6. Insects and Disease

Goals: Part 219 of the National Forest System Land and Resource Management Planning regulations (36 CFR section 219.12) requires monitoring of forest health to determine whether destructive insect and disease organisms increase following various vegetation management treatments. Forest health conditions are monitored, and areas that have experienced an increase in damage are documented.

Objectives: Identify areas where destructive insect and disease organisms increase or there are changes in forest health following management. Evaluate the results and modify vegetation management practices if insects and disease agents increase to populations at which they cause significant damage.

Background: A key premise of ecosystem management is that native species have evolved with natural disturbance events. Management activities can cause changes to stand structure and composition that impact insect and pathogen population dynamics, and can also affect host tree conditions. Climate change or acute weather events can alter natural disturbances; stimulate changes in insect and pathogen populations, damage levels, or distributions; and influence the vigor or susceptibility of trees and understory plants. Yellow-cedar decline (described below) represents a situation in which the vulnerability of a tree species is revealed by a modest change in climate, particularly warmer winters and reduced snowpack. Along with wind, avalanche, and other disturbance agents, insects and pathogens are important factors in the health of the Tongass National Forest.

The native spruce beetle is the most destructive forest insect in Alaska, killing mature spruce on hundreds of thousands of acres. In Southeast Alaska, notable outbreaks have occurred on Kosciusko Island and in Glacier Bay National Park. Traditionally, outbreaks in Southeast Alaska are usually small in size because beetle development is limited by cool, wet weather. Disturbance events that create an abundance of host material, such as windthrow or improper slash management, coupled with the right climatic conditions can lead to a spruce beetle outbreak. Windthrow and improper slash management can lead to spruce beetle outbreak under some conditions.

Unlike much of North America, few non-native insects and pathogens have become established in Southeast Alaska. The non-native green alder sawfly, which defoliates alder, has been found in Sitka, Juneau, and Ketchikan (confirmed 2013); however, its impact is thought to be minimal because it is in competition with native insect species that also feed on alder. The spruce needle aphid is a European species that feeds on Sitka spruce needles. Aphid populations have been gradually migrating north and outbreaks are correlated with mild winters.

Most insect and disease activity is considered a natural part of our forest ecosystems, contributing to compositional and structural diversity and wildlife habitat. Management intervention to prevent or control insects and pathogens are not usually implemented in Southeast Alaska, but silvicultural practices can be used to fine-tune their impacts. Non-native species are monitored because, if established, they have the potential to cause significant tree mortality. The early detection and rapid response program has been in place since 2001 and the main focus is to detect non-native insect introductions using insect traps near ports and other potential points of entry. Asian gypsy moth egg masses have been detected on vessels approaching Southeast Alaskan port communities in 2008, 2012, and 2014. Preventing establishment of this highly destructive insect is critical in maintaining the health of the forests in Alaska.

Insects and Disease Question: *Are destructive insect and disease organisms increasing to potentially damaging levels following management activities?*

The Forest Service's State and Private Forestry, Forest Health Protection staff conducts annual aerial detection surveys of Southeast Alaska. The location of insect and disease activity is mapped and entered in a geographic information system (GIS) database. Forest health observations are also made through site visits, monitoring networks, and other fieldwork. In addition, Forest Inventory Analysis (FIA) plots are

used to assess the extent of some diseases (e.g., hemlock dwarf mistletoe) that can be consistently detected and documented by observers with minimal training. Ground observations and FIA plots are used because some agents cannot be detected from the air or by remote sensing. This information is summarized in annual Forest Health Conditions Reports (http://www.fs.usda.gov/detail/r10/forest-grasslandhealth/?cid=fsbdev2_038884).

With a lack of fire activity in Southeast Alaska, insects and pathogens are key disturbance agents, as are wind, landslides, and flooding. In general, clearcut harvests represent larger scale and more frequent disturbance events than would naturally take place in our forests. Overall, current management reduces damage from most insects and diseases by removing older trees, which are more susceptible to some insects (e.g., woodborers) and diseases (e.g., stem decays), or by altering tree species composition to manage the concentration of susceptible hosts. Even-aged vegetation management (clearcutting, seed tree or shelterwood regeneration methods) removes defective trees with stem decay or mistletoe. Timber harvest has created around 730,000 acres of young stands in Southeast Alaska, including approximately 440,000 acres on the Tongass NF. Disease and insect activity in old stands is important to a number of interconnected ecological processes, such as nutrient cycling, carbon storage, and creation of wildlife habitat in trees with stem decay. This is an important consideration for habitat restoration in young stands managed for diverse or non-timber objectives and older stands slated for harvest or other management activities.

Tait et al. (1985) found that insects and disease organisms were present in young-growth stands, but not at populations or intensities at which they caused significant damage (Table 1). *Sirococcus* shoot blight of hemlock, shoot blight of yellow-cedar (causal fungus identified as *Kabatina thuje*), hemlock canker (causal fungus tentatively identified as *Discocainia treleasei*), other foliar pathogens, and spittlebug on spruce (*Aphrophora* sp.) are additional insects and pathogens known to cause damage to conifer saplings in Southeast Alaska that were not detected in the 1985 study. Hemlock canker of western hemlock appears to be most common and severe in unthinned young-growth stands, suggesting that dense stand conditions can exacerbate this disease. More information is needed about the activity of insect and disease agents in thinned and unthinned older young-growth stands.

Management activities also have the potential to mitigate losses of yellow-cedar resulting from yellow-cedar decline root freezing injury. Knowledge of the two key risk factors for yellow-cedar decline, shallow soils and insufficient insulating snowpack, can provide the basis for management decisions to make yellow-cedar stands more resilient to the effects of climate change. Yellow-cedar can be favored through thinning or planted on sites that are expected to be suitable for long-term yellow-cedar survival, including high-elevations, northern portions of the current range, or assisted migration beyond the current range. Deer browsing pressure must be taken into account when selecting planting locations. Salvaging dead yellow-cedar on sites with abundant yellow-cedar snags, gentle slopes, and road access can help to offset yellow-cedar harvests elsewhere. Salvage sales have the potential to financially support restoration efforts. A draft restoration strategy for yellow-cedar is now complete and provides detailed information about current and future suitable habitat for yellow-cedar throughout its range in Alaska.

Insects and Disease Table 1. Pathogens and insects detected on Sitka spruce and western hemlock in the 1985 survey of 16, 12-27 year old thinned and unthinned stands in Southeast Alaska (Tait et al. 1985).

	Sitka spruce	Western hemlock	Spruce and hemlock
Pathogens	*Spruce needle cast/blight (Lophodermium picea)* *Spruce needle rust (Chrysomyxa ledicola)* *Cankers (Discocainia treleasii and Heliotium resinicola)* *Armillaria* in 36% of stumps *Annosus* in 2% of stumps	*Hemlock needle rust (Pucciniastrum vaccinia)* Hemlock dwarf mistletoe (*Arceuthobium tsugense)* *Armillaria* in 39% of stumps	Shoot blight (*Sirococcus strobilinus)*
Insects	Shoot moth (*Zeiraphera* sp.) Moth (*Dioryctrias* sp.) Green spruce aphid (*Elatobium abietinum)*	Bark beetles (*Pseudohylesinus tsugae)* Woolly aphid/adelgid(*Aldeges tsugae)*	Sawflies (*Neodiprion tsugae)* Geometrid moths (includes *Melanolophia imitate)* Blackheaded budworm (*Acleris gloverana)*

Note: Information on percentages of stumps with *Armillaria* and *Annosus* root diseases was only recorded in thinned stands.

Harvest and stand entry patterns impact the rate of wounding to residual trees. Wounds are infection courts for decay fungi, so higher rates of wounding translate to greater defect as stands age. The Forest Service is exploring alternatives to clearcutting, in which portions of stands, either single trees or groups of trees, are left as legacy (residual) trees (McClellan et al. 2000). Three research installations across the Tongass (Hanus Bay in the Sitka Ranger District, Portage Bay in the Petersburg Ranger District, and Lancaster Cove in the Craig Ranger District) were used to investigate whether changes to harvest patterns led to greater incidence of windthrow, damage from insects and diseases due to bole wounding of residual trees, or more severe dwarf mistletoe infestations. Logging injury to residual trees varied by both the intensity and spatial arrangement of harvest. A higher rate of residual tree injury was found with greater log removal. Stands with scattered tree harvest suffered higher rates of injury than those where tree removal was concentrated in patches. Wounding residual trees is expected to reduce timber values but provide wildlife habitat.

The Tongass-Wide Young-Growth Study (TWYGS) has installed treatments in young-growth stands (0-45 years old) to examine the effects of various silvicultural treatments on understory development and productivity. Treatments include: planting alder in clearcuts 0 to 5 years post-harvest; pre-commercial thinning in 15 to 25 year-old stands; pre-commercial thinning and pruning in 25 to 35 year-old stands; and pre-commercial thinning of 35 to 45 year-old stands by cutting or girdling, plus slash treatment. In 2008 and 2009, an insect and disease survey was conducted at sites on Prince of Wales that had been thinned by girdling from 2005 to 2006. Proposed benefits of girdling include reduced treatment cost and hazard, lower peak slash loads, and limited damage to residual trees compared to mechanical thinning and stacking treatments. There was some concern that snags might attract spruce bark beetles (*Dendroctonus rufipennis*) and facilitate the spread of *Armillaria* from dead trees to adjacent healthy trees. Although bark beetles and *Armillaria* were detected on a large proportion of girdled trees by 2009, they were not causing damage to retained trees. Girdled trees fell earlier than expected, probably due to wind and snow loads, and many retained green crowns for more than 1 year. It is thought that the cool summers of 2006, 2007 and 2008, combined with the persistent green crowns of snags, slowed the development of bark beetles and woodborers.

Monitoring Results

Pathogens and Yellow-Cedar Decline

The most important diseases and forest declines in late-seral hemlock-spruce forests on the Tongass NF are stem decays of live trees, hemlock dwarf mistletoe, and yellow-cedar decline. Dwarf mistletoe is present in some stands following partial harvest, but at lower density and severity than pre-harvest. Bole injury from pre-harvest silvicultural activities may increase decay rates in managed stands relative to unmanaged stands when they reach old age, as wounds act as entry points for decay pathogens.

There is now increased emphasis on young-growth stand management. The diseases of greatest importance in young stands detected through monitoring efforts include shoot blights of yellow-cedar and western hemlock, hemlock canker disease, and yellow-cedar decline. The severity of shoot diseases may be greater in young stands because of increased availability of susceptible shoot tissue and greater concentration of susceptible hosts. The cause of hemlock canker is under investigation, but dense stand conditions in unthinned young-growth appear to contribute to outbreaks of this disease. Yellow-cedar decline was documented for the first time in young-growth yellow-cedar on Zarembo Island in 2013.

Stem decays are caused by a number of fungal species in mature forests, and result in enormous annual wood volume loss of Alaska's major tree species (Table 2). Approximately one-third of the old-growth timber in Southeast Alaska is defective, largely due to decay from heart and butt rot fungi (Kimmey 1956, Farr et al. 1976). Conversely, there is very little decay in young-growth stands (Tait et al. 1985) unless there is prevalent wounding from commercial thinning activities, blowdown, or animal feeding. By predisposing large old trees to bole breakage, stem decays serve as important small-scale disturbance agents that create canopy gaps, influence stand structure and succession, increase biodiversity, cycle nutrients, and enhance wildlife habitat for many species. Decay fungi are classified as white rots, which degrade both cellulose and lignin, or brown rots, which primarily degrade cellulose. Wood impacted by brown rot may be more brittle and prone to breakage in high winds, and cannot be used for pulp production. White rots are particularly important for providing decay that leads to the development of cavities for wildlife in live hemlock trees.

Insects and Disease Table 2. Stem decay fungi of live conifer trees in Alaska with decay type, hosts, and common modes of infection. Includes the conifers: western hemlock (*Tsuga heterophylla*), mountain hemlock (*Tsuga mertensiana*), western redcedar (*Thuja plicata*), shore pine (*Pinus contorta* spp. *contorta*), and Sitka, Lutz, white, and black spruce (*Picea sitchensis, P. lutzii [glauca x sitchensis], P.glauca, P. mariana*).

Heart and Butt Rot Fungi[1]	Type of Rot/ Decay	Hosts in Alaska	Mode of Infection
Armillaria spp.	white	all conifers (& hardwoods)	vegetative spread (or spores) to stressed, dying, or dead trees
Ceriporiopsis rivulosa	white	western redcedar	likely through root-to-root contact & subsequent spread into butt
Coniophora spp.	brown	spruce, hemlock (occasionally hardwoods)	through wounds
Echinodontium tinctorium	brown	mountain hemlock, occasionally western hemlock)	through branch stubs or live branches
Fomitopsis pinicola	brown	spruce, hemlock, pine; sometimes redcedar & birch	through wounds

Fomitopsis officinalis	brown	spruce, hemlock	through wounds, broken tops
Ganoderma spp.	white	hemlock (& hardwoods)	through wounds, broken tops
Heterobasidion annosum	white	western hemlock, Sitka spruce	through wounds
Laetiporus sulphureus	brown	spruce, hemlock, shore pine (some hardwoods)	through wounds, basal scars
Onnia tomentosa	white	white/Lutz spruce (occasionally Sitka spruce & shore pine)	through root-to-root contact
Phaeolus schweinitzii	brown	spruce, pine, western redcedar, occasionally hemlock	through wounds, basal scars & disturbed roots
Phellinus hartigii	white	hemlock	through bole wounds, branch stubs, or cracks
Phellinus pini	white	hemlock, spruce, western redcedar, shore pine	through branch stubs or live branches
Phellinus weirii	white	western redcedar	likely through root-to-root contact & subsequent spread into butt

[1] Some root rot fungi are included because they are capable of causing both root and butt rot of conifers.

The incidence of decay is significantly related to tree age; with negligible volume losses to hemlock and spruce less than about 100 years of age (Kimmey 1956). Brown rots are the most important source of cull for Sitka spruce, while white rots are most important for western hemlock and western redcedar. For any given size class, redcedar was the most defective species, followed by western hemlock and Sitka spruce. It is believed that specialized decay fungi are able to overcome the decay resistance of live redcedar trees, even though cedar wood in service is highly decay-resistant. At 151 to 200 years old, defect is estimated to be 5 percent for Sitka spruce and 16 percent for hemlock (Farr et al. 1976). By 300 to 400 years of age, spruce is still relatively rot-free, whereas decay in hemlock averaged 30-40 percent on a board-foot basis (Farr et al. 1976). A project is underway to improve cull estimates for yellow-cedar and western redcedar and to determine what fungi contribute to decay.

Annosus/Heterobasidion Root Disease and Armillaria Root Disease

Annosus/Heterobasidion root disease and *Armillaria* root disease are the important root diseases of Southeast Alaska. Although root diseases play an important disturbance role in Alaska's forests, they do not create disease centers and cannot be mapped through aerial survey. *Heterobasidion annosum* causes root and butt rot in old-growth western hemlock and Sitka spruce forests in Alaska. In other regions and countries, cut stumps are frequently treated with fungicidal chemicals or biocontrol during harvest to prevent disease spread, but this is not necessary in Alaska as its incidence and severity is apparently unaffected by timber harvest or management activities. All tree species in Alaska are affected by one or more *Armillaria* species. The *Armillaria* species present in Alaska generally act as secondary pathogens, hastening the death of stressed trees. Tomentosus root disease, caused by *Onnia tomentosa* (*Inonotus tomentosus*), is common in spruce stands of south-central and interior Alaska. The disease was recently

documented on Sitka spruce near Skagway and Dyea, but not elsewhere in Southeast Alaska. The cedar form of *Phellinus weirii* is also present, causing butt rot in western redcedar. It is rarely lethal, but contributes to very high defect in Southeast Alaska. The type of *P. weirii* that causes laminated root rot in forests of British Columbia, Washington, and Oregon does not occur in Alaska.

Hemlock Dwarf Mistletoe

Hemlock dwarf mistletoe is an important disease of western hemlock throughout the Tongass National Forest, causing growth loss, top-kill, and mortality on a conservatively estimated one million acres. The occurrence of dwarf mistletoe is apparently limited by climate, becoming uncommon or absent above 500 feet in elevation and 59°N latitude (Haines, AK) despite the continued distribution of western hemlock from Cross Sound to Prince William Sound. Hemlock dwarf mistletoe brooms (prolific branching) provide wildlife habitat, and suppression or mortality of mistletoe-infected trees plays an important role in gap-creation and succession in coastal rainforest ecosystems. Clearcutting eliminates dwarf mistletoe from second-growth timber stands unless residual trees are infected. The incidence and severity of disease following partial harvest is related to the number, height, and infection severity of residual hemlocks and site productivity. Dwarf mistletoe seeds are able to disperse a greater distance from taller trees. The retention of infected codominant and dominant trees can cause significant infection of nearby trees in the developing young stand; in contrast, small infected trees (less than 8 inches dbh) have a short mistletoe spread distance, and height growth of trees in the young stand outpaces mistletoe spread. On productive sites, small infected residuals may outgrow mistletoe as they gain height and lose infected branches in the lower crown to shading. Managers are able to target some desirable amount of mistletoe in their stands for wildlife benefits without incurring significant growth losses by retaining small, lightly infected trees on moderately productive sites or through green tree retention adjacent to harvest units.

Shoot Blight

Damage from yellow-cedar shoot blight (*Kabatina thuje*) has been noted in regenerating young-growth stands. Hemlock shoot blight (*Sirococcus tsugae*) was more noticeable in 2014 than in recent years, affecting the new growth of western and mountain hemlock trees near Juneau, Yakutat, and other locations in Southeast Alaska.

Hemlock Canker

Hemlock canker has been in an outbreak on Prince of Wales Island since 2012 with greatest impacts between Thorne Bay and Coffman Cove and Staney Creek and Whale Pass. This disease kills young western hemlock trees and lower crowns of large trees, primarily in dense young stands along roads and creeks. An inoculation trial is underway near Thorne Bay and Staney Creek in collaboration with the University of Nebraska to determine the causal pathogen. We consider *Discocainia treleasei* the mostly likely pathogen; trees inoculated with this fungus will be evaluated in 2015. Widespread, synchronized mortality from this disease have been documented 1-2 times per decade on Prince of Wales, Kosciusko, Kuiu, and Chichagof islands. Disease symptoms include branch or small tree mortality (less than 14 inches dbh) accompanied by foliage discoloration and shed, bark lesions, and bleeding or resinous cankers. This disease may help dense stands to naturally thin, but long-term impacts on timber quality are unknown.

Damage from hemlock canker appears to be most severe in dense, even-aged stands; although this disease is not widespread and is only periodically in outbreak, stands that regenerate following clearcut harvest are thought to have increased incidence of hemlock canker compared to unmanaged stands.

Yellow-cedar Decline

Yellow-cedar decline is associated with freezing injury to fine roots that occurs where snowpack in early spring is insufficient to protect roots from late-season cold events. Yellow-cedar trees are protected where snow is present in spring to insulate tree roots or where better-drained soils allow cedar to root more

deeply. Impacted forests tend to have mixtures of old dead, recently dead, dying, and living cedars, indicating the progressive nature of tree death.

In 2014, aerial survey mapped active yellow-cedar decline (dying trees with red crown symptoms) on nearly 20,000 acres. Active decline was most dramatic in the northern panhandle near Slocum and Ford Arms and Klag Bay (Chichagof Island); it continued and increased on other parts of Chichagof, including Hoonah Sound and the area north of Deep Bay and Poison Cove along Peril Strait. Active decline was also scattered throughout Kupreanof, Kuiu, and Northern Prince of Wales islands, with more concentrated decline on the southwestern shore of Etolin Island and to the south near Carroll Inlet (Revillagigedo Island) and Twelvemile Arm (near Hollis on Prince of Wales Island). Cumulatively, about 585,000 acres of yellow-cedar decline have been mapped in Southeast Alaska though Aerial Detection Survey, with extensive mortality occurring in a wide band from western Chichagof and Baranof islands to the Ketchikan area. This cumulative estimate has been refined, but varies depending on the methods used.

Forest Health Protection evaluated dying yellow-cedar trees in portions of two young-growth stands on Zarembo Island (Wrangell Ranger District) in 2013. Affected trees showed signs and symptoms consistent with decline (necrotic root and root collar lesions, and *Armillaria* fungus and *Phloeosinus* beetles as secondary agents). Relatively low site productivity, wet site indicator plants in the understory, and evidence of yellow-cedar decline in adjacent, unmanaged forest suggest that shallow rooting in portions of these stands predisposes yellow-cedar to root-freezing injury. It is not known whether precommercial thinning in 2005 triggered or accelerated symptom development through its influence on snowpack. Forest Health Protection will continue to monitor these stands. This is the first time decline has been documented in a managed young-growth forests. Harvest increased in moderately productive old-growth in the 1990s; wetter portions of moderately productive young-growth stands with yellow-cedar may show decline symptoms in areas with limited late-winter snow.

Yellow-cedar snags accumulate on affected sites and forest composition is altered as yellow-cedar trees die. Yellow-cedar is extraordinarily decay resistant and snags often remain standing a century after tree death. Salvage recovery of dead standing yellow-cedar trees in declining forests can help produce valuable wood products and offset harvests in healthy yellow-cedar forests. A project was initiated this year with the Alaska Coastal Rainforest Center, Forest Service, State of Alaska, and University of Alaska Southeast to evaluate the economic feasibility of salvaging dead yellow-cedar. Study areas include Kupreanof and Mitkof islands. A spatial GIS aspect of the project estimates the acres of yellow-cedar decline that are available for salvage recovery by their proximity to roads, slope, and land use designation.

A draft Yellow-cedar Conservation Strategy is now complete and the final product should be available in 2015. This report was produced as a collaboration between the Pacific Northwest (PNW) Research Station, Region 10, and Forest Health Protection (S&PF). It provides a comprehensive resource on the ecology, silviculture and cultural values of yellow-cedar; describes the risk factors for decline; and uses the two primary risk factors (snow and hydrology) to model locations that are currently unsuitable/suitable for yellow-cedar and then projects this information into the future using General Circulation Models with conservative greenhouse gas emissions estimates. This resource should help managers to prioritize areas for active yellow-cedar management and to identify lands under protected status that can help to meet conservation goals for the species. Appropriate sites to plant and manage yellow-cedar include those with good soil drainage, those at higher elevation, and those in the northeastern portion of the panhandle or in the vicinity of Yakutat. Key management treatments include promoting yellow-cedar through planting and thinning in areas suitable for the long-term yellow-cedar survival in the context of climate change. Deer browse has the potential to negatively impact survival of planted seedlings, as was demonstrated in a recent progeny trial on Prince of Wales Island. On a regional scale, excessive yellow-cedar mortality may lead to diminished populations (but not extinction), especially considering this species' low rate of regeneration and recruitment in some areas.

Damage from Abiotic Factors and Animals

Hemlock fluting is characterized by deeply incised grooves and ridges that extend vertically along boles of western hemlock. Fluting may not be outwardly visible in old trees when fluting patterns have been engulfed within the stem. Affected logs yield less merchantable volume and bark is contained in some of the wood. The cause is not completely understood, but fluting is associated with increased wind-firmness, shallow soils, and may be triggered during growth release by some stand management treatments, disturbance, or genetic predisposition. The economic impacts of bole fluting on National Forest System timber harvest are probably less significant than in the past, since minimal harvest occurs within the 1000-foot beach buffer where fluted trees are most concentrated.

Porcupines represent one of the main biotic disturbance agents in the young-growth forests of Southeast Alaska. In 2014, nearly 1,815 acres of porcupine damage were mapped, up from the preceding four years. The most extensive damage was observed in young-growth stands on Kupreanof Island, with smaller pockets of damage observed near Excursion Inlet, the mouth of the Endicott River, south Mitkof Island, Etolin Island, and the southern Cleveland Peninsula. The variability in mapped acreage can result from differences in survey methods. Porcupine damage must be severe enough to girdle and kill trees to be visible from the air, and is therefore under-mapped during the aerial survey. Porcupines are absent from several islands in Southeast Alaska, including Admiralty, Baranof, Chichagof, and Prince of Wales. Feeding damage reduces timber values but enhances stand structure. This form of tree injury can provide a form of thinning in young forests; however, porcupines feed on groups of trees and usually “thin from above,” targeting the largest, fastest growing trees. Feeding can be locally concentrated in young growth stands that are about 10 to 30 years of age and on trees that are 4 to 10 inches in diameter. As stands age, porcupine feeding typically tapers off, but top-killed trees often survive with forked tops and internal wood decay as a legacy of earlier feeding. Porcupines feed only sparingly on western redcedar or yellow-cedar. Young stands with a cedar component provide more thinning treatment options. For example, where porcupines are problematic, managers can prescribe a lighter thinning treatment and favor tree species that are not as attractive to porcupines.

Less than 400 acres of windthrow were mapped statewide in 2014, with most affected areas less than 25 acres. In Southeast Alaska, the limited wind disturbance was most concentrated between Port Snettisham (Speel Arm) and Endicott Arm. Wind is a common and important small-scale disturbance in Alaskan forests, contributing to bole snap or complete failure of trees (or clumps of trees) with stem, butt or root decay or trees rooted on shallow, saturated soils. Stand-scale windthrow may occur on exposed sites when heavy rain is followed by extreme wind. Stand characteristics (tree height to diameter ratios and tree density) and tree mechanics (height, diameter, crown size and rooting depth) also impact windthrow potential. Topographic conditions and stand management activities influence windthrow potential, because wind accelerates as it moves over and around landscape obstacles. Depending on landscape position, thinned stands or stands adjacent to clearcut harvests may experience increased susceptibility to windthrow.

Insects

Forest insect outbreaks are often linked to weather conditions, but can also be linked to forest management practices and disturbance events (i.e., windthrow). There have been no significant recent introductions of non-native insects and diseases in Southeast Alaska; still, Asian gypsy moth egg masses were intercepted off Juneau in 2014 and Ketchikan in 2008 and 2012. Spruce aphid was introduced from Europe around 1927, but has only caused mortality in 1 to 2 percent of heavily infested trees. The green alder sawfly was found in Sitka, Juneau, and Ketchikan in 2013. However, this non-native insect occurs alongside native defoliators and only partially contributes to alder defoliation damage.

In 2014, spruce aphid (*Elatobium abietinum*) defoliation was only mapped on 425 acres in Southeast Alaska, an increase from 2013, however, still low compared to more than 900 acres in 2012 and 4,000 acres in 2011. Spruce aphid activity mapped during the aerial detection survey was contained entirely

along the western edge of the Chilkat Peninsula. In addition, heavy spruce aphid activity was reported in Petersburg and at the Auke Recreation Area near Juneau. A very short term but intense outbreak began in 2010 on 40,680 acres of Sitka spruce on sites with moderate winter temperatures. This acreage was similar to the largest number of acres of defoliation recorded during the 12-year outbreak from 1995 until 2006. Spruce aphids usually favor the same trees year after year and outbreak after outbreak. Spruce needle aphids feed on older needles of Sitka spruce; after a few years of defoliation, some trees have only the most recent year or two of foliage. Due to temperature controls on aphid populations, this will be an important insect to monitor under changing climate.

Hemlock sawfly (*Neodiprion tsugae*) is a native defoliator of western hemlock found throughout Southeast Alaska. Defoliation attributed to hemlock sawfly was mapped on approximately 4,000 acres in 2014, a third less than the acreage mapped in 2013. Symptom expression after the aerial survey may have led to an underestimate of damaged acreage. The majority of the damage was found on Etolin and Revillagigedo islands, with the heaviest concentration along Behm Canal. There were also small pockets of defoliation along Bradfield Canal. Hemlocks can survive severe defoliation, but radial growth is likely affected. Heavily defoliated stands usually recover within a few years. Hemlock sawfly populations are controlled by parasitoids, predators, and viral and fungal pathogens, and these natural controls agents increase in number during outbreak. Hemlock sawfly has over 20 known species of parasitoids. Sawfly outbreaks can provide net benefits to wildlife. Larvae provide a valuable food source for birds, small mammals, and other insects. Defoliation can promote canopy openings that enhance the growth of understory forbs and shrubs for deer.

Spruce beetle (*Dendroctonus rufipennis*) activity was mapped on 1,600 acres in Southeast Alaska in 2014. The Kupreanof Island outbreak decreased in acreage from 2013 with approximately 220 acres of ongoing spruce beetle activity mapped. The rest of the activity was scattered through the region, from Skagway to Ketchikan, in patches of less than 100 acres. An area of significant spruce beetle activity mapped in 2013 on non-Forest Service lands northwest of Haines along the lower Klehini River and around Chilkat Lake appears to have decreased as well. These two general areas and a few scattered damage polygons nearby comprised 1,400 acres of spruce beetle damage in 2014, compared with 4,700 acres in 2013. These areas were also heavily impacted during the spruce beetle outbreak in the 1990s. Spruce beetle has been a rather minor problem on the Tongass compared to other lands in Alaska, but disturbance such as major windthrow events can lead to increased populations. Ground-checks to verify and monitor mapped spruce beetle activity on the Tongass are planned for 2015.

Defoliating insects eat the leaves or needles of trees and understory plants and are found throughout Alaska on all tree species. When defoliator populations become large enough, vast acreages can be affected. During an outbreak, nearly every tree in a stand can be damaged to varying degrees. In addition to the effects on individual tree physiology, defoliators can also have ecological and socioeconomic impacts on wildlife habitat and forage, aquatic ecosystems dependent on terrestrial inputs, forest aesthetics, and timber, property, and recreation values. Defoliators belong to diverse insect orders and families, including beetles (Coleoptera: Chrysomelidae), sawflies (Hymenoptera: Tenthredinadae), and moths (Lepidoptera: Geometridae, Tortricidae), which contribute the greatest amount of activity. Defoliator outbreaks tend to be cyclic and dramatic. Outbreaks of some species are closely tied to weather conditions that affect insect development, reproduction, and dispersal, as well as host phenology. Understory hardwood defoliators have the potential to significantly reduce browse available to deer.

Tree and shrub species throughout Alaska have been affected by several geometrid (inchworm) defoliators in recent years. Bruce spanworm (*Operophtera bruceata*) is thought to be responsible for widespread blueberry and salmonberry defoliation early in the summer.

Leaf rollers, such as *Epinotia solandriana*, roll leaves into protective shelters to feed within. The damage causes crowns to appear thin. Leaf roller defoliation was mapped on over 800 acres in Southeast Alaska in 2014. The alder along Perseverance Trail in Juneau has been heavily impacted by birch leaf roller in 2013 and 2014 and may result in dieback.

The Sitka spruce weevil (a.k.a. white pine weevil, *Pissodes strobi*), is a damage agent of young Sitka spruce that has yet to be found in Southeast Alaska. However, this native insect is one of the most damaging pests of young Sitka spruce in coastal British Columbia, Washington, and Oregon. Adult weevils lay their eggs in the spring on last year leaders of spruce trees. Resin flows are visible where females have laid their eggs. The larvae hatch in the summer and feed gregariously on phloem, working down the leader. Feeding damage girdles leaders, resulting in multi-topped trees with shrub-like form, crooked stems, and reduced height growth. Attacked leaders turn reddish-brown and droop in late summer or fall. Attacked leaders can be cut vertically and viewed in cross section to reveal last-year's larval feeding tubes and shredded wood fiber beneath the bark. Populations of the Sitka spruce weevil are largely controlled by temperature (degree-days); therefore, this will be a species to watch closely in the future as temperatures increase. Alternatively, the Sitka spruce weevil is more successful on water-stressed trees which could prevent their establishment in the coastal rainforest of Southeast Alaska.

Invasive Insect Surveys

In 2014, several agencies (Alaska Department of Natural Resources, USDA Animal and Plant Health Inspection Service and Forest Service and others) continued detection surveys for European (EGM) and Asian gypsy moths (AGM) (*Lymantria dispar*), rosy gypsy moths (*Lymantria mathura*), nun moths (*Lymantria monacha*), and Siberian silk moths (*Dendrolimus superans sibiricus*). EGM has been intercepted in monitoring traps five times in Anchorage and Fairbanks between 1987 and 2006. The interceptions were single moths found in recreational vehicle (RV) parks demonstrating how the insect is often transported and the effectiveness of this monitoring method. Trapping efforts primarily focus on likely introduction pathways, such as port communities, international borders, shipping and container facilities, and high-use recreational sites. In recent years, AGM egg masses have been detected on marine vessels from Asian ports destined for ports along the west coast, and several of these occurred on vessels headed for ports in southeast Alaska. In 2008, 2012, and 2014 vessels destined for Southeast Alaska that contained AGM egg masses were intercepted by Customs and Border Protection. The AGM poses a more significant risk to Alaska's forested resources than the EGM, as it has a broader host range (over 600 hardwood and conifer species) and female moths are able to fly, allowing for faster dispersal. The relatively recent offshore vessel detections warrant concern for the possibility of overwintering egg masses in or near Alaska's port communities.

A similar trapping program is in effect to survey for invasive bark and wood boring beetles. The Alaska early detection and rapid response (EDRR) non-native bark beetle and wood borer monitoring project goals are to (1) detect, delimit, and monitor newly-introduced non-native bark beetles, ambrosia beetles, and wood boring beetles at selected high-risk forest areas, (2) identify additional pathways and areas for expanding annual monitoring, and (3) quickly assess and respond to newly detected non-native forest insect infestations. Providing early detection of non-native beetles entering Alaska requires a cooperative monitoring network. Key partners assist the Alaska Division of Forestry and the USDA Forest Service Forest Health Protection - Region 10 (R10 FHP) with identification and risk assessment. As of 2014, no tree-killing non-native bark beetles or woodborers have been detected through EDRR monitoring in Alaska, initiated in 2001.

A study was completed in 2014 by entomologists with Forest Health Protection (Juneau) and Xavier University to investigate trapping methods of a specific family of wood boring beetles known as long-horned beetles. Non-native wood boring beetles are easily transported in wood packing materials and can pose a considerable threat to forests. The results of this study will help to improve EDRR monitoring efforts for this family of beetles.

Evaluation of Results

At this time, management activities do not appear to be exacerbating insect and disease problems in the Tongass National Forest. Hemlock dwarf mistletoe and many stem decay pathogens are less frequent after silvicultural treatment. Yellow-cedar decline in young-growth, hemlock canker, and shoot diseases are issues to watch for in young, managed stands. Stem decays may become prevalent in managed stands as they age due to bole wounding caused by partial harvest or commercial thinning treatments. It is possible to promote or maintain stem decays and mistletoe in stands managed for non-timber objectives in order to enhance habitat, ecological processes, and other old-growth characteristics. Yellow-cedar decline is a leading example of the impacts of changing climate on a tree species. Management can favor yellow-cedar on sites with deeper soils or sufficient snowpack to meet conservation goals for this valuable species. Prospects for the salvage of dead yellow-cedar are promising in some areas with concentrated yellow-cedar snags, road access, and land-use designations that permit harvest or salvage. The completed draft yellow-cedar strategy provides guidance for 33 management zones in Alaska that contain yellow-cedar. The EDRR program monitors several invasive insects that present a threat to Alaskan Forests. The Sitka spruce weevil is another insect species to watch carefully, as it occurs close to our southern border and its populations are influenced by temperature. Damage from already established, non-native spruce aphid may increase under a warming climate scenario.

Although insect and diseases are not currently causing significant problems in managed stands, we must remain vigilant in our monitoring efforts, because this may change with time under altered climate scenarios, or with the accidental introduction of exotic pathogens or insects. The monitoring work conducted annually by the State and Private Forestry branch of the Forest Service, Forest Health Protection group, and Tongass National Forest silvicultural staff is sufficient to assess threats and impacts from insects and disease.

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