the Southern U.S. Using Forest Inventory and Analysis Data. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. pp. 236-242.

O'Brien, J. G., M. E. Mielke, S. Oak, and B. Moltzan. 2002. Pest Alert: Sudden Oak Death. USDA-FS-SPF-NA. NA-PR-02-02.

O'Brien, J., M. Mielke, D. Starkey, J. Juzwik. 2011. How To Identify, Prevent, and Control Oak Wilt. USDA Forest Service, Department of Agriculture, Northeastern Area, State & Private Forestry, NA-FR-01-11

Ohio, 2012. Ohio Asian Longhorned Beetle (ALB) Cooperative Eradication Program MEDIA UPDATE. http://www.agri.ohio.gov/Public_Docs/TopNews/ALB/Ohio%20Media%20Update_01242012.pdf

Organization for Bat Conservation (OBC). 2012. http://www.batconservation.org

Ostry, M. E., G. Rink and R. L. Anderson, 1996. How to Identify butternut canker and manage butternut trees. USDA-FS NA S&PF HT-70.

Ostry, M. E.; Woeste, K. 2004. Spread of butternut canker in North America, host range, evidence of resistance within butternut populations and conservation genetics . In: Michler, C.H.; Pijut, P.M.; Van Sambeek, J.W.; Coggeshall, M.V.; Seifert, J.; Woeste, K.; Overton, R.; Ponder, F., Jr., eds. Proceedings of the 6th Walnut Council Research Symposium; Gen. Tech. Rep. NC-243. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 114-120.

Pears, Sarah; Wallin, Kimberly. 2011. North American host tree response to Amylostereum areolatum, the fungal symbiont of the woodwasp Sirex noctilio. In: McManus, Katherine A; Gottschalk, Kurt W., eds. 2010. Proceedings. 21st U.S. Department of Agriculture interagency research forum on invasive species 2010; 2010 January 12-15; Annapolis, MD. Gen. Tech. Rep. NRS-P-75. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 118..

Petrice, T. R. and R. A. Haack. 2011. Effects of Cutting Time, Stump Height, and Herbicide Application on Ash (Fraxinus Spp.) Stump Sprouting and Colonization by Emerald Ash Borer (Agrilus planipennis). NORTH. J. APPL. FOR. 28(2).

Poland, T. M., R. A. Haack,, D. A. Haugen,, I. M. Wilson, 2001. Be on the lookout for Asian longhorned beetles. Arborist News. Vol. 10, no. 2: p. 55-57.

Poland, T. M., D. G. McCullough, D. A. Herms, L. S. Bauer, J. R. Gould and A. R. Tluczek. 2010. Management Tactics for Emerald Ash Borer: Chemical and Biological Control. In. 2010 USDA Research Forum on Invasive Species. GTR-NRS-P-75

Pugh, S. A., A. M. Liebhold, and R. S. Morin. 2011. Changes in ash tree demography associated with emerald ash borer invasion, indicated by regional forest inventory data from the Great Lakes States. Can. J. For. Res. 41: 2165–2175.

Roden, D.B.; Haack, R.A.; Keena, M.A.; McKenney, D.W.; Beall, F.D.; Roden, P.M. 2009. Potential northern distribution of Asian longhorned beetle in North America. In: McManus, Katherine A; Gottschalk, Kurt W., eds. Proceedings. 19th U.S. Department of Agriculture interagency research forum on invasive species 2008; 2008 January 8-11; Annapolis, MD. Gen. Tech. Rep. NRS-P-36. Newtown Square, PA: USDA_FS_NRS: 68.

Sawyer, A. J. and W. S. Panagakos. 2009. Spatial Dynamics of the Asian Longhorned Beetle: Carteret, NJ, to Staten Island, NY, in Nine Years? In: McManus, Katherine A; Gottschalk, Kurt W., eds. Proceedings. 19th U.S. Department of Agriculture interagency research forum on invasive species 2008; 2008 January 8-11; Annapolis, MD. Gen. Tech. Rep. NRS-P-36. Newtown Square, PA: USDA_FS_NRS: 68.

Schlarbaum, S. E., F. Hebard, P. C. Spaine and J. C. Kamalay. 1997. Three American tragedies:chestnut blight, butternut canker, and Dutch elm disease. In Britton, K. O. (ed.)

Proceedings: Exotic Pests of Eastern Forests. Nashville, Tennessee. Pp. 45-54.

Seybold, S., D. Haugen, and A. Graves. 2011. Pest Alert: Thousand Cankers Disease. USDA-FS-NASPF. NA_PR_02_10. Revised from 2010. 2 pages.

Skelly, J. M., D. D. Davis, W. Merrill, E. A. Cameron, H. D. Brown, D. B. Drummond, and L. S. Dochinger. 1990. Diagnosing Injury to Eastern Forest Trees. Penn State Univ. University Park, PA 16802. 122 pages.

Smith, G. F. and N. S. Nicholas. 1999. Post-disturbance spruce-fir forest stand dynamics at seven disjunct sites. Castanea 64(2): 175-186.FHP. 2005. Hemlock Woolly Adelgid. USDA-FS Pest Alert NA-PR-09-05. 2 pages.

Snyder, C. D., J. A. Young, R. M. Ross and D. R. Smith. 2005. Long-term Effects of Hemlock Forest Decline on Headwater Stream Communities. In. B. Onken and R. Reardon eds. Third Symposium on Hemlock Woolly Adelgid in the Eastern United States. Asheville, NC. February 1-3, 2005. USDA-FS FHTET-2005-01. pages 42-55.

Tisserat, N. and W. Cranshaw. 2012. Pest Alert: Walnut Twig Beetle andThousand Cankers Disease of Black Walnut. Colorado State University Extension Website 8 pages. http://www.colostate.edu/Depts/bspm/extension%20and%20outreach/thousand%20cankers.html

Tobin, P. C., Barry B. B., D. A. Eggen and D. S. Leonard. 2012. The ecology, geopolitics, and economics of managing Lymantria dispar in the United States. International Journal or Pest Management. Vol. 58, No. 3, 195-210.

United States Department of Agriculture (USDA). 2012. http://www.invasivespeciesinfo.gov/aquatics/didymo.shtml.

USDA-FS. 2001. Decision Notice and Finding of No Significant Impact for Suppression of Southern Pine Beetle on the Nantahala and Pisgah National Forests. Asheville, NC. 20 pages.

USDA-FS_FHP. 2012. http://www.fs.fed.us/foresthealth/news/news_sirexnoctilio.shtml

United States Fish and Wildlife Service (USFWS) 2012. http://www.fws.gov/r5crc/didymo.htm.

United States Department of Agriculture (USDA). 2012. http://www.invasivespeciesinfo.gov/aquatics/asianclam.shtml.

United States Geological Service (USGS). 2012. http://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=92.

Van Arsdel, E. P. 1972. Environment in Relation to White Pine Blister Rust Infection. In. R. T. Bingham, R. J. Hoff and G. I. McDonald. Biology of Rust Resistance in Forest Trees: Proceedings of a NATO_IFURO Advanced Study Institute. August 17-24, 1969. Moscow, ID. USDA-FS Misc Pub 1221.

Wang, G. G., B. o. Knapp, S. L. Clark. And B. T. Mudder. 2013. The silvics of Castanea dentate (Marsh.) Borkh., American Chestnut, Fagaceae (Beech Family). USDA – FS, SRS GTR 173. 18 pares.

Wargo, P. M., D. R. Houston and L. A. LaMadeleine. 1983. Oak Decline. USDA-FS Forest Insect & Disease Leaflet 165.

Wetteroff, James J.; Dwyer, John P. 1993. Management and prediction of red oak decline in the Missouri Ozarks. In: Gillespie, Andrew R.; Parker, George R.; Pope, Phillip E.; Rink, George: eds. Proceedings of the 9th Central Hardwood Forest Conference; Gen. Tech. Rep. NC-161. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 488.