

Chapter 3. Threats to Forest Health

3.a.

Insects, Diseases, and Non-native Invasive Plants: Threats to Forest Health

Key Findings

- Major forest pests and non-native invasive (NNI) plants significantly damage the ecological and economic vitality of North Carolina's forests.
- Risks to the ecological and economic vitality of North Carolina's forests will intensify as new forest pests and NNI plants are introduced. The challenges of protecting forests from threats will increase and become more complex.
- Pathways for the introduction of new pest species vary greatly, ranging from intentional introductions with unintended results to accidental introductions. Movement of very diverse items—such as timber, firewood, outdoor household articles, and ornamental plants—add to the complexity of monitoring and managing threats to forest health.

Introduction

Insect, disease, and non-native invasive (NNI) plant species have long threatened the health and productivity of North Carolina's forest resources. Presently native, naturalized, and recently introduced forest insects, diseases, and NNI plant species directly threaten North Carolina's forests. Native and naturalized insect and disease threats are responsible for mortality, loss of tree growth, tree deformity, and reduced tree quality. In addition, non-native insect and disease pests may also contribute to loss of forest tree species and alter forest composition. NNI plants can crowd out native plants, decreasing species diversity, simplifying natural systems, and even creating monocultures, all of which make these areas less resilient. Invasive weeds can also limit production of native wildlife food and habitat.

Current threats include major and locally significant forest pests and NNI plants already found in the state. Major forest pests

can eliminate species, significantly alter forest compositions, or cause mortality and loss of growth. Locally significant pests can cause considerable damage, but impacts are normally confined to localized areas or limited by the host species range.

In addition to pests and NNI plants currently found in the state, North Carolina's forests may be vulnerable in the future to other biological threats that have been brought from other countries into the United States. These potential or imminent threats are not currently found in North Carolina, but are spreading in other parts of the country. When these species reach the state, they could cause significant damage to our forest resources.

The movement of firewood and other wood products that can harbor various insects and diseases facilitates the spread of some of these forest pests; as such, these pests will be treated as a separate threat at the close of this section.

Current Major Forest Health Threats

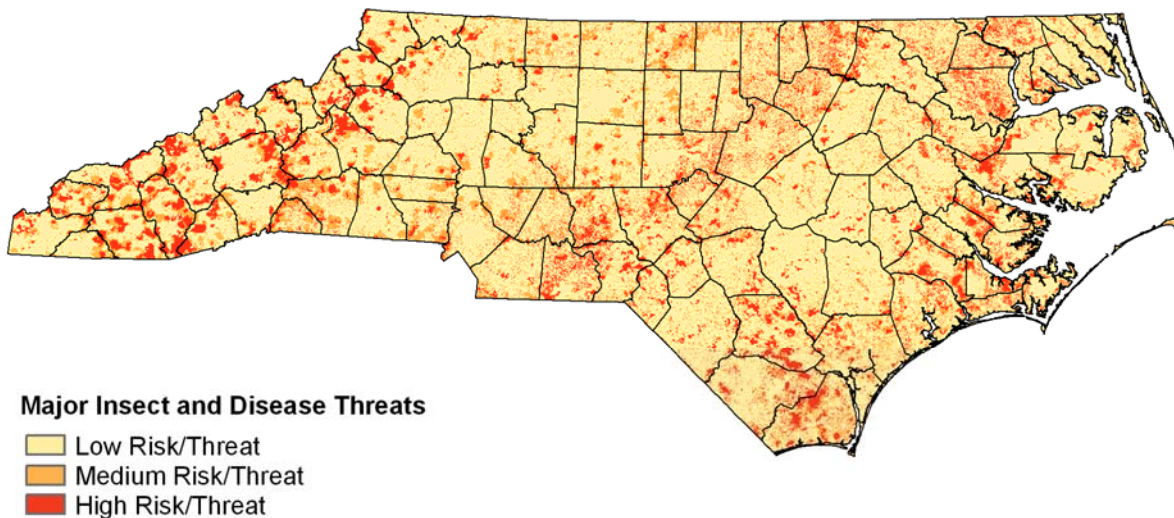
Background

Major forest pests can cause significant ecological and economic damage to North Carolina’s forest resources. Major forest health threats consist of native and non-native species of insects, diseases, and invasive plants. Losses from native forest insects and diseases are typically cyclical as native forest tree and pest species have coexisted for many years. The intensity and duration of cyclical outbreaks can be aggravated by anthropogenic land use and lack of proper management. Non-native insects and diseases provide unique challenges to forest health because native forest trees have not evolved with these pests and therefore never developed adequate natural defenses. In addition, major NNI plants crowd out native species; their impacts minimize diversity, simplify natural

systems, limit production of native wildlife food, and foster monocultures. Many non-native species continue to spread and may not have reached their full biological impact, so the full economic and ecological losses have yet to be realized.

A major insect and disease threat map was developed from several data layers (FIGURE 3a-1). These layers included (1) the USDA Forest Service, Forest Health Technology Enterprise Team (FHTET), southern pine beetle hazard map; (2) the “forest health” layer from the Southern Forest Land Assessment (including annosus root rot, fusiform rust, southern pine beetle, balsam woolly adelgid, gypsy moth, and beech bark disease); and (3) hazard maps related to littleleaf disease, balsam woolly adelgid, and hemlock woolly adelgid. These layers were combined to show areas of medium or high risk for forest mortality based on geographical analysis. This analysis is not necessarily based on a specific time frame.

FIGURE 3a-1. Map of North Carolina’s major insect and disease threats by risk level.



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Current Major Forest Pests

Major Diseases

Annosum root disease or root rot is caused by the native fungus *Heterobasidion annosum*. This disease can be a serious problem in thinned pine stands. Loblolly (*Pinus taeda*), slash (*P. elliottii*), and white (*P. strobus*) pines are the most affected species, but shortleaf (*P. echinata*) and longleaf (*P. palustris*) pines and red cedar (*Juniperus virginiana*) are also commonly infected. The airborne fungal pathogen enters stands by infecting freshly cut stumps or wounded roots, causing root rot. Once gaining access to a stand, the fungus can spread to adjacent healthy trees through root contacts and grafts. Advanced infection increases the risk of windthrow and can result in growth loss and mortality, either from the direct effects of root disease or from bark beetle attacks on the stressed trees.

Since 2005, between 25,000 and 30,000 acres per year of pine timber in North Carolina on nonindustrial private forest lands have been commercially thinned with the twin goals of improving forest health and increasing wood production (NCDNR, 2009). An increased risk of *H. annosum* infection may be likely where thinning is conducted on high risk sites. Increased damage may occur in thinned pine stands where the disease is already present.

Fusiform rust is caused by the native fungus *Cronartium quercuum* f. sp. *fusiforme* and is most abundant in young, rapidly growing pine plantations of loblolly and slash pines in high-rust hazard areas. Fusiform rust stem infections in young trees normally cause tree death. Later infections result in quality loss at harvest or in stem weakness and breakage at the canker. Trees not killed or structurally weakened may suffer a loss of growth. This disease can

severely limit the productivity of pine forests in the South, and rust-infected trees may succumb to other pest problems.

Littleleaf disease is caused by *Phytophthora cinnamomi*, a non-native fungus-like microorganism, in combination with other factors. This disease is most commonly found in North Carolina's piedmont, where shortleaf pine is the most seriously damaged host. This pathogen damages tree roots, sapping vigor, reducing tree growth, and often leading to tree mortality. Littleleaf disease is caused by a complex of factors, which includes the presence of the pathogen, heavy clay soil, and soil that is low in nitrogen. Shortleaf and loblolly pine stands growing on sites at high risk for littleleaf disease are also at high risk for southern pine beetle infestations.

On poor sites, trees may survive up to 6 years after initial infection. On better sites, trees may persist 15 to 20 years. Concerns over the potential for loss of pine stands to littleleaf disease have caused a decline in planting shortleaf pine in much of North Carolina's central piedmont. Acreage of shortleaf pine has been declining in the state since the early 1980s.

Oak decline is due to abiotic and biotic influences and tends to be most damaging among members of the red oak group: northern red (*Quercus rubra*), scarlet (*Q. coccinea*), pin (*Q. palustris*), and black oaks (*Q. velutina*). Members of the white oak group, white oak (*Q. alba*) and chestnut (*Q. prinus*), are not immune but are less prone to decline-associated mortality. Decline diseases, such as oak decline, are not caused by a single insect or pathogen but are instead the product of interactions among physiologically mature trees, environmental stresses, and forest pests. Oak decline can be problematic in both urban and rural areas. Trees predisposed by drought stress become weakened and more susceptible to the

effects of spring defoliating insects or frost. Insects and pathogens of opportunity combine to cause tree death. Oak decline generally takes several years to kill susceptible trees.

Predisposing factors for oak decline include older stands with a large proportion of oaks and less productive sites characterized by shallow or clay soils. Inciting factors, such as prolonged drought, repeated insect defoliation, or late-season frosts, then trigger decline events. Finally, contributing factors, such as diseases and insects, combine with inciting factors to further weaken and kill stressed oaks. Management of oaks to create more complex age and species mixtures on the landscape, reduce competition for moisture and nutrients, and promote healthy hardwoods is the best defense against oak decline but is lacking in many areas.

Major Insects

Southern pine beetle (SPB), *Dendroctonus frontalis*, is a native insect and the most destructive insect pest of pine in the South. Preferred hosts in North Carolina include loblolly, shortleaf, pond (*Pinus serotina*), and Virginia pines (*Pinus virginiana*). SPB colonizes and feeds on the inner bark of pine trees and introduces fatal blue-stain fungi. Weakened, stressed stands are most susceptible.

During periodic outbreaks, SPB populations can rise, attack, and quickly kill acres of trees. During epidemics, SPB can attack and kill even healthy pines. Abundance of dead trees, both standing and down, following an outbreak can lead to large amounts of fuel loading and create hazardous conditions for forest firefighting. The last outbreak in North Carolina was in the mountains between 1998 and 2002. During that time, 2.7 million acres of forest were affected and a total of \$6.4 million worth of timber was destroyed.

Practicing good silviculture before outbreaks, which reduces basal area and encourages healthy radial growth, can prevent the spread of SPB in stands. The NCDFR administers a cost-share program to help forest landowners thin young stands to help prevent southern pine beetle susceptibility. This Southern Pine Beetle Prevention Program is funded by a federal grant from the USDA Forest Service, Forest Health Protection. Planting less susceptible species (longleaf pine) and planting pines at low stocking (less than 500 trees per acre) are also acceptable prevention practices.

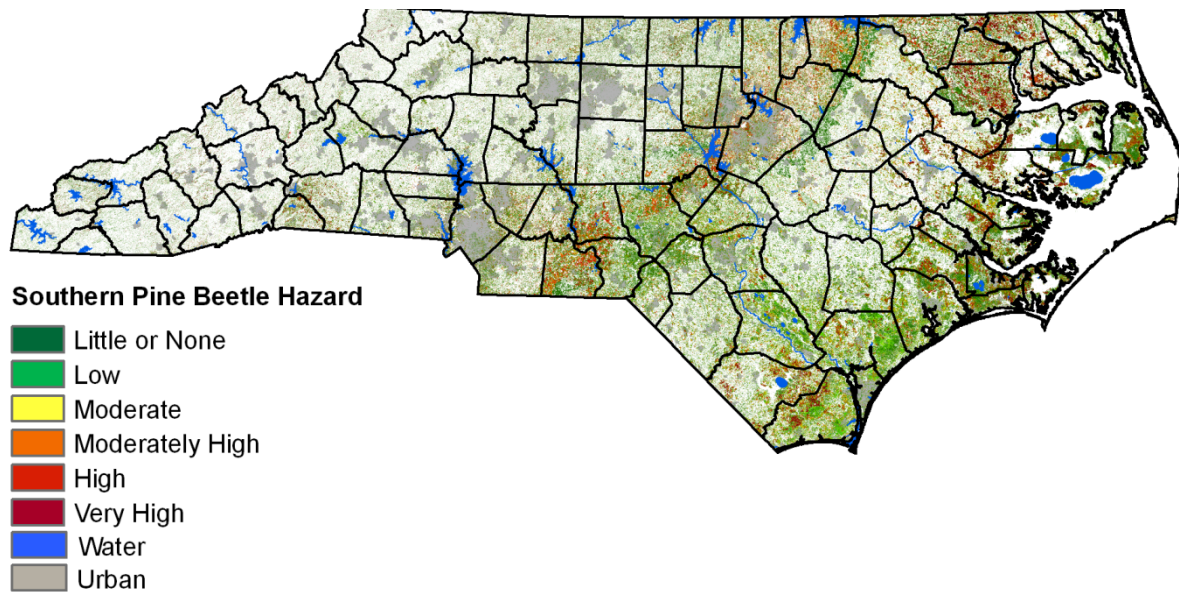
Control of outbreaks is usually limited to salvaging affected stands or felling and leaving affected trees and a small buffer to prevent spread. In urban forests, control can become contentious due to infestations crossing multiple ownerships.

A southern pine beetle hazard map was developed through modeling by the USDA Forest Service FHTET (FIGURE 3a-2). The FHTET hazard modeling aims to predict areas that will lose 25 percent or more of the total basal area in stems more than 1 inch (2.54 cm) in diameter due to southern pine beetles within the next 15 years. FHTET has developed SPB hazard designations for North Carolina using both remotely derived data and forest inventory data. The FHTET hazard modeling framework uses many datasets to predict where susceptible forest types occur, including those derived from land cover, topography, soil types, elevation, climate, and previous forest inventories.

Gypsy moth, *Lymantria dispar*, is a non-native pest. Oaks (*Quercus spp.*) are the preferred host species for feeding caterpillars, but a variety of other hardwoods serve as hosts as well. Older larvae will also feed on several conifer species. Since being introduced from Europe into the United States (Massachusetts) around 1869, the gypsy moth has infested 19 states. Current

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FIGURE 3a-2. Southern pine beetle hazard map.



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quarantined areas include two counties in North Carolina and all Virginia counties along the state line from the Atlantic Ocean to Martinsville, Virginia (FIGURE 3a-3). Occasional populations of this defoliator are found in North Carolina and are quickly controlled by the NC Department of Agriculture and Consumer Services (NCDA&CS) in cooperation with the USDA Slow the Spread (STS) Program. The goal of STS is to slow the spread of the gypsy moth by using integrated pest management strategies. Despite these efforts, it is likely that the gypsy moth will expand its range to include all of North Carolina over the next 25 years.

Without intervention, the gypsy moth spreads about 13 miles per year. Artificial movement dramatically hastens the moth's spread because it 'hitchhikes' on items that are moved long distances, such as nursery stock, firewood, vehicles, forest products, and outdoor household articles.

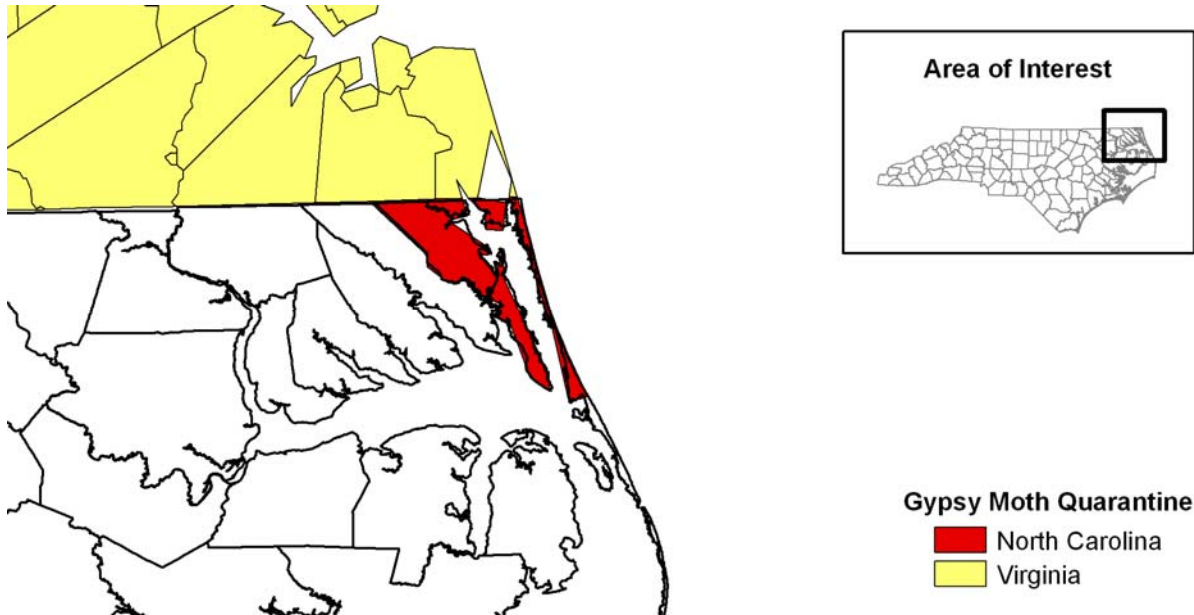
Because the gypsy moth has infested only a small area in North Carolina, it can be treated in this assessment as both a current

threat to that area and an imminent threat to forests in the rest of the state.

Hemlock woolly adelgid (HWA), *Adelges tsugae*, is native to Asia. It is a small, aphid-like insect that threatens the health and sustainability of eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*). HWA was first reported in the eastern United States in 1951 and has since been established in 16 states. The tiny sucking insect now infests most of the range of native hemlocks in North Carolina. Mortality is very apparent in infested stands—primarily in forested stands where control is difficult and cost-prohibitive. Heavy infestations can kill trees in as little as 4 years, yet some trees have survived infestations for more than 10 years.

Hemlocks are an important habitat component for deer, small mammals, and almost 90 species of birds. Hemlocks also provide shade for favorable brook trout habitat and supply important riparian ecology benefits. Because of the hemlock's important role in riparian ecology, its loss

FIGURE 3a-3. European gypsy moth quarantine map, 2008.



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could have a devastating impact on these ecosystems.

Most control measures are confined to application of systemic insecticides on urban landscape trees and on easy-to-access forest trees of high ecologic, aesthetic, historic, and sentimental value. However, the impact of the adelgid continues to outpace efforts to control the pest. The USDA Forest Service and several universities, including NC State University, are conducting research into releasing predatory beetles to control HWA. Unfortunately, most of our hemlocks will be lost from North Carolina's mountains before adequate control can be developed.

Balsam woolly adelgid (BWA), *Adelges picea*, is a non-native insect that infests the Fraser fir (*Abies fraseri*) in North Carolina's mountains. This tiny sucking insect was introduced into North America from Europe around 1900 and appeared in North Carolina in the 1950s. BWA has altered the age and species composition of Fraser fir, resulting in its listing as a "Federal Species of Concern." Currently, there is no reliable long-term control of BWA in forest settings.

Research investigating releases of predator beetles has shown promise, yet control is limited to chemical applications on Christmas tree farms and in urban landscapes.

Major Non-Native Invasive Plants

Bradford pear, *Pyrus calleryana*, is a tree cultivar from China that was thought to produce sterile seeds. Bradford pear has been planted as an ornamental tree for many years. More recently it has been found to be an invasive species in the NC piedmont and coastal plain. These aggressive pears invade roadsides, utility rights of ways, forest edges, and cutover areas by forming dense, thorny thickets. Starlings and other fruit-eating birds spread nonsterile seeds. Early chemical control is not difficult; however, the entire root system must be killed or removed to prevent resprouting.

Garlic mustard, *Alliaria petiolata*, is a perennial herb native to Europe that invades moist, shaded understories, trails and roadsides, forest openings, and floodplains. Once established, this plant increases in

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density and replaces native vegetation, leading to decreases in native plant richness and diversity. Mostly a problem in the North Carolina mountains and piedmont, garlic mustard also has implications for wildlife management as the weed is not used by wildlife. Presence of garlic mustard also interferes with reproduction of a rare species of butterfly and can kill emergent larvae.

Control by hand removal of entire root systems may be practical for light infestations, but stems need to be disposed of properly to prevent seed dissemination. Fire can control garlic mustard, but fire also stimulates germination. Five-year monitoring is necessary for full eradication.

Japanese knotweed, *Polygonum cuspidatum*, is a shrub-like perennial herb found along water sources and low lying areas, spoil and gravel pits, driveways, utility rights of way, and old home sites. It spreads quickly and forms dense thickets in open areas. This weed tolerates high salinity, extreme drought, high temperatures, full shade, and periodic flooding. Knotweed aggressively competes with and displaces native species, ultimately forming a monoculture groundcover. Japanese knotweed can affect forest management following harvest, thinning, or wildlife food plot openings.

Meadowsweet refers to two shrub species: *Spirea japonica* and *S. thunbergii*. These escaped ornamental shrubs can dominate disturbed areas along streams and riparian areas, roadsides, meadows, forest openings, and other sites. *Spirea japonica* is most notably a problem in the Sandhills, while *S. thunbergii* is more problematic in the mountains. The shrubs rapidly form dense infestations of entangled stems, branches, and abundant foliage that choke out native species. Seeds are prolific and can survive for many years in the soil, making control extremely difficult. Repeated mowing or

cutting can control but not eradicate the shrub. More than one chemical application may be necessary with large populations.

Miscanthus, *Miscanthus sinensis*, is a tall clump grass native to tropical Asia that infests many sites, particularly after fire: disturbed sites; forest margins; roadsides; and shores of reservoirs, lakes, and streams. *Miscanthus* can be found statewide, but is particularly aggressive in the mountains. It tolerates shade and thrives in moist, well-drained soil. *Miscanthus* is extremely flammable and increases the risk of wildfire. Herbicide treatment generally is the only effective method of control.

Oriental bittersweet, *Celastrus orbiculatus*, is an ornamental woody vine that is capable of climbing native vegetation and ultimately strangling or smothering its hosts, or breaking their stems with weight loads. Oriental bittersweet is primarily found in the mountains and piedmont along forest edges, hedgerows, roadsides, fields, and disturbed woodlands. This Oriental species hybridizes with native bittersweet (*Celastrus scandens*), causing the native species to lose its genetic identity. Oriental bittersweet is classified as a “Class C State Noxious Weed” and is quarantined in 18 mountain counties in North Carolina. Movement of this noxious weed from quarantine areas is prohibited except under certificate or permit from the NCDA&CS Plant Industry Division, Plant Protection Section. Control options include manual, mechanical, and chemical techniques, which work best in combination.

Paulownia, *Paulownia tomentosa*, was introduced as an ornamental tree and has become naturalized in the mountains and piedmont. Paulownia grows fast and sprouts prolifically. Its seed is disseminated long distances by wind and water. Paulownia trees often invade forest edges, roadsides, disturbed forest openings, and streamsides,

where the trees displace native species and can outcompete rare plants in marginal habitats. Control options include manual, mechanical, and chemical means, most successfully in combination.

Chinese privet and Japanese privet, *Ligustrum sinense* and *L. japonicum*, are ornamental shrubs that have invaded forest edges and fence rows statewide, primarily in bottomlands. Although they both prefer full sun, Japanese privet tolerates more shade than Chinese privet. Both shrubs create dense thickets that replace native plant species and fundamentally alter forest edge composition and structure. Seeds are dispersed across the landscape by birds. A number of manual, mechanical, and chemical control options exist; however, combinations or repeated efforts are required because of the prolific seed supply and sprouting stems and roots.

Stilt grass, Japanese stilt grass, or Nepalese browntop grass, *Microstegium vimineum*, is an aggressive grass that tolerates shade and adapts to a variety of soil conditions. This bamboo-like grass is a threat to many native plants in open woods, floodplain forests, wetlands, uplands, fields, paths, clearings, roadsides, ditches, utility corridors, yards, and gardens statewide. Dense patches displace native groundcover and shade young tree seedlings. Stilt grass can quickly take over an area and can adversely affect afforestation and reforestation efforts. Once established, stilt grass is very difficult to control. Small patches can be removed by hand. Effective herbicides do not offer complete control as seeds can remain viable in the ground for many years.

Tree of heaven, *Ailanthus altissima*, is an invasive Chinese tree found across the state; it is most aggressive in the mountains and piedmont. This tree is somewhat shade-tolerant and grows quickly after invading

any type of disturbance. In urban areas, *A. altissima* will take over unmaintained sidewalks, alleys, and abandoned properties. In rural areas, it invades forest edges and openings, fields, and fence rows and can adversely affect afforestation and reforestation efforts.

Tree of heaven thrives on high quality sites and will outcompete and displace even a fast-growing native tulip poplar (*Liriodendron tulipifera*). Eliminating *A. altissima* is difficult due to its abundant viable seeds and prolific root and stem sprouting. Persistent monitoring and control using biological, manual, mechanical, or chemical techniques is needed.

Locally Significant Forest Threats

The major pests and NNI plants listed above are by no means the only threats to forests and trees in North Carolina. Locally significant pests and NNI plants also have the ability to cause significant damage and impact diversity in local areas. Some of these threats are confined to a small geographic area and pose little risk of spreading into unaffected areas. NNI plants in this category also have the ability to crowd out native species, alter natural systems, limit production of native wildlife food, and create monocultures. Non-native species of this category usually spread into uninfected ranges more slowly. Table 3a-1, 3a-2, and 3a-3 provides lists of significant localized threats.

Certain localized threats, such as dogwood anthracnose, kudzu, and bamboo, easily could have been included as major threats. These forest pests and NNI plants could not be ignored; their presence in an area causes major problems. The threats in the major threats assessment were deemed to be those that will have the *most* impact on forest health, productivity, afforestation and reforestation, and diversity over the next 30

a. Insects, Diseases, and Non-native Invasive Plants

TABLE 3a-1.—Locally significant diseases

Diseases
Beech Bark Disease , <i>Neonectria coccinea</i> var. <i>faginata</i> – Exotic fungal disease that is of major concern in high elevation forests in Western North Carolina. No real control known in forested areas at this time.
Brown Spot Needle Blight , <i>Scirrhia acicola</i> – Needle blight fungus causing defoliation of longleaf pines in the sandhills and coastal plain. Can be controlled by prescribed burning.
Butternut Canker , <i>Sirococcus clavigenti-juglandacearum</i> – Exotic fungal disease has all but wiped out butternut trees in the mountains and piedmont. Few residual trees are heavily cankered. No known control.
Dogwood Anthracnose , <i>Discula destructive</i> – Exotic fungal tree disease that has killed more than 60% of the native dogwoods in the mountain region. No real control known in forested areas.
Oak Wilt , <i>Ceratocystis fagacearum</i> - Potentially a destructive disease (origin debated) confined to and causing little damage to oaks in five mountain counties. Removing affected trees can control spread.
Pitch Canker , <i>Fusarium circinatum</i> – Native tree disease causes bleeding cankers, dieback, and mortality of loblolly and longleaf pines statewide.
White Pine Decline/Loblolly Pine Decline , <i>Leptographium procerum</i> , <i>Phytophthora</i> spp., <i>Pissoides</i> spp. – Complex of environmental, insect and disease factors that cause decline and mortality of white and loblolly pines. Primarily a problem with older pines and pines planted off-site.

TABLE 3a-2.—Locally significant Insects

Insects
Black Twig Borer , <i>Xylosandrus compactus</i> – Non-native tip boring insect found primarily in the coastal plain. Causes twig dieback and flagging of branches in a variety of hardwoods including bays, magnolias and dogwoods. Mortality is rare as only smaller branches are affected. Damage often confused with the more serious redbay ambrosia beetle.
Fall Cankerworm , <i>Alsophila pometeria</i> - Native defoliator of oaks, this caterpillar is usually kept under control under normal forest conditions by natural predators. Populations periodically build up to damaging levels in Charlotte/Mecklenberg County and require chemical control to limit nuisance and tree mortality.
Fall Webworm , <i>Hyphantria cunea</i> and Eastern Tent Caterpillar , <i>Malacosoma americanum</i> and Forest Tent Caterpillar , <i>Malacosoma disstria</i> - Native defoliators of hardwoods found statewide. Except during extreme outbreaks, these pests primarily cause only aesthetic damage and are rarely controlled. They are often nuisances in urban areas. Forest tent caterpillars experience periodic outbreaks, defoliating tupelo gum and other bottomland hardwoods along the Roanoke River basin.
Locust Leafminer , <i>Odontata dorsalis</i> – Native late season defoliator of black locusts. Rarely a tree killer, the pest mostly causes aesthetic damage over the range of locusts in the state. Creates numerous citizen calls in late summer. Usually not controlled.
Nantucket Pine Tip Moth , <i>Rhyacionia frustrana</i> – Native tip boring insect that attacks all pine species in North Carolina. Larvae feeding on buds and branch tips can lead to mortality in seedlings and young pines, but usually causes tip dieback, and deformities and forked stems.
Pales Weevil , <i>Hylobius pales</i> and Reproduction Weevils , <i>Pachylobius picivorous</i> – Native weevils found statewide cause mortality of seedlings by feeding on stem bark. Can be controlled by timing of harvest/reforestation and by chemically treating seedlings.
Pine Bark Adelgid , <i>Pineus strobe</i> – Native sap sucking aphid like insect found throughout the range of white pines. Causes loss of vigor that can lead to decline and mortality.
Pine Engraver Beetle , <i>Ips</i> spp. And Black Turpentine Beetle , <i>Dendroctonus terebrans</i> – Opportunistic native bark beetles that can kill pines stressed by drought, lightning, root or stem damage, fire, or wind/ice events. Practices to reduce stress can prevent attacks and large infestations can be controlled by salvage harvests.
Redheaded Pine Sawflies , <i>Neodiprion lecontei</i> – Native defoliator of loblolly and longleaf pines. Repeated defoliations can potentially lead to mortality. Natural predators usually keep populations under control though there can be periodic localized outbreaks.

TABLE 3a-3.—Locally significant Non-native Invasive Plants

Non-native Invasive Plants
Chinaberry , <i>Melia azedarach</i> - Tree that invades disturbed areas, roadsides and forest edges throughout the state. It has the potential to grow in dense thickets, restricting the growth of native vegetation. Control usually requires a combination of chemical and mechanical practices.
Common Reed , <i>Phragmites australis</i> - Herbaceous or grasslike weed that invades wet areas in the coastal plain. Can hamper forestation efforts by shading out young trees. Requires a combination of burning and chemicals to control.
English Ivy , <i>Hedera helix</i> - Weedy vine sometimes used as ornamental groundcover statewide. On the ground, vines create a dense covering that crowds out other vegetation. As a climbing vine, it engulfs and kills branches, either by blocking sunlight or by weight making trees susceptible to breakage or windthrow during storms. Provides hiding habitat for defoliating gypsy moth caterpillars and harbors the bacterial leaf scorch pathogen.
Japanese Honeysuckle , <i>Lonicera japonica</i> - Weedy vine thrives in a variety of habitats including fields, forests, wetlands, barrens, and all types of disturbed lands. Fast growing and spread easily by birds, this weed can quickly outcompete native vegetation. Vines have the ability to twist tightly around trunks and branches of host trees and effectively 'choke' their hosts. Several chemical and non-chemical controls exist, but control requires persistence.
Kudzu , <i>Pueraria montana</i> - Weedy vine that invades roadsides, old fields, forest edges and disturbed areas statewide. While difficult to control, its rate of spread to new areas is slow. Control requires a commitment and is rarely, if ever, effective with one treatment.
Mimosa , <i>Albizia julibrissin</i> - Tree that is a strong competitor to native trees and shrubs in open areas or forest edges. Often spreads easily from nearby landscape trees. Control is possible with a combination of chemical and mechanical practices.
Multiflora Rose , <i>Rosa multiflora</i> - Woody shrub creates dense thickets in a variety of light, soil and moisture conditions statewide. Can be controlled with a variety of mechanical and chemical treatments.
Periwinkle , <i>Vinca minor</i> - Weedy vine that invades open to shady forests often around former plantings at old homesites statewide. This species forms dense and extensive mats along forest floors that exclude native vegetation. Easily controlled mechanically or in combination with chemicals.
Sericea, Korean or Chinese Lespedeza , <i>Lespedeza cuneata</i> - Herbaceous weed which invades fields, meadows, marshes, pond borders, open woodlands and roadsides statewide. Difficult to control, this plant can hamper forestation efforts by crowding and shading young trees, thus requiring additional chemical site preparation.
Wisteria, Chinese , <i>Wisteria sinensis</i> and Japanese , <i>Wisteria floribunda</i> - Found statewide, vines impair and overtake native shrubs and trees through strangling or shading. Both species are hardy and aggressive, capable of forming dense thickets where little else grows. Can be controlled with a variety of mechanical and

years. The categorization of threats described in this section as “locally significant” does not diminish the need to monitor and control outbreaks and spread.

Imminent Forest Health Threats

Background

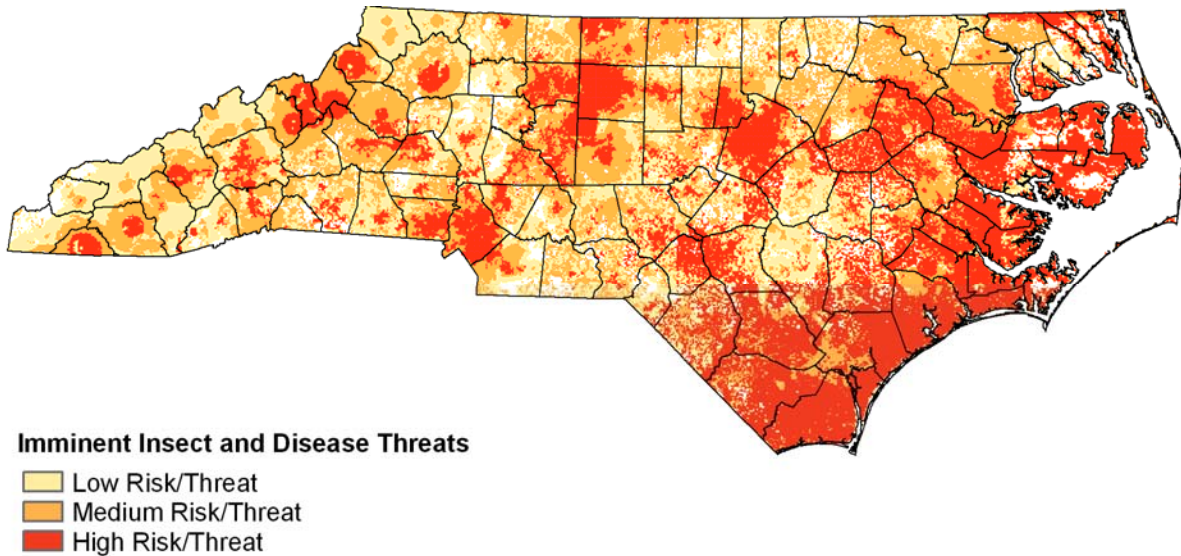
Imminent forest health threats are threats not yet in North Carolina, but these pests and NNI plants are in adjacent states or have the capability to move large distances, either naturally or artificially. Such species have the potential to invade North Carolina within

the next few years. Short descriptions of each of these threats follow.

An imminent insect and disease threat map (FIGURE 3a-4) was developed in much the same way as the major insect and disease map. The layers included in the analysis were the FHTET emerald ash borer risk map, the FHTET sirex woodwasp risk map, the FHTET Asian longhorned beetle risk map, and a redbay ambrosia beetle–laurel wilt risk map developed by Koch and Smith (2008). The three layers created by FHTET all address invasive pests that are likely to be introduced into North Carolina via

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FIGURE 3a-4. Imminent forest health threats map; includes emerald ash borer, Asian longhorned beetle, redbay ambrosia beetle, and sirex woodwasp.



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firewood and thus show the highest risks in urban and suburban areas and transportation corridors. The redbay ambrosia beetle–laurel wilt hazard map was derived from forest inventory data, current rate of spread, and climate data to predict where the insect and pathogen would make the largest impact in North Carolina. This map shows areas determined to be low, medium, or high risk based on geographical analysis and is not necessarily based on a specific time frame.

Imminent Forest Pathogen Threats

Sudden Oak Death (SOD), *Phytophthora ramorum*, is mostly confined to the West Coast of the United States. Sudden oak death is a recently discovered disease caused by a fungus-like microorganism. While the destruction from this disease is far away, the pathogen causing ramorum leaf blight and sudden oak death was first introduced into North Carolina in 2004 in plant nursery shipments from California. Affected plants were quickly eradicated.

The host list for this disease is broad, continues to expand, and includes a good number of forest and landscape trees species

found throughout North Carolina, including native oaks. While *P. ramorum* can kill oaks, it does not usually kill susceptible nonoak hosts. Instead, depending on the plant, it may cause symptoms such as leaf spots, defoliation, twig and branch dieback, or blighting. Yet, nonoak hosts (most notably rhododendron and mountain laurel) can spread inoculum (spores) and subsequently infect and kill susceptible oaks.

Forests in all areas of the state may be vulnerable to this disease, but suitable hosts and cool moist weather conditions make forests in the mountains and foothills especially at risk. Because the most likely introduction of *P. ramorum* into the state would be through movement of infected ornamental plants, trees in urban forests could be susceptible sites for early infections.

Eradication is easiest to achieve in nursery settings where regulatory controls have reduced the risk of spread into the state. The NCDA&CS Plant Industry Division inspects plant nurseries on a regular basis and puts a high priority on detecting and eradicating

any new introductions on nursery stock. In addition, the NCDFR conducts annual surveys of areas outside of suspected nurseries to detect the presence of any pathogen that may have escaped into the environment. These annual surveys are conducted as a part of a cooperative national project coordinated and funded by the USDA Forest Service Forest Health Protection Program. To date, surveys in North Carolina have not detected the presence of the pathogen outside of nurseries receiving infected plants. If detected in the forest environment, control is extremely difficult.

Imminent Forest Insect Threats

Emerald ash borer (EAB), *Agrilus planipennis*, is a tiny wood-boring insect that most likely arrived in the United States around the Great Lakes area in solid wood packing material from Asia. This borer has killed millions of ash trees in Michigan, Ohio, Illinois, Indiana, Pennsylvania, West Virginia, Maryland, Missouri, Wisconsin, Minnesota, Kentucky, and Ontario and Quebec, Canada, through July 2009. Massive eradication efforts where it has been detected involve removal of affected trees and healthy tree buffers, with varying degrees of success. Quarantines on the movement of non-heat-treated wood materials, including firewood, have been placed around areas of known infestations.

All North Carolina species of ash (*Fraxinus* spp.) are susceptible to attack by this insect. Though ash is a minor component of forests statewide, green ash is a common riparian tree in the piedmont and on the largest coastal plain rivers. Rapid mortality of green ash could have significant water quality implications. In addition, green ash is a popular street tree, and its loss is a major concern to urban dwellers and professionals alike. Surveys so far have not detected the presence of the EAB in North Carolina.

Currently, there is no reliable control method to stop the local spread of this insect.

Asian longhorn beetle (ALB), *Anoplophora glabripennis*, entered the United States inside solid wood packing material from China. The Asian longhorn beetle was discovered in 1996 in New York, with recent urban outbreaks in Illinois, New Jersey, and Massachusetts, and Toronto, Canada. Massive eradication efforts remove affected trees and healthy tree buffers, with varying degrees of success. Quarantines on the movement of non-heat-treated wood materials, including firewood, have been placed around areas of known infestations.

The beetle prefers maples (*Acer* spp.), buckeyes (*Aesculus* spp.), elms (*Ulmus* spp.), birches (*Betula* spp.), and willows (*Salix* spp.), but will also attack a variety of other hardwood species. Introduction of this pest in North Carolina could lead to a major change in forest species composition. Host species are found throughout the state, especially along riparian corridors, wetland areas, and mountain cove sites that are rich in plant species and diversity. Surveys so far have not detected the presence of the ALB in North Carolina.

Sirex woodwasp, *Sirex noctilio*, is native to Europe, Asia, and northern Africa, but now has been introduced onto every continent. Introduced into the United States, most likely on solid wood packing material, *S. noctilio* was first detected in New York and has since been detected in Pennsylvania and Ontario, Canada. In North Carolina, it has the potential to attack and kill even healthy southern yellow and white pine species. Sirex woodwasps have caused up to 80 percent tree mortality in yellow pine plantations in the Southern Hemisphere where outbreaks were detected (Haugen and Hoebeke, 2005). North Carolina's timber industry, especially in the piedmont and

a. Insects, Diseases, and Non-native Invasive Plants

coastal plain, could also be at risk or severely impacted by any potential losses inflicted by the discovery or presence of sirex woodwasp. Efforts to control the spread of sirex woodwasp include surveys, trapping, biocontrol research, and quarantines. The NCDA&CS has enacted an external quarantine regulating the movement of unprocessed pine materials into the state. Surveys, to date, have not detected the presence of the sirex woodwasp in North Carolina.

Imminent Insect-and-disease Complex Threat

Redbay ambrosia beetle (RAB), *Xyleborus glabratus*, and **laurel wilt**, caused by the fungus *Raffaelea lauricola*, together constitute an insect-and-disease threat. The redbay ambrosia beetle serves as an insect vector for the fungus causing laurel wilt, a destructive disease of redbay (*Persea borbonia*) and other trees in the laurel family, including swampbay (*Persea palustris*), sassafras (*Sassafras albidum*), spicebush (*Lindera* spp.), and pondspice (*Litsea aestivalis*). *Lindera melissifolia* is a federally listed endangered plant, and *Litsea aestivalis* is listed as a threatened plant in multiple states.

The non-native redbay ambrosia beetle was first detected in Georgia in 2002; the associated pathogen, a highly virulent, invasive, wilt-inducing fungus, is believed to have arrived in the United States along with the beetle. Investigators believe that RAB was introduced into the United States in wooden crating material from Southeast Asia. Both RAB and laurel wilt have been observed as far north as Myrtle Beach, South Carolina. Mortality has been documented to spread about 20 miles per year on average. Neither threat has been detected in North Carolina, but its arrival in North Carolina is imminent within the next few years.

Redbay and swampbay are prominent species in North Carolina's coastal plain. In addition, pondspice and spicebush are found in the coastal plain and sassafras is found throughout the state. Laurel wilt has the potential to extirpate (cause local extinction) of any of these species in the Lauraceae family from much of the coastal plain. As the insect and pathogen go through an area, all affected plants eventually wilt and die. Dead foliage persisting on plants in areas with high densities of bay species will create fire hazards due to dead, dry aerial fuels. Because redbay trees resemble young live oaks, they are popular choices for retention during development in urban areas along the coast.

Various species of wildlife would also be impacted by the reduction or elimination of laurel wilt host species. Songbirds, bobwhite quail, and turkeys often feed on the fruit, while deer and bears frequently feed on foliage and fruits of redbay and sassafras. Several rare species of swallowtail butterflies rely heavily on redbay, sassafras, and spicebush for completion of their life cycle. At this time, no reliable controls exist for either the *Raffaelea lauricola* fungus or the *Xyleborus glabratus* insect vector.

Imminent Weed Threats

Cogongrass, *Imperata cylindrical*, is a 2- to 4-foot-tall perennial Southeast Asian grass infamously ranked as one of the 10 worst weeds of the world (Holm et al., 1977). Cogongrass is currently found in Alabama, Florida, Georgia, Mississippi, South Carolina, and Tennessee. The grass is headed toward North Carolina, mainly from the south.

Disturbed roadsides, forests, and open fields can be invaded and overtaken by cogon grass. It forms dense thatch and leaf mats that make it virtually impossible for other plants to compete or coexist. In addition,

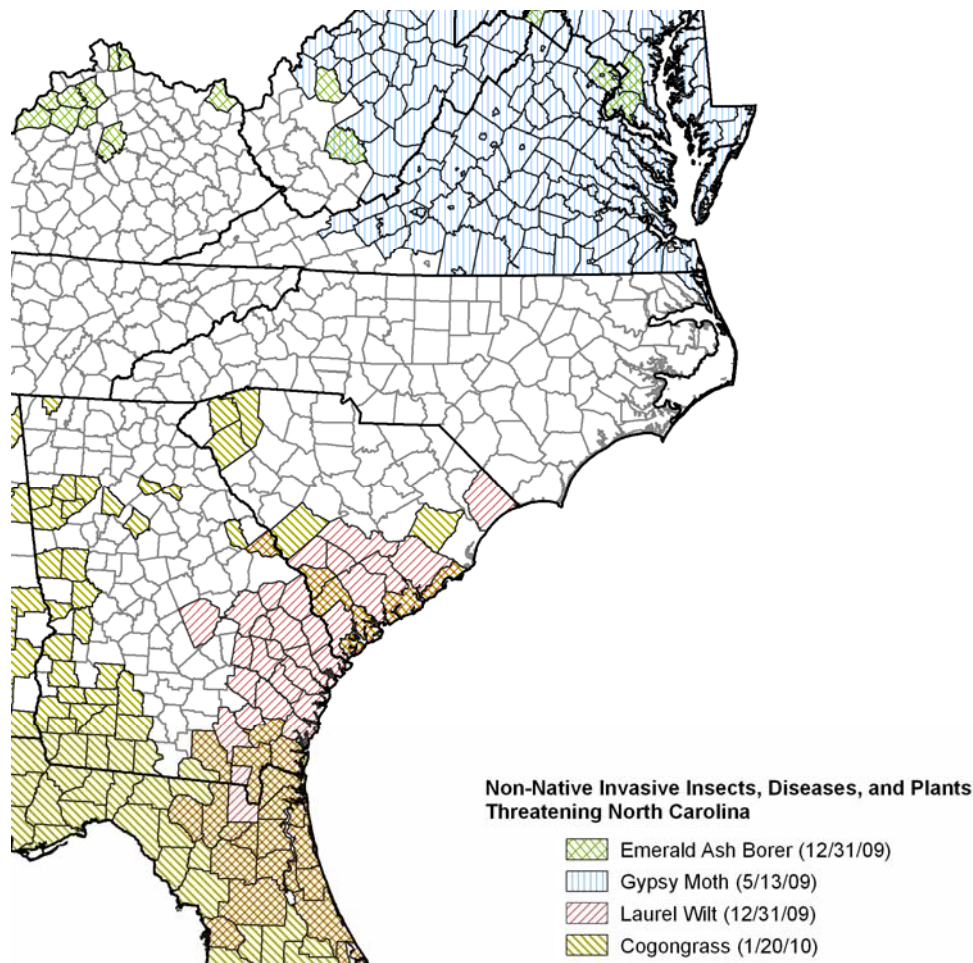
cogongrass is cold hardy and tolerates shade, high soil salinity, and drought. It has even been found growing on sand dunes and up to the edges of ponds and lakes. Large infestations of cogon grass can alter the normal fire regime of a fire-driven ecosystem by causing more frequent and intense fires that injure or destroy native plants. Cogongrass displaces a large variety of native plant species used by native animals as forage, host plants, and shelter.

Cogongrass is easiest to control when colonies are very small. Once established, it is nearly impossible to eradicate and very difficult to effectively control without persistent chemical and mechanical (tilling) practices.

Major Non-native Invasive Imminent Threats

Although all of the imminent threats described above have the potential to spread into the state, emerald ash borer, redbay ambrosia beetle–laurel wilt, and cogongrass have been detected in adjacent states and have the greatest potential to spread into North Carolina (FIGURE 3a-5). In addition, gypsy moth—described as a current threat due to its presence in Currituck and Dare counties—is considered an imminent threat to the remainder of the hardwood forest resources statewide.

FIGURE 3a-5. Major non-native invasive imminent threats.



Created by: J. Moan, NC DFR 2010

a. Insects, Diseases, and Non-native Invasive Plants

Additional threats to North Carolina’s forests that are not currently known to exist in the United States may also be looming. Though regulations are in place to intercept the movement of non-native invasive insects, pathogens, and plants at ports and borders, increases in global trade also increase the risk of these threats making their way into the country. On average, a new non-native invasive species arrives in the United States every 2 years. Each provides unique challenges to protecting threatened resources.

Forest Health Threats Related to the Movement of Firewood

Insects and diseases that are transported via commercial, residential, or recreational firewood affect many species of forest trees. Many damaging non-native invasive forest pests are directly traceable to interstate and intrastate movement of firewood (TABLE 3a-4). Natural movement of invasive pests may be limited to a few hundred feet or up to 20 miles per year. However, movement of pests in firewood can be 300 to 600 miles per day. A national campaign is underway to limit the movement of firewood due to the potential for transporting pests, primarily non-native invasive insects and diseases, from one geographic area to another.

A survey of firewood for sale in Virginia by the VA Department of Agriculture found that about two-thirds of the firewood came from outside state borders, including 13 states (western states among them) and three countries (Canada, Honduras, and Estonia) (Asaro, 2008). Even though North Carolina has not completed a similar survey similar results could be expected. Firewood that has not been heat treated (disinfected) and/or thoroughly inspected for pests has the potential to be a transportation vector for the pests in TABLE 3a-4.

TABLE 3a-4.—Forest threat organisms found in transported firewood

Present in North Carolina	
Insects	Disease Pathogens
Balsam woolly adelgid *	Beech bark disease
Gypsy moth	Butternut canker*
Hemlock woolly adelgid *	Dogwood anthracnose
Pine bark adelgid *	Oak wilt *
Not Present in North Carolina, but can be introduced	
Insects	Diseases/Pathogens
Asian longhorn beetle	Laurel wilt
Emerald ash borer	
Redbay ambrosia beetle	
Sirex woodwasp *	

* Movement of this pest in firewood is not likely but possible.

Source: NC Forest Health Working Group, 2009

Resource Capability and Availability

Native and naturalized insects and diseases have long been monitored on state and private lands in North Carolina by the NCDNR. On federal lands, the USDA Forest Service, the federal agency owning the property, or both, monitors these pests. Though research, monitoring, management methods, information and educational materials, and extension and outreach capabilities continue to evolve, these pests have been around for long enough that knowledge and standard procedures are generally in place to deal with them. Resource capabilities at the local and NCDNR Pest Control Branch level are usually adequate to handle normal threats except during certain epidemics, when additional resources are requested of other state and federal partners.

Recent and imminent invasions by aggressive non-native species provide other unique challenges to protecting the health and vitality of North Carolina’s forests. Many new pests entering the country require

extensive research into biology, host preferences, host responses, monitoring techniques, and safe management methods because they are often not considered pests, or are easily overlooked, in their native countries. In addition, NNI plants are increasingly being recognized as threats to forest diversity, wildlife habitat, and forest establishment and management.

No single agency or organization alone can handle these new and diverse threats to the health of North Carolina's forests. It will take a concerted and collaborative effort by many natural resource agencies and organizations in the state to address these threats and their potential impacts. Few state and private resources specialize in forest entomology and pathology in North Carolina. For weedy plant species, some individuals in state agencies, nongovernmental organizations, and private companies specialize in identification and/or

control of NNI plants. However, most who deal with invasive plant issues as related to forestry usually concentrate in other areas of forestry or agriculture, and invasive plant issues are collateral duties. Adequate training for natural resource professionals and information for landowners will need to be an ongoing priority.

Summary

Many insects, diseases, and NNI plants have been identified as significant forest health threats to North Carolina's forests. The identification of current and imminent threat exposure offers an opportunity to prioritize risks and responses as these threats materialize. Appropriate strategies to combat these present threats are generally adequate, but multi-partner strategies to deal with complex issues concerning non-native invasive pests and plants are clearly needed.

Map Data Sources

FIGURE 3a-1: USDA Forest Service - Forest Health Technology Enterprise Team, Southern Forest Land Assessment

FIGURE 3a-2: USDA Forest Service - Forest Health Technology Enterprise Team

FIGURE 3a-3: USDA Animal & Plant Health Inspection Service

FIGURE 3a-4: USDA Forest Service - Forest Health Technology Enterprise Team (FHTET), Koch and Smith 2008

FIGURE 3a-5: USDA Forest Service - Forest Health Monitoring and FHTET

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- Haugen, D. A. and E. R. Hoebeke. 2005. Sirex woodwasp—*Sirex noctilio* F. (Hymenoptera: Siricidae). NA-PR-07-05. Washington, DC: USDA Forest Service.
- Holm, L. G.; Plucknett, D. L.; Pancho, J. V.; and Herberger, J. P. 1977. *The World's Worst Weeds: Distribution and Biology*. Honolulu, HI: University Press of Hawaii.

a. Insects, Diseases, and Non-native Invasive Plants

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

Glossary

current forest health threats. Insects, diseases, and non-native invasive weeds currently found in North Carolina that threaten trees and forest ecosystems. Insects and diseases may be native or non-native.

extirpate. To cause extinction in a localized area.

imminent forest health threats. Forest health threats that are not currently found in North Carolina but are in adjacent states or have the capability to invade North Carolina within the next few years.

locally significant forest health threats. Current forest health threats that can cause significant damage and impact diversity in local areas. These pests may be confined to a small geographic area, spread more slowly, or pose little ability to spread into unaffected areas.

major forest health threats. Current forest health threats that can cause significant ecological and economic damage to North Carolina's forest resources.

non-native invasive pest Insects or diseases that are not indigenous to North Carolina and when introduced aggressively infest or infect forest trees and plants.

non-native invasive plant. Plants that are not indigenous to North Carolina and when introduced aggressively outcompete or otherwise impact native vegetation.

3.b.

Fire and Fire Exclusion in North Carolina's Forests

Key Findings

- Fire exclusion contributes to the decline or loss of fire-dependent ecosystems and species, and creates fuel conditions that produce destructive wildfires.
- Population increases in North Carolina's wildland-urban interface areas create significant challenges for firefighters and residents.
- Firefighting capacity to rapidly and effectively control wildfires has decreased over the past decade across North Carolina.
- The public lacks awareness of wildfire hazards and “Firewise” concepts.
- Smoke-sensitive areas occur in much of North Carolina. These areas and air quality regulations restrict controlled burning and necessitate coordinated planning at state, regional, and national levels.

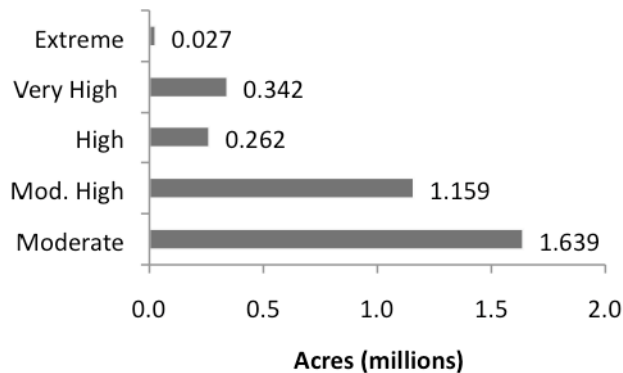
Introduction

North Carolina has more than 3.4 million acres at moderate to extreme risk of wildfire (FIGURE 3b-1). Protecting citizens, communities, forest resources, and other natural resources from the negative effects

of wildfires occurring on the lands of North Carolina is crucial.

Over the past 10 years, North Carolina has experienced an average of 5,500 fires a year that have burned an average of 38,200 acres annually. Wildfires occur throughout the state and are not limited to one geographical

FIGURE 3b-1. North Carolina acreage at moderate to extreme risk of wildfire by risk level.



Source: Southern Wildfire Risk Assessment, 2008

3. Threats to Forest Health

area (FIGURE 3b-2). It is crucial that cooperating and assisting agencies form partnerships to (1) identify and mitigate the hazards, risks, and effects from wildfire; (2) educate the public to ensure their safety and emergency responder safety; and (3) continue protecting and enhancing our forest resources. Current and projected issues that fire service agencies and cooperators face relating to wildland fire can be addressed via four focus areas: forest health, population demographics and growth, the wildland-urban interface, and resource capability and availability.

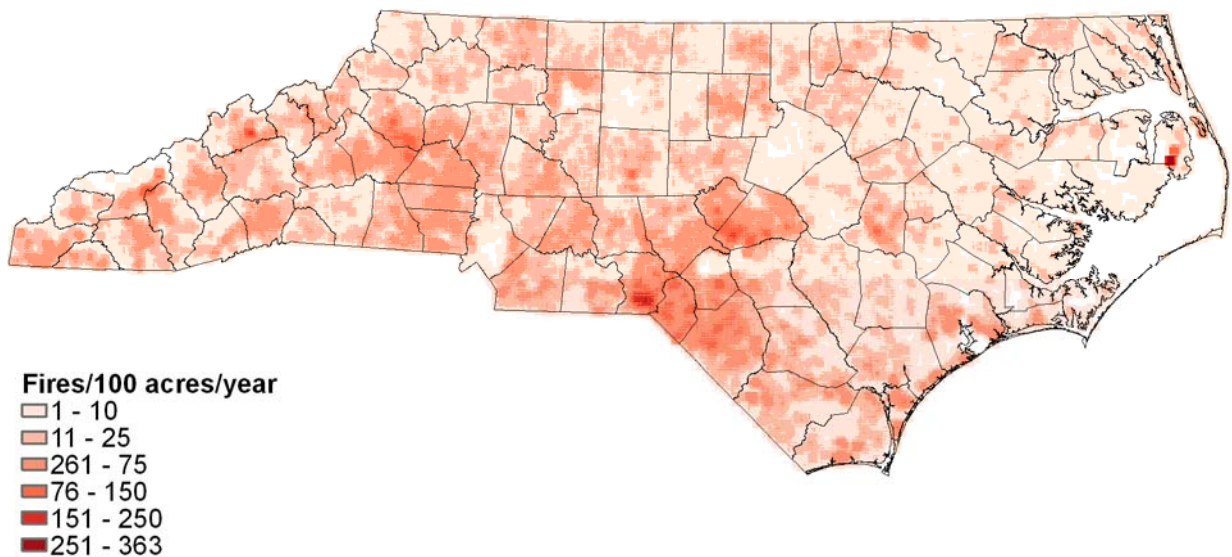
Forest Health

Increased fuel loading in North Carolina forests has greatly influenced the intensity and size of fires. Lack of controlled burning is a primary cause of this increased fuel loading. Pest insects and diseases, natural disasters, and invasive species also have increased fuel loads.

Historically, many of North Carolina's forests burned on a regular basis (FIGURE 3b-3). Fuels and vegetation responded accordingly with lower fuel loadings and flashier, quicker burning fuels that resulted in lower intensity wildfires.

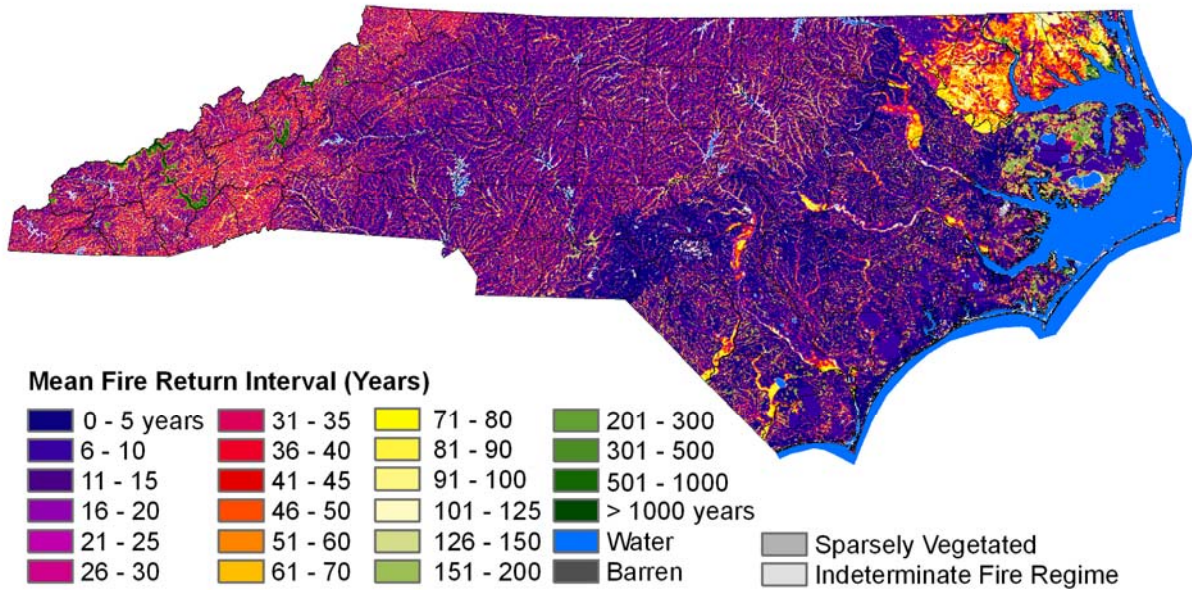
Fire contributes to the diversity of plant communities supporting fire-dependent and fire-adapted ecosystems in North Carolina. Over the last two decades, increased population and the corresponding infrastructure have produced smoke-sensitive areas across much of the state (FIGURE 3b-4). These smoke-sensitive areas make burning difficult or impractical where forestland would often benefit the most from a controlled burn. In addition, North Carolina's prescribed fire and smoke management programs must comply with new federal Clean Air Act requirements that include regional haze regulations, revisions to the National Ambient Air Quality Standards (NAAQS) for particulate matter and ozone, and the Exceptional Event Rule.

FIGURE 3b-2. Fire occurrences in North Carolina, 2000 – 2008.



Created by: J. Shedd, NCSU, & A. Bailey, NCDFR, 2010

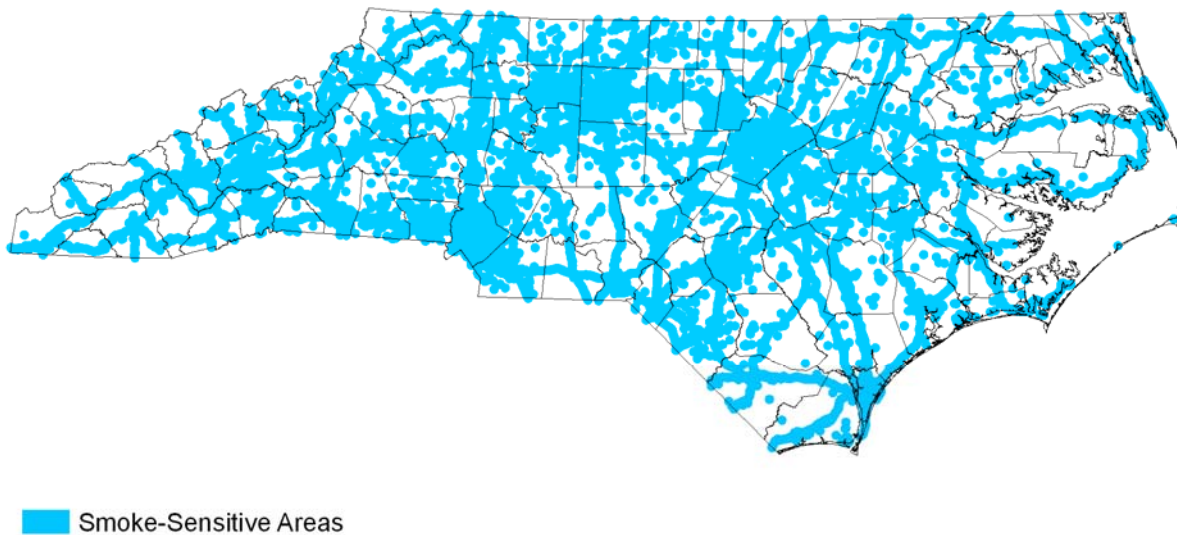
FIGURE 3b-3. Presumed mean interval (years) between fire return in NC under a presumed historical regime.



***Northeastern NC data subject to change.**

Created by: J. Shedd, NCSU, & A. Bailey, NCDFR, 2010

FIGURE 3b-4. Smoke-sensitive areas in North Carolina, 2009.



Created by: J. Rogers & A. Bailey, NCDFR, 2010

3. Threats to Forest Health

Smoke management is a high priority in fire planning and implementation. It will take working cooperatively with our strategic partners to address smoke management and facilitate the planned increased burning for all native fire-adapted ecosystems while complying with state and federal air quality laws. An average of 104,354 acres of controlled burning has been accomplished annually over the past 10 years, with the majority being performed on government-owned land or military reservations.

Forest insects or disease outbreaks have frequently affected fuel loading and fire behavior and will continue to do so. Fire intensity in damaged areas is elevated due to continual accumulation of dead fuels in all fuel size classes. Specific pests of significance from a fire control perspective are discussed in Chapter 3.a., “Insects, Diseases, and Non-native Plants.”

Natural disasters, including hurricanes and ice storms, occur regularly in North Carolina. In affected areas, fire behavior and safety issues arise. Damage usually occurs over large areas, and the sudden increase in fuel loading significantly influences fire behavior and affects accessibility. The increased fire intensity and limited accessibility for equipment and personnel often require a change in tactics to a more indirect attack, which leads to larger fire acreage.

The spread and introduction of invasive plant species that burn rapidly and propagate fire has become an issue in certain areas. This trend is expected to increase. Fuel characteristics of invasive species of concern include volatile foliage and species that produce high volumes of fine fuels. Species of concern from a fire control perspective are discussed in detail in Chapter 3.a.

Population Demographics and Growth

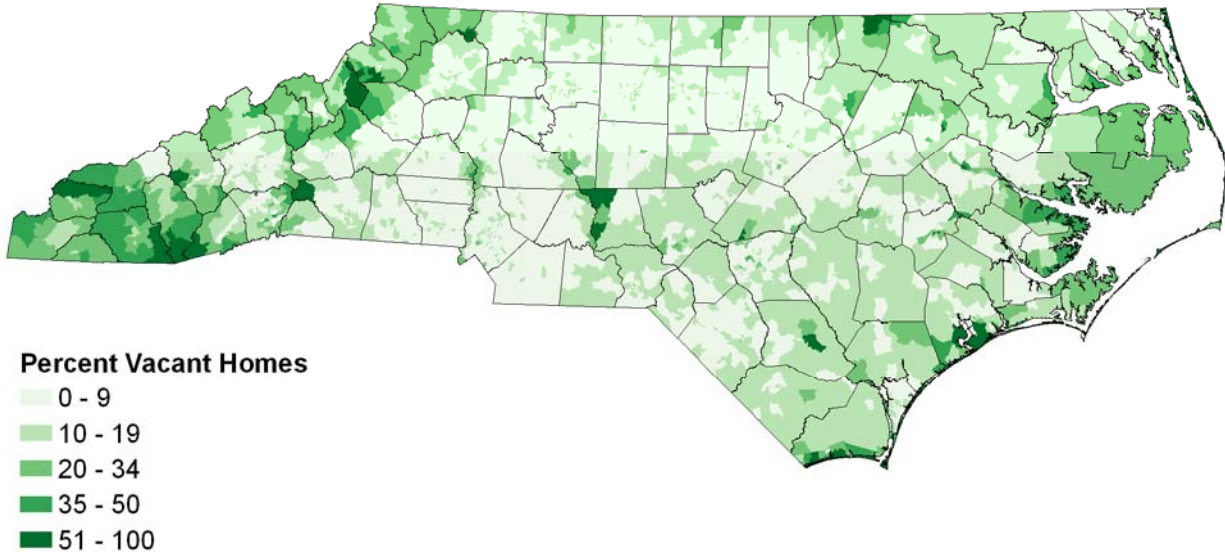
As North Carolina continues to transition from a rural and agricultural state to an urban and suburban one, people’s perception of fire and their expectations of fire services have changed. Many people moving to forested areas are coming from metropolitan areas or states where forestland is not as fire-dependent and fire is not as frequent.

Historically, North Carolina’s rural population understood the role of fire and its importance in wooded areas. Many residents who are new to living in forested areas are not aware of the benefits that prescribed fire has on an ecosystem. This lack of ecosystem and fire familiarity may also lead to a lack of awareness about wildfire hazards that threaten their homes and property. Many residents living in the wildland-urban interface (WUI) expect that the local fire service will be able to respond to a wildland fire threatening their property with engines and other resources. In reality, most subdivisions in the WUI contain more structures than local fire departments can protect.

North Carolina’s population increased by 14.6 percent from 2000 to 2008; it is expected to increase another 16 percent by 2020 (U.S. Census Bureau, 2005). Fire records indicate that humans cause over 85 percent of the state’s fires. As population increases, so will the number of structures located in the WUI and human interactions with forestland.

In addition to the increase in permanent residences, the number of vacation or secondary homes has also increased statewide. These homes are predominantly located in the mountains; along the coast; and around lakes, reservoirs, and rivers (FIGURE 3b-5). Without full-time residents,

FIGURE 3b-5. Percentage of NC homes vacant in 2000.



Created by: A. Bailey, NCDFR, 2010

many secondary or vacation homes have yards or exteriors that are not maintained regularly, which causes fuel buildup on and around the structures. As more residences are built, subdividing increases, turning large pine plantations and large blocks of forestland into subdivisions or minifarms. Often these developments are sited in forestland with minimal vegetation being removed for home construction to maintain a concealed, secluded, natural setting. This practice may create aesthetically pleasing developments, but it also places residents and property in areas of high fire danger.

Wildland-Urban Interface (WUI)

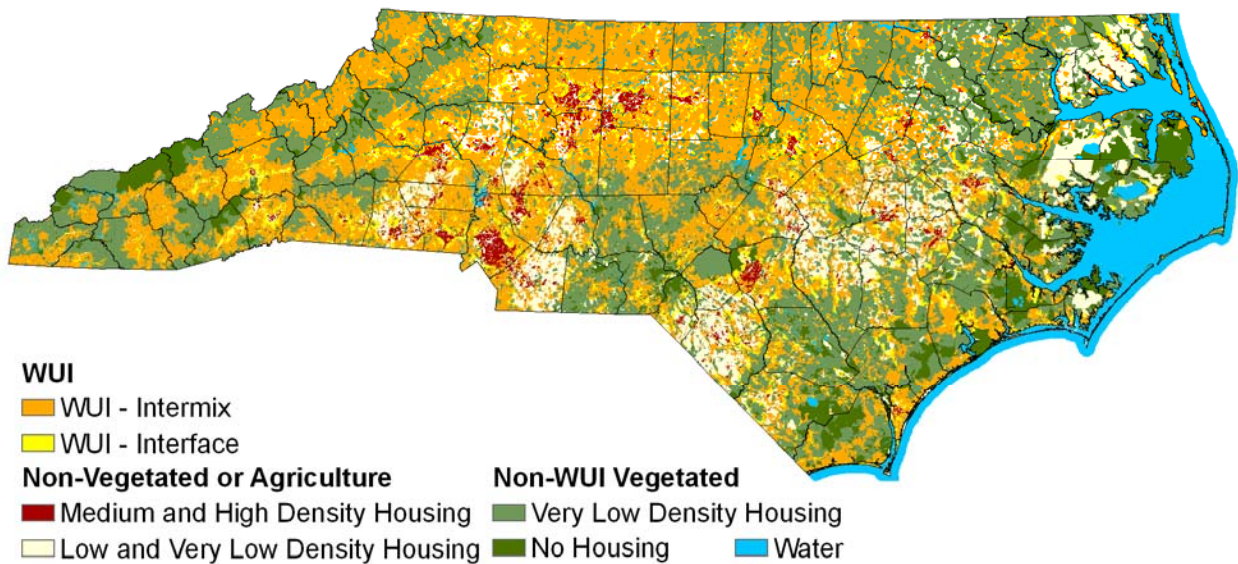
As the population increases, more structures are being built in historically forested areas. A University of Wisconsin study in 2005 found that North Carolina had more than 5.5 million acres in the WUI (FIGURE 3b-6).

In 1998, 32 percent of all wildland fires occurring in North Carolina threatened residences. By 2008, that number had increased to 42 percent. During the drought year of 2007, 29 homes and 265 structures were destroyed by wildfire in the state.

Many new homes are constructed without any community wildfire planning (FIGURE 3b-7). This has created neighborhoods with limited accessibility plus flammable building construction and flammable landscaping with no defensible space incorporated. Currently, state building code and most county building codes and ordinances do not include Firewise practices and principles (as defined by Firewise Communities/USA). Lack of Firewise planning greatly increases the probability that if a wildland fire occurs in the community, more homes will be threatened and emergency response personnel will be at greater risk. In addition, the number of

3. Threats to Forest Health

FIGURE 3b-6. Wildland-urban interface areas in North Carolina based on vegetation and housing density, 2000.



Created by: A. Bailey, NCDFR, 2010

communities with homeowner rules or covenants, codes, and restrictions has increased. Some stipulations are so restrictive that fuel mitigation projects on homeowners' property cannot be accomplished.

On-the-ground designation and recognition of the communities at risk is accomplished through the creation of Community Wildfire Protection Plans (CWPPs). North Carolina has implemented the CWPP process at the fire department district level. This level of implementation allows for data collection at the local level; provides an excellent tool for use by the local fire departments, fire managers, and emergency management officials; and captures the needs and details specific to a portion of a county. The communities at risk, which are determined and identified during the CWPP process, then become target communities for implementing the practices and principles of the Firewise Communities/USA program. As of January 1, 2010, 236 CWPPs are in

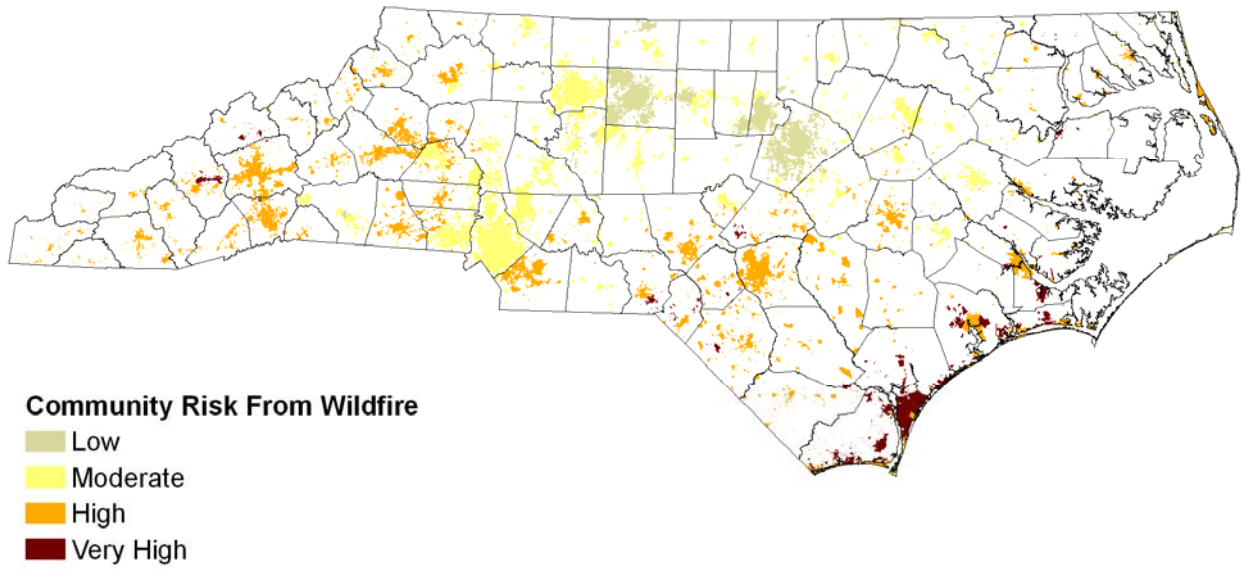
various stages of completion statewide (FIGURE 3b-8). Completion of approximately 1,350 CWPPs to include all fire departments is projected by 2014.

Resource Capability and Availability

No single agency or organization alone can handle the wildland fire situation in North Carolina. It takes a concerted effort by all agencies to safely deal with wildland fire and its impact. Through reduction in workforces and retirements, wildland fire agencies have less firefighting experience than in years past. The many collateral duties of current employees also make it difficult for employees to attain the needed level of fireline qualifications.

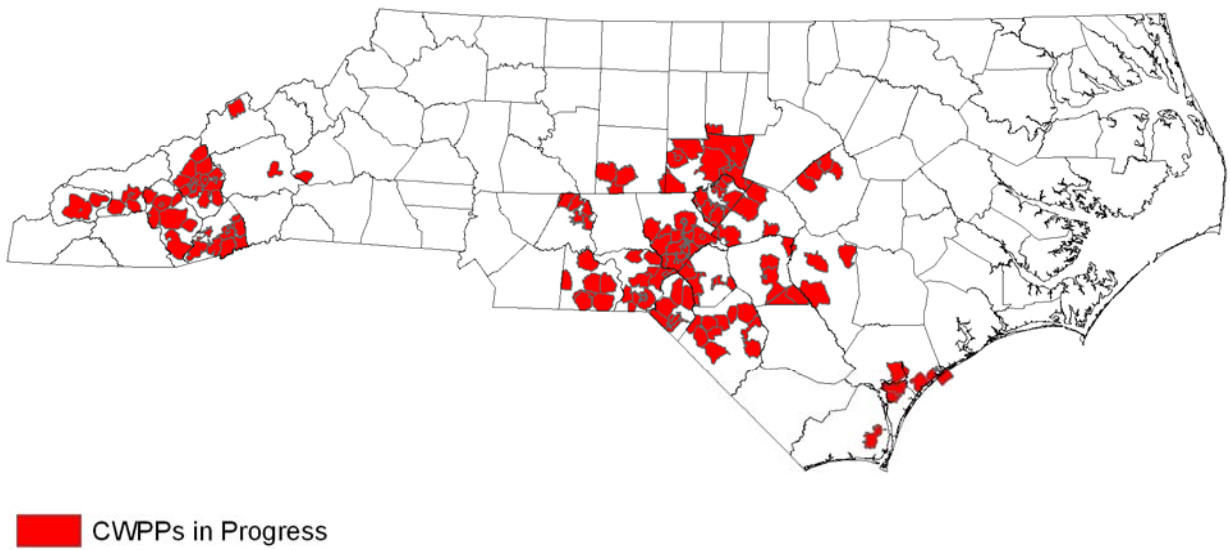
The first responders to the majority of wildland fires in North Carolina are community fire departments. These local departments rely on approximately 50,000 volunteer and paid firemen in the state, and

FIGURE 3b-7. NC communities at risk of wildfire, 2009.



Created by: J. Shedd, NCSU, & A. Bailey, NCDFR, 2010

FIGURE 3b-8. North Carolina CWPPs, 2009.



Created by: J. Rogers & A. Bailey, NCDFR, 2010

3. Threats to Forest Health

records indicate that only 20 to 30 percent have received any wildland fire training in the last 10 years. Due to limited funding, many fire departments are unable to purchase wildland personal protective equipment for all their members.

Another substantial reduction in wildland firefighting resources occurred as the timber industry companies went out of business or reorganized. Since 1985, 85 industry tractor-plow units with qualified operators have been lost, which is nearly half the number of tractor-plows that were available for wildfire response in the state before 1985. In addition to handling initial fires on their properties, timber companies also conducted thousands

of acres of prescribed burning to protect their woodlands.

Summary

As North Carolina's population increases and home construction continues in the WUI, wildfire risk threatens not only forest habitats but the public as well. The increased fuel loading in forests and lack of controlled burning in fire-dependent ecosystems has added to the threat. It will take a unified effort by all wildland fire organizations to educate the public, address smoke issues, conduct fuel mitigation projects, and protect North Carolina citizens and forest resources from wildfire.

Map Data Sources

FIGURE 3b-2: NC Division of Forest Resources, USDA National Forest Service, USDI National Park Service, USDI Fish and Wildlife Service, USDI Bureau of Indian Affairs

FIGURE 3b-3: Wildland Fire Leadership Council: Landfire

FIGURE 3b-4: NC OneMap, NC Department of Transportation

FIGURE 3b-5: US Census Bureau

FIGURE 3b-6: Radeloff et al. 2005

FIGURE 3b-7: Southern Wildfire Risk Assessment

FIGURE 3b8: NC Division of Forest Resources

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Southern Wildfire Risk Assessment. 2008. Southern Fire Risk Assessment System. ArcGIS software application. Colorado Springs, CO: The Sanborn Map Co. Inc. Online: <http://www.southernwildfirerisk.com/sfras/aboutsfras.html>

U. S. Census Bureau. 2005. *Interim State Population Projections*. Washington, DC: U. S. Census Bureau, Population Division.

Glossary

controlled burn. The use of fire under specific environmental conditions to achieve forest management objectives. Used to reduce hazardous fuel levels, control unwanted vegetation, favor desired vegetation, and improve visibility and wildlife habitat.

Firewise. An approach that emphasizes (1) community responsibility for wildfire planning via the design of a safe community; (2) effective emergency response; and (3) individual responsibility for safer home construction and design, landscaping, and maintenance,

smoke-sensitive area. An area in which smoke from outside sources is intolerable. North Carolina's smoke-sensitive areas are calculated as a 2-mile buffer surrounding medical facilities, major roads, schools, and universities.

wildfire. A rapidly spreading fire, often occurring in wildland areas, that is out of control.

wildland-urban interface. The area where people's homes and structures meet the natural environment of forests and wildlands.

3.c.

Climate, Atmosphere, and Natural Disasters

Key Findings

- Though not fully understood, climate change and atmospheric conditions may differentially impact North Carolina forests' composition and resilience.
- Natural disaster events will continue to threaten the health and productivity of North Carolina's forests. Forest and tree damage offer challenges and opportunities for forest management, forest use, and public safety.
- Sea level is predicted to rise by 1 to 2 feet or more by 2100, increasing the salinity of estuaries, coastal wetlands, and tidal rivers. This will likely alter coastal ecosystems and displace them farther inland.

Climate Change Concerns

Forested lands cover more than 50 percent of North Carolina and help clean and naturally regulate freshwater supply. North Carolina's climate is warm and wet, with mild winters and high humidity. The average annual temperature in the Southeast did not change significantly over the past century (NC Climate Office).

Since the 1970s, there has been a clear warming trend in North Carolina, however, local climate variability is so high in the state that significant trends are difficult to deduce at this point. (State Climate Office of North Carolina, 2010a). Local climate variability is high in the state, making it difficult to deduce significant trends. The number of freezing days has declined by four to seven days per year for most of the Southeast region since the mid-1970s. Average autumn precipitation has increased by 30 percent for the region since 1901. Heavy downpours have increased in many parts of the region, while the percentage of the region experiencing moderate to severe drought increased over the past three

decades. The area of moderate to severe spring and summer drought has increased by 12 percent and 14 percent, respectively, since the mid-1970s. Even in the fall months, when precipitation tends to increase in most of the region, the extent of drought increased by 9 percent.

Climate models project continued warming in all seasons across the Southeast and an increase in the rate of warming through the end of this century. The projected rates of warming are more than double those experienced in the Southeast since 1975, with the greatest temperature increases projected to occur in the summer months. The number of very hot days is projected to rise at a greater rate than the average temperature. Under a lower emissions scenario, average temperatures in the region are projected to rise by about 4.5°F by the 2080s, while a higher emissions scenario yields about 9°F of average warming (with higher summer temperatures and higher heat indexes) by the 2080s. Rainfall from individual hurricanes will increase, but results for future precipitation for the Southeast are variable.

The frequency, duration, and intensity of droughts are likely to increase. Changes in precipitation patterns, longer growing seasons, and late freeze vulnerability will alter forests in unpredictable ways.

Increased Hurricane Intensity

The destructive potential of Atlantic hurricanes has increased since 1970, correlated with an increase in sea surface temperature. An increase in average summer wave heights along the U.S. Atlantic coastline since 1975 has been attributed to a progressive increase in hurricane power. The intensity of Atlantic hurricanes is likely to increase during this century, with higher peak wind speeds, rainfall intensity, and storm surge height and strength. Even with no increase in hurricane intensity, coastal inundation and shoreline retreat would increase as sea-level rise accelerates, which is one of the most certain and most costly consequences of a warming climate.

An increase in hurricane intensity will further affect low-lying coastal ecosystems and coastal communities along the South Atlantic coastal margin; these communities are already quite vulnerable. An increase in intensity is very likely to increase inland and coastal flooding, coastal erosion rates, wind damage to coastal forests, and wetland loss. (Karl et al., 2009)

Major hurricanes pose a severe risk to people, personal property, and public infrastructure in our state; and these risks are likely to be exacerbated. Hurricanes make their greatest impact at the coastal margin where they make landfall, causing storm surge, severe beach erosion, inland flooding, and wind-related casualties for both cultural and natural resources (Karl et al., 2009). Major hurricanes, such as Fran and Hugo, damaged rural forests inland and significantly harmed urban forests in the

densely populated areas of Raleigh and Charlotte.

Heat-related Stress

The warming projected for the Southeast during the next 50 to 100 years will create heat-related stress for people, agricultural crops, livestock, trees, transportation and other infrastructure, fish, and wildlife. Maximum and minimum temperature increases will impact natural systems more than the projected average temperature change (Karl et al., 2009).

Examples of potential impacts on forest ecosystems include decline in forest growth due to the combined effects of thermal stress and declining soil moisture, as well as decline in dissolved oxygen in streams, lakes, and shallow aquatic habitats, leading to fish kills and loss of aquatic species diversity. Other effects of the projected increases in temperature include more frequent outbreaks of shellfish-borne diseases in coastal waters, altered distribution of native plants and animals, local loss of many threatened and endangered species, displacement of native species by invasive species, and more frequent and intense wildfires (Karl et al., 2009). Such catastrophic fires put communities at risk, can be devastating even to fire-adapted species such as longleaf pines, and can deplete soil nutrients if topsoil layers are actually burned. In 2007, drought-related fires burnt about 600,000 acres in Georgia and Florida, the largest fires in the history of either state (National Interagency Fire Center, 2007).

Decreased water availability due to increased temperature and lack of rainfall events, coupled with an increase in societal demand, will likely affect many sectors of North Carolina's economy. Climate change will also alter the amount and timing of

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water available to natural systems (Karl et al., 2009).

During droughts, recharge of groundwater will decline as the temperature and spacing between rainfall events increase. Increased groundwater pumping will further stress or deplete aquifers, placing increased strain on surface water resources. Increasing evaporation and plant water-loss rates alter the balance of runoff and groundwater recharge, which is likely to lead to saltwater intrusion into shallow aquifers in many parts of the Southeast (Karl et al., 2009).

Sea-level rise

An increase in average sea level of one to two feet or more by 2100 (FIGURE 3C-1) and the likelihood of increased hurricane intensity and associated storm surge (Karl et al., 2009) are likely to be among the most costly consequences of climate change for North Carolina. As sea level rises, coastal shorelines will retreat (FIGURE 3C-2). Wetlands will be inundated and eroded away, and low-lying areas, including some communities, will be flooded more frequently—some permanently—by the advancing sea. Catastrophic damage to existing buildings and infrastructure is expected, as these structures were not designed to withstand the intensity of the projected storm surge.

As temperatures increase and rainfall patterns change, soil moisture and runoff to the coast are likely to be more variable. The salinity of estuaries, coastal wetlands, and tidal rivers is likely to increase in North Carolina's coastal plain, thereby altering coastal ecosystems and displacing them farther inland, especially where no barriers exist. More frequent storm surge flooding and permanent inundation of coastal ecosystems and communities is likely in low-lying areas, particularly along the Outer Banks and Pamlico-Albemarle Peninsula

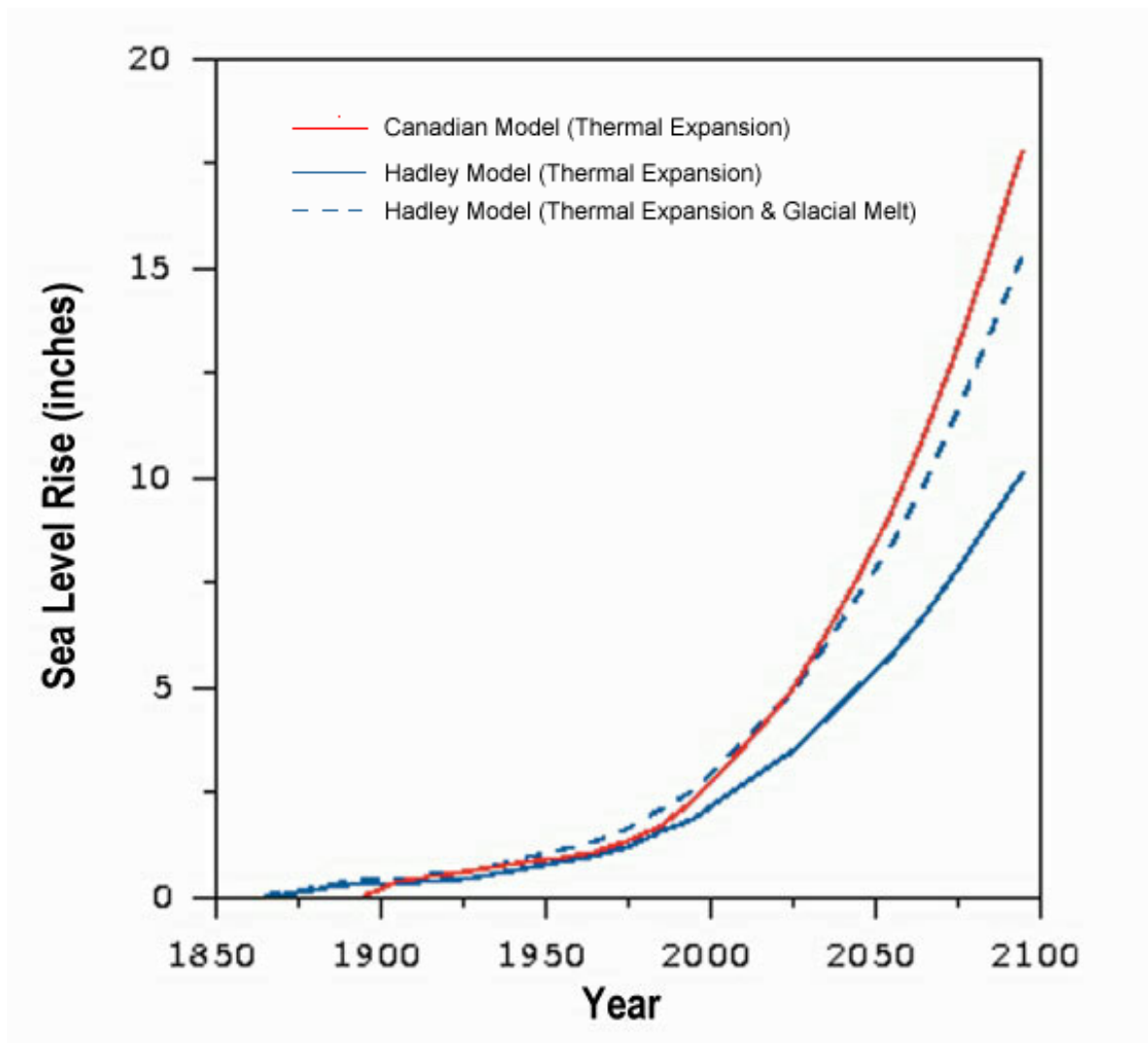
where the land surface is sinking. Rapid acceleration in the rate of increase in sea-level rise could threaten a large portion of the coastal zone. The likelihood of a catastrophic increase in the rate of sea-level rise is dependent upon ice sheet response to warming, currently the subject of much scientific uncertainty. Such rapid rise in sea level is likely to result in the destruction of barrier islands and wetlands (Corbett et al., 2008).

Ecological Tipping Points

Ecological systems provide important services that have high economic and cultural value in the Southeast. Ecological effects cascade among living and physical systems, yet few are aware of the impacts to ecological systems until their livelihood or life style is affected. Below are examples of ecological disturbances that result in abrupt responses to warming, as opposed to gradual and proportional responses (Karl et al., 2009):

- The sudden loss of coastal landforms that serve as a storm surge barrier for natural resources and coastal communities (such as in a major hurricane).
- Saltwater intrusion into coastal forests and freshwater aquifers once sea level reaches a critical elevation.
- Intense wildfires in southeastern forests once lower soil moisture and higher temperatures reach critical levels.
- Intense droughts leading to the drying of lakes, ponds, and wetlands and the local or global extinction of riparian and aquatic species.
- A precipitous decline of wetland-dependent coastal fish and shellfish populations due to the rapid loss of coastal marsh.

FIGURE 3c-1. Historic and projected changes in sea level based on the Canadian and Hadley model simulations.



Source: U.S. Global Change Research Program, National Assessment Team, 2000

Note: The Canadian model projection includes only the effects of thermal expansion of warming ocean waters. The Hadley projection includes both thermal expansion and the additional sea-level rise projected due to melting of land-based glaciers. Neither model includes consideration of possible sea-level changes due to polar ice melting or accumulation of snow on Greenland and Antarctica.

Other abrupt impacts from climate change may include increased activity by damaging forest tree insects, pathogens, and non-native plant species.

Direct Effects on Trees and Forests

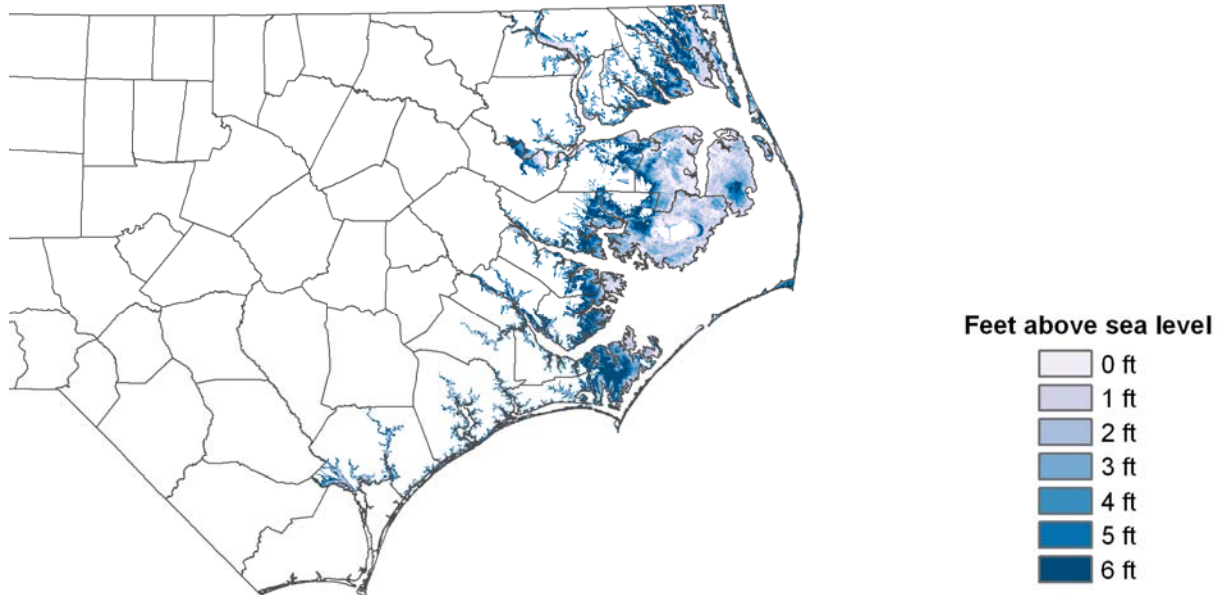
Except in areas directly affected by sea-level change, much needs to be learned about the direct impacts of climate change on individual tree species and populations. Affects depend on not only climate change

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variables, but also species tolerance to current and future conditions. Further research assessment needs to be made on

species and populations occurrence, abundance, and genetics to prioritize those

FIGURE 3c-2. NC coastal areas within 6 feet of sea level.



Created by: M. Fields, The Nature Conservancy of NC, 2009

species and ecosystems at highest risk of negative impact and to develop long-term strategies to manage these impacts.

Atmospheric Deposition

High elevation forests, coastal forests, and wetlands can be impacted by atmospheric deposition (Sullivan 2000). High elevation forests continue to be impacted because sulfur deposition is greatest, the depth of the soils are shallow, and the soils are cooler and have lower microbial activity. The most sensitive sites are strongly influenced by the parent geology, which influences the amount of base cations (calcium, magnesium, and potassium) present to neutralize acid anions (sulfates and nitrates) deposited from the atmosphere (Snyder et al. 2004, Sullivan et al. 2002a, Sullivan et al. 2002b, and Sullivan et al. 2007). Deposition of nitrogen compounds can lead to eutrophication of certain ecosystems and cause competitive imbalances between vegetative species

(SAMAB 1996, and Sullivan 2000). Deposition of mercury in wetland ecosystems is a great concern when sulfur-loving bacteria can convert the mercury into biologically toxic forms (Sullivan 2000).

In severe cases of acidic deposition, the soil pH is lowered below 4.5 and aluminum is released, which can kill the fine roots. A reduction in the amount of fine roots is likely to reduce the amount of nutrient and water uptake by vegetation, and potentially increase susceptibility to disease and insect attack (Elliott et al. 2008, and Sullivan 2000). Decreases in the base cations supplies in the soil can also lead to aquatic impacts in sensitive watersheds by causing reductions in health and mortality of sensitive aquatic organisms, such as phytoplankton, zooplankton, aquatic insects, and fish species (Sullivan 2000, and Sullivan et al 2007). Too much nitrogen deposition can lead to an increase in the abundance of certain species that can adapt

to the increased availability of nitrogen. Mercury can accumulate to toxic levels in biological organisms as it moves through the food web (Sullivan 2000).

High elevation soils are typically derived from soil low in base cations, making atmospheric deposition a threat. Historical sulfur deposition (since the 1860s) has been accelerating the loss of base cations from soils. A delayed recovery from sulfur dioxide reductions will occur, partly because the soils have been retaining a portion of the sulfur deposited historically in sensitive ecosystems (Sullivan et al. 2007).

Air Quality

Fine particles (especially sulfates) reduce a person's enjoyment of scenic views. High levels of fine particulates and ground-level ozone may impact the health of terrestrial organisms, and ground-level ozone may cause a physiological response or biomass reductions in sensitive vegetation (SAMAB 1996). Ground-level ozone concentrations are greater at the high elevations (where the National Ambient Air Quality Standards have been exceeded) than valley sites in western North Carolina.

Natural Disasters

Background

Forests in North Carolina have been shaped by cyclical weather events. Tropical storms, hurricanes, winter storms, and droughts are most notable among these. Forests and forest trees adapt to wind, ice loading, and droughts or are replaced by species that can withstand these threats. These events influence natural forests to a large degree, but have a significant impact on urban forests where placement and maintenance of trees can affect personal safety, property, utility infrastructure, and transportation corridors during natural disasters.

Storm damaged forests create challenges related to forest management and wood use. After storms, massive volumes of valuable timber, some still marketable, may be damaged—uprooted, windthrown, or stems broken above the ground. Assessment and salvage may be difficult after the storm due to infrastructure damage, panic, and flooded wood markets. Rehabilitating the forest and returning it to a productive state may also be difficult because of the sheer mass of damaged timber.

Forests damaged by wind also create extreme fire hazards. Down and dead trees increase fire fuel loading, create hazards, and cause forest access problems for firefighters. In addition to forest trees, damage to and loss of urban trees causes immeasurable losses, injuries, and deaths. Falling limbs and trees can cause injury and loss of life, property damage, disruption of utility services, and road blockages. Trees weakened by storm damage and drought may be vulnerable to infestation or infection by opportunistic insects and diseases, demonstrated contributors to overall forest fire risk.

Tropical Storms and Hurricanes

North Carolina has a long and notorious history of destructive hurricanes (FIGURE 3C-3 and TABLE 3C-1). The coast of North Carolina can expect to receive a tropical storm or a hurricane once every 4 years. The state's protruding coastline makes it vulnerable to tropical cyclones that curve northward in the western Atlantic Ocean. Cape Fear and Cape Lookout are also favored areas for tropical cyclones to make landfall. Between 1886 and 1996, North Carolina experienced 28 direct landfalls from tropical cyclones, while a total of 82 tropical cyclones passed through the state (State Climate Office of North Carolina, 2010b).

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The most widespread type of wind damage to forests in North Carolina is caused by tropical storms and hurricanes; additional wind damage can be caused by tornadoes, downbursts, and severe thunderstorms. Trees normally can withstand prevailing wind conditions. Extreme wind conditions (force and duration) from unusual directions or accompanied by soaking rains can directly result in windthrow or damage. Damage may take the form of stem, branch, or root failure (breakage), wood shaking, crown twist, and direct mechanical damage from flying debris.

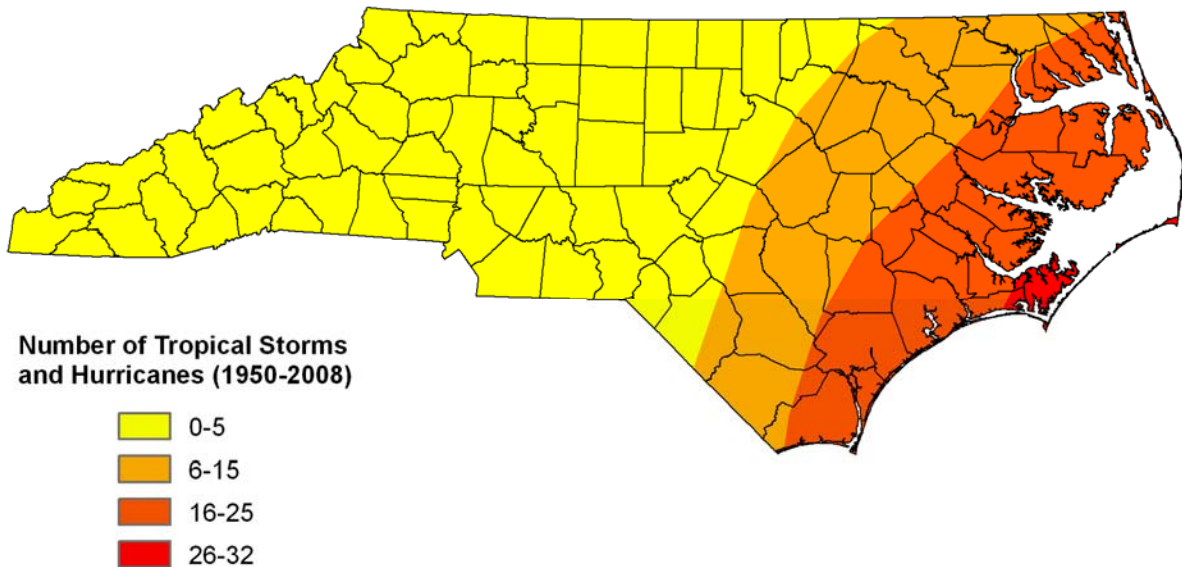
Ice Storms

Winter weather (snow, sleet, and freezing rain) occurs with the greatest frequency in

the northern latitudes and higher altitudes (the Appalachian Mountains). However, such weather regularly affects the southeastern United States as far south as Georgia during each cold season.

Perhaps the most destructive form of precipitation is freezing rain (or ice loading). Freezing rain accumulation on trees and power lines can cause them to snap, resulting in power outages and damage to homes, automobiles, and ecosystems. The fact that each frozen precipitation type occurs with some regularity throughout the Southeast is due mainly to the topography of

FIGURE 3c-3. Tropical storms and hurricanes, 1950 – 2008. A storm was counted if its eye passed within 50 miles.



Created by: A. Bailey, NCDFR, 2010

TABLE 3c-1.—Acres damaged and value lost when timber was damaged by three recent major hurricanes

Hurricane Name, Year	Acres Damaged	Estimated Value of Losses
Isabel, 2003	833,192 acres of timber sustained some level of damage in the Northern Coastal Plain	Timber damage valued over \$565 million
Fran, 1996	Damaged or destroyed 8.25 million acres of forest in 58 counties	Exceeded \$1 billion
Hugo, 1989 (Hugo made landfall in South Carolina.)	More than 2.7 million acres of forests in twenty-six counties mainly in the Piedmont	Over \$250 million

Source: NC forest damage appraisals of hurricanes (Doggett, 1989, 1996; Trickett, 2003)

the region as well as its geography. Continental polar air masses from Canada typically supply the cold air necessary for snow, while cold, dry air from New England entering the region can become entrained against the east slopes of the Appalachian Mountains, forming a dome (or wedge) of near-surface cold air. The moisture necessary for precipitation is brought up from the Gulf of Mexico, where the thermal contrast between the cold land surface and the relatively warmer gulf waters provides a favorable environment for storm development and intensification. In these situations, if a cold dome is already in place east of the mountains, the warm frontal boundary and moisture associated with the developing storm may migrate northward over the cold dome, setting the stage for a mixed precipitation (freezing or frozen) event (State Climate Office of North Carolina, 2010c).

Ice storms are frequent in North Carolina, with the piedmont experiencing a freezing rain event once every 2 years (FIGURE 3c-4

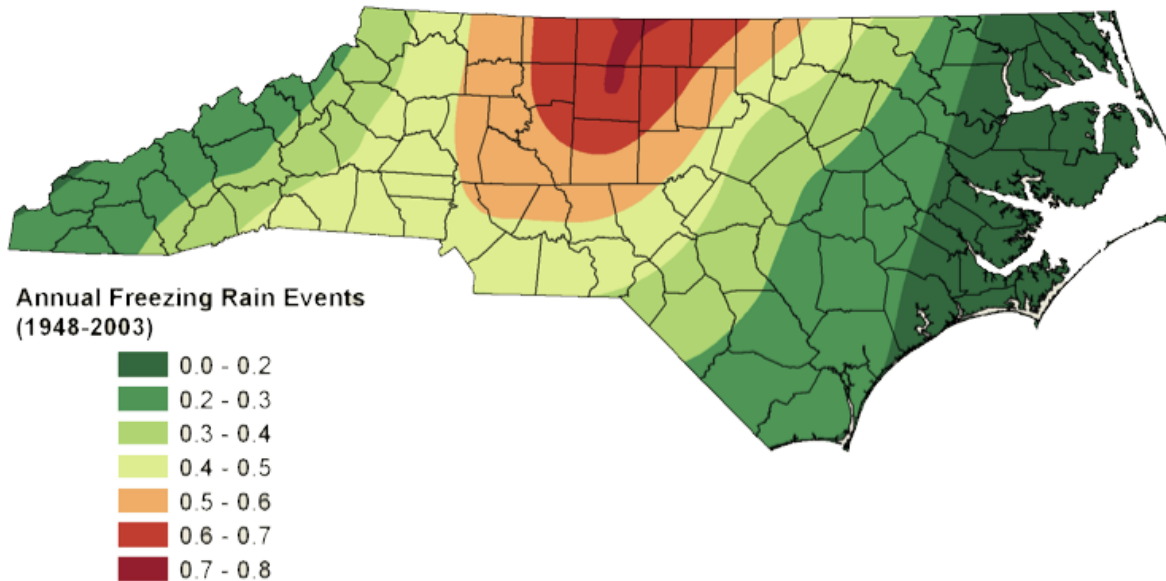
and TABLE 3c-2). Ice damage to trees can be caused by episodes of freezing rain and to some degree by heavy, wet snowstorms. Heavy ice accumulation can cause trees to carry extreme loads. In addition, wet soil conditions and wind can magnify the effects of heavy loading, resulting in branch and stem failure (breakage), crown twisting, uprooting and bent stems. Most species of trees may be affected by ice, though some species are more tolerant than others. (Shortleaf is more tolerant of ice than loblolly pine.)

Drought

North Carolina experiences periodic drought episodes that put a great deal of stress on forest and landscape trees. Drought is defined by the State Climate Office of North Carolina as a deficit in normal precipitation for a region over a period of time sufficient to cause impacts. Dry weather alone does not constitute a drought; impacts define a drought. Drought from the forest impact

c. Climate, Atmosphere, and Natural Disasters

FIGURE 3c-4. Annual freezing rain event frequency, 1948 – 2003.



Created by: A. Bailey, NCDFR, 2010

TABLE 3c-2. Acres damaged and value lost during three recent major winter storms

Year	Acres Sustaining Some Level of Timber Damage	Estimated Value of Timber Damaged
Winter, 2000	578,000 acres in the Sandhills and southern piedmont.	> \$264 million
Winter, 2002	2,008,805 acres in the northern coastal plain and piedmont, and parts of the mountains and Sandhills.	> \$481 million
Winter, 2004	249,704 acres in the southern coastal plain.	> \$97 million

Source: NC forest damage appraisals of winter storms—(Trickel, 2000, 2002, 2004)

perspective is often realized in the form of fire danger and moisture stress to trees.

Continued thermal stress and declining soil moisture will cause a decline in tree growth.

Lower soil moisture and higher temperatures may lead to the failure of newly established seedlings, intense wildfires, or pest outbreaks (such as the southern pine beetle) in southeastern forests. Intense droughts may cause the drying of lakes, ponds, and wetlands, and the local or global extinction of riparian and aquatic species.

Drought may kill weak trees outright, but more frequently drought predisposes trees to pests because of lower food reserves, poorer response to pest attack, and poorer adjustment to pest damage. Recent droughts have led to increases in *Ips* spp. and black turpentine bark beetles, oak decline, procerum root rot, and other insect and disease activity. In addition, some pines and wetland hardwoods died directly because of drought stress. Although it is still too early to determine if the recent drought will lead

to increased southern pine beetle activity, previous droughts were thought to have contributed to southern pine beetle outbreaks. “Unhealthy trees are more prone to drought—drought creates unhealthy trees” (Coder, 1999). Trees in urban landscapes are especially susceptible to stress from dry conditions. Often, dry compacted soils make acquiring sufficient moisture difficult; and the heat created and trapped in urban areas by automobiles, asphalt, and concrete creates a higher demand for water by urban trees.

Summary

Climate change, atmospheric change and pollution, and natural disasters have real and

potential effects on forest and natural ecosystems. The most immediate impact of climate change is realized in rises in sea level. As sea levels continue to rise, coastal forests will be displaced as shorelines retreat. Impacts of temperature change to North Carolina’s forests are less apparent and in need of further research. Atmospheric deposition and air quality also have impacts on both forest health and enjoyment of our forests. Ice- and wind-storms cause millions of dollars worth of damage to North Carolina’s forests. Some climate models suggest that these storms may become more frequent, more intense, or both in the future.

Map Data Sources

FIGURE 3c-2: US Global Change Research Program 2000

FIGURE 3c-3: NOAA Coastal Services Center

FIGURE 3c-4: Fuhrmann and Konrad II 2010

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Glossary

atmospheric deposition. Occurs when pollutants are transferred from the air to the earth's surface.

cation. An ion or group of ions having a positive charge and characteristically moving toward the negative electrode in electrolysis.

3. Threats to Forest Health

eutrophication. An increase in the concentration of chemical nutrients in an ecosystem to an extent that increases the primary productivity of the ecosystem.

tropical cyclone. An intense low-pressure system typically associated with high winds, flooding due to storm surge, and intense rainfall, and thunderstorms. Tropical cyclones are broken into three categories based on sustained wind speeds: tropical depression, tropical storm, and hurricane.