United States Department of Agriculture

Forest Health Conditions in Alaska - 2015

A Forest Health Protection Report

Forest Service
Alaska Region

State of Alaska
Department of
Natural Resources
Division of Forestry

R10-PR-38

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Cover photo: Black spruce along the Glenn Highway.

You can request our aerial survey team to examine specific forest health concerns in your area. Simply fill out this form, and return it to:

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Name: ______________________________

Organization: ______________________________

Contact Information: ______________________________

General description of forest health concern (host species affected, damage type, disease or insects observed).

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The general location of damage. If possible, attach a map or marked USGS Quadrangle map or provide GPS coordinates. Please be as specific as possible, such as reference to island, river drainage, lake system, nearest locale/town/village.

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Do you need additional forest pest information (GIS data, extra copies of the 2015 Forest Health Conditions in Alaska Report, etc.)? Please be as specific as possible. If hardcopies are desired, provide a mailing address.

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WE NEED YOUR FEEDBACK!

Would you like to remain on our mailing list for the annual Forest Health Conditions in Alaska Report?
Simply fill out this form, and return it to:

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Do corrections need to be made to your physical or electronic address? Has the contact person for your organization changed? Please update any details here.

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How can we make this report more useful to you and/or your organization?

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How do you and/or your organization use the information in this report and/or maps on our website (www.fs.usda.gov/goto/r10/fhp)?

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Forest Health Conditions in Alaska - 2015

FHP Protection Report R10-PR-38

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Introduction

By Michael Shephard, Deputy Director,
State and Private Forestry, Alaska

On behalf of the Forest Service's Forest Health Protection work group and our partners, I am excited to present to you the *Forest Health Conditions in Alaska—2015* report. We hope you find it interesting and informative.

This report summarizes monitoring data collected annually by our Forest Health Protection team and some of our key partners. It is provided to you, as one of our core missions, to provide technical assistance and information to stakeholders on the forest conditions of Alaska. The report also helps to fulfill a congressional mandate (The Cooperative Forestry Assistance Act of 1978, as amended) that requires survey, monitoring, and annual reporting of the health of the forests. This report also provides information used in the annual *Forest Insect and Disease Conditions in the United States* report.

We hope this report will help you, whether you are a resource professional, land manager, other decision-maker or someone who is interested in forest health issues affecting Alaska. This report is an integration of a vast array of information from many sources summarized and synthesized by our forest health team. Please feel free to contact us if you have any questions or comments.

We also want to let you know about some recent personnel changes (Figure 1) in our Alaska forest health team:

New Arrivals: Please join us in welcoming **Stephen Burr**, our new Forest Health Protection entomologist to the Fairbanks office (Stephen started in October, 2015). Stephen and his wife, Meredith, come to us from Flagstaff, AZ, where he is completing his PhD in forestry at Northern Arizona University (NAU). The focus of his work has been insect/tree interactions. He received his Master's degree from Michigan State University studying population dynamics of emerald ash borer and monitoring ash mortality and stand regeneration following infestations of this invasive pest. At NAU, Stephen is studying the role of bark beetle associated fungi on beetle colonization from a tree physiological perspective. His research is testing to determine if fungi disrupt tree water relations and/or deplete tree defenses more rapidly than beetle activity alone. He will be completing his program in 2016. Stephen is extremely happy to be joining the Alaskan FHP team, and is excited to tackle the challenges of working in the boreal forest. Stephen comes in behind Jim Kruse who moved to Lakewood, CO in the fall of 2014.

Figure 1. Forest Health Protection entomologist, Stephen Burr (right), and Deputy Director for Alaska, Michael Shephard (left).

I also rejoined the group in 2015 as the new Deputy Director for Alaska. Previously I worked as the Inventory and Monitoring Program Manager for the National Park Service in Southwest Alaska parks for the last eight years. Before that, I began my career with the Forest Service working on the Tongass National Forest in Sitka in 1993.

Highlights from 2015

In 2015, aerial surveyors mapped a little over 500,000 acres of forest damage from insects, diseases, declines and abiotic agents on 32.9 million acres (Maps 1 and 2, Table 1). The total recorded damage is down 55% from 2014 (Table 2). Much of the decrease in mapped damage from last year was due to the reduced acreage of birch with thin crowns as well as decreases in cottonwood, hemlock and willow defoliation.

Diseases

Dothistroma needle blight continues to cause significant damage and mortality to shore pine (*Pinus contorta* subsp. *contorta*) near Gustavus and Glacier Bay National Park. Aerial surveys have mapped this outbreak across 7,700 cumulative acres since 2012. Our monitoring plots revealed that over half of the shore pine trees in severely affected areas are dead; many died between 2013 and 2014 and the outbreak is ongoing. A new 950-acre outbreak began this year near Haines (Figure 2). There has been negligible mortality associated with this outbreak and monitoring plots will enable us to track tree survival over time. The species of *Dothistroma* present in Southeast Alaska has been confirmed as *D. septosporum*.

Figure 2. Dothistroma needle blight crown symptoms on shore pine north of Haines.

For the first time, a destructive canker disease of red alder (*Alnus rubra*) was observed in Southeast Alaska (Sitka, Wrangell, Zarembo, Etolin, and Prince of Wales Islands). This disease, caused by the fungus *Melanconis* spp., contributed to scattered stem and tree mortality. Warm, dry conditions in spring (http://climate.gi.alaska.edu/) may have stressed alder trees, increasing their susceptibility to this normally weak pathogen. Alder canker caused by *Valsa melanodiscus*, has contributed to widespread thinleaf alder (*A. tenuifolia*), and some Sitka alder (*A. sinuata*) and green alder (*A. fruticosa*) mortality throughout Southcentral and Interior Alaska since 2003. In 2015, it was mapped on only 12,000 acres, compared to 125,000 acres in 2014. This disease has also been confirmed but is not severe in Southeast Alaska on Sitka alder in mainland valleys along the Stikine River, Taku Inlet, and near Haines.

The hemlock canker outbreak on Prince of Wales Island continues. This outbreak, which began in 2012, has persisted longer than historic hemlock canker outbreaks in Southeast Alaska. In addition to the 70 miles of diseased western hemlock mapped along Prince of Wales Island roads, smaller outbreaks were also detected in Sitka, Zarembo Island, Kake, Juneau, Cordova, and other remote locations. An inoculation trial is under way to determine the causal pathogen, which is thought to be *Discocainia treleasei*.

Stem decays and hemlock dwarf mistletoe (*Arceuthobium tsugae*) are ubiquitous and pervasive diseases that fluctuate little annually, but are often missing from young forests following harvest. They are important disturbance agents that contribute to forest structure and function, wildlife habitat, and nutrient cycling in older forests, but also result in lost timber value and hazard trees in established recreation areas. In Southeast Alaska, we are working to determine the key stem decay pathogens of yellow-cedar and western redcedar, which cause significant defect but seldom produce fruiting structures to facilitate identification.

New collaborations with permanent forest inventory plot networks have allowed us to begin constructing robust datasets of pathogen distribution in the boreal forest. The consolidated monitoring records will allow us to characterize incidence and patterns of disease disturbance. This dataset is expected to contribute to a region-wide understanding of how changing climate and disturbance regimes affect boreal forest ecosystem dynamics.

Two aggressive canker diseases of trembling aspen have been documented at multiple locations hundreds of miles apart. One is a target canker that is associated with *Cytospora notastroma*, a newly described pathogen that has been found to be a major contributor to sudden aspen decline in the Rocky Mountains. Another aspen canker is even more widespread and lesions rapidly run the length of tree boles (Figure 3). This unknown fungus can kill trees within a single season.

Figure 3. Aggressive running canker killing a trembling aspen. Obvious discolored lesion of dead cambium showing through bark on left side of trunk (left), the right side of the trunk has only subtle discoloration and debarked margins of the two coalescing lesions (middle), and dead crown (right).

Diplodia gall (caused by *Diplodia tumefaciens*), a common disease on *Populus* species in North America, has only recently been verified on trembling aspen in Alaska. This disease is eye-catching, if unsightly, but causes little long-term damage to trees (Figure 4).

Figure 4. *Diplodia tumefaciens* gall on a trembling aspen.

Noninfectious Diseases and Disorders

This was a significant year for active yellow-cedar decline (dying trees with red-yellow crowns) mortality in Southeast Alaska. The 39,500 acres of active decline mapped in 2015 came from the standard July survey (11,200 acres) and an additional comprehensive survey of Prince of Wales Island in October. For more information on this comprehensive survey, see page 28.

Yellow-cedar decline in young-growth is an emerging issue. We have compiled a database of young-growth stands that contain yellow-cedar to facilitate monitoring. Decline has been confirmed in multiple stands on Zarembo Island and one stand on Kupreanof Island. Additional stands with decline symptoms have been aerially identified and remain to be ground-checked. Affected stands tend to be 30 to 40 years old and thinned within the last decade. We have much to learn about the key risk factors, extent and potential impacts of decline in young-growth.

Invasive Plants

Elodea has now been found in more than 20 locations around Alaska. A range of government agencies and NGOs are collaborating on efforts to eradicate the species from the state, but this remains a daunting prospect. In 2015, Elodea was found in Anchorage's Lake Hood, the world's busiest seaplane base. It was treated with aquatic herbicides about 6 weeks after discovery. Chemical treatments are underway or being planned for several other places around the state. The Chugach National Forest has developed a comprehensive picture of the distribution of Elodea on the forest. A team led by the Pacific Northwest Research Station is examining the impacts on aquatic ecosystems in the Copper River Delta, and the Cordova Ranger District is laying the groundwork for a pilot herbicide application study in 2016.

Alaska Association of Conservation Districts continued its mini-grant program in 2015, awarding more than $88,000 to 10 different organizations. Metlakatla Indian Community continued its efforts to eradicate two small infestations of orange hawkweed (*Hieracium aurantiacum*) and tansy ragwort (*Senecio jacobaea*), and Homer Soil & Water Conservation District conducted invasive plant surveys in the remote village of Nanwalek on the south side of Kachemak Bay.

A partnership between FHP, the Anchorage Park Foundation and private industry has led to substantive progress in controlling invasive plants in some of the city's public parks. In 2015, this partnership led to 22 volunteer weed-pull events, twenty-one acres of bird vetch (*Vicia cracca*) was controlled and more than 70 acres of European bird cherry (*Prunus padus*) infestations were treated, using both mechanical and chemical means.

The Alaska Department of Natural Resources Division of Mining, Land, and Water Northern Region Office (NRO) has increased its attention to invasive plants within its managed lands. During routine site visits, the NRO has begun to document the presence of invasive plant species on land where it authorizes activities, specifically at material sale sites and leased land. In 2014, the focus was on the Elliot Highway and south Tok areas. Twenty-three material sites were visited, of which 15 were found to have invasive plants. In 2015, 26 material sites and 18 lease tracts were visited in the Delta Junction and north Tok areas. Invasive plants were found only at seven of the 44 material sites and lease tracts visited. This effort represents the beginning steps toward one day integrating with the Division of Agriculture's weed-free gravel program.

Alaskans can now identify invasive weeds using a new, free mobile application for both Android and iOS devices, thanks to a project spearheaded by the University of Alaska Fairbanks Cooperative Extension Service. Since the mobile application was released in late August, 2015, 788 users have downloaded the application on their devices.

The Alaska Region has convened its Regional Invasive Species Issue Team (RISIT). The Alaska RISIT is reviewing the 2006 Alaska Region invasive strategy along with current Forest Service strategic direction, policy and guidance. A new, updated invasive species strategy for the Alaska Region will be the result of the review. The strategy identifies invasive species priorities and action items, which will provide guidance and highlight priorities for the Alaska Region invasive species program.

Insects

Spruce beetle (*Dendroctonus rufipennis*) activity was observed on 33,000 acres during aerial surveys this year, roughly doubling the observations from 2014. Although spruce beetle activity mapped in 2015 remains low compared to historical numbers, spruce beetle is the leading non-fire cause of spruce mortality in the state. The bulk of the increase in spruce beetle damage appears to be concentrated primarily in the Yentna and Susitna River Valleys and the northwestern Kenai Peninsula. Spruce beetle damage was also mapped in western and Southeast Alaska. Widely scattered small pockets of spruce beetle activity continue to be observed in Northwestern Alaska, along the Noatak, Squirrel, Omar, and Kobuk Rivers. Northern spruce engraver (*Ips perturbatus*) (NSE) activity was observed on 9,300 acres in 2015, a slight increase over the NSE activity of 7,340 acres mapped in 2014. Most NSE activity occurred along or near the major river systems and their tributaries in the northeastern and central portions of Interior Alaska. Observed western balsam bark beetle (*Dryocoetes confusus*) damage tapered off considerably in 2015, with only 24 acres mapped along the Skagway River and White Pass Fork northeast of Skagway; 186 acres of damage were observed in this area in 2014.

The aerially observed extent of alder defoliation, caused by the green alder sawfly (*Monsoma pulveratum*), striped alder sawfly (*Hemichroa crocea*), woolly alder sawfly (*Eriocampa ovata*), spotted tussock moth (*Lophocampa maculate*) and several other insect species, decreased substantially from previous years, and cottonwood defoliation was also much lower. In contrast, approximately 20,000 acres of damage was caused by the large aspen tortrix (*Choristoneura conflictana*) in 2015, which is an increase over the ~8,000 acres infested in 2014. Forested areas experiencing the greatest large aspen tortrix impact were west of Allakaket, near McGrath, the Nowitna River, and in neighborhoods around Fairbanks.

Hemlock defoliation, which is caused by feeding damage of the hemlock sawfly (*Neodiprion tsugae*), western blackheaded budworm (*Acleris gloverana*), and several other foliage-feeding insect species, was down in 2015. Most defoliation was mapped in the northern half of Southeast Alaska near Hobart Bay and on Douglas, Admiralty and Baranof Islands. Hemlock woolly adelgid (*Adelges tsugae*) was found on Prince of Wales Island; however the population was at a low density and not causing significant damage.

An unidentified generalist defoliator caused severe defoliation on several hardwood species in scattered locations around western Alaska and east of the Alaska Range: various areas around Lake Clark National Park, Yentna River and Chakachamna Lake, in Wood-Tikchik State Park, and near the confluence of the Innoko River and Yukon Rivers. Although the causal agent could not be confirmed, the damage and larvae description are consistent with *Sunira verberata* (Family Noctuidae), a species that has caused substantial damage in the past.

Approximately 38,000 acres of willow leafblotch miner (*Micrurapteryx salicifoliella*) damage was reported in 2015. Roughly 75% of this damage occurred on the Yukon Flats, and the rest was widely scattered across Interior Alaska from the Canadian border to the Holy Cross Hills. Approximately 82,000 acres of aspen forests were damaged by aspen leaf miner (*Phyllocnistis populiella*); a notable decrease from the >120,000 acres mapped in 2014. Stands heavily infested with aspen leaf miner occurred along the Yukon River near Ruby and Rampart, the Tanana Valley State Forest west of Fairbanks, and the Copper River Valley near Glennallen.

Birch leaf roller (*Epinotia solandriana*) showed a dramatic decrease in area infested during 2015 with a total of 1,600 acres affected. Most infested area occurred in the northern and eastern part of the range of its hosts. Roadside reconnaissance noted heavy leaf roller activity along the Taylor Highway between Tok Junction and Eagle.

Spruce aphid (*Elatobium abietinum*) activity is on the increase after repeated mild winters throughout Southeast Alaska (http://climate.gi.alaska.edu/). Aphid activity was prevalent in Petersburg, Juneau, Sitka, and on Prince of Wales Island, especially near Craig. Significantly, spruce aphid was also reported and positively confirmed on the south side of Kachemak Bay and in Homer. This is the first confirmation of spruce aphid on the Kenai Peninsula and represents a significant extension of its known distribution.

In 2015, the primary insect pests in urban trees included spruce beetle and birch leaf rollers. Birch leaf rollers have been reported for several years and it appears as though their populations are subsiding. Several more spruce beetle calls and site visits were addressed in Anchorage in 2015 than in 2014. Additional arthropod pests affecting urban trees in 2015 include birch aphids (*Euceraphis betulae*), yellow-headed spruce sawfly (*Pikonema alaskensis*), larch sawfly (*Pristiphora erichsonii*), pear slug sawfly (*Caliroa cerasi*), and spruce spider mites (*Oligonychus ununguis*). A notable detection in 2015 was the identification of the non-native Sitka spruce weevil (*Pissodes strobi*) in newly planted Colorado blue spruce imported from the Pacific Northwest.

Injury to birch trees caused by the amber-marked birch leaf miner (*Profenusa thomsoni*) (Figure 5) and the late birch leaf edge miner (*Heterarthrus nemoratus*) was reported in birch stands at the outskirts of Anchorage, while severity levels within Anchorage remained very low. Populations in Fairbanks and North Pole have increased in the last decade and spread into parts of the surrounding area.

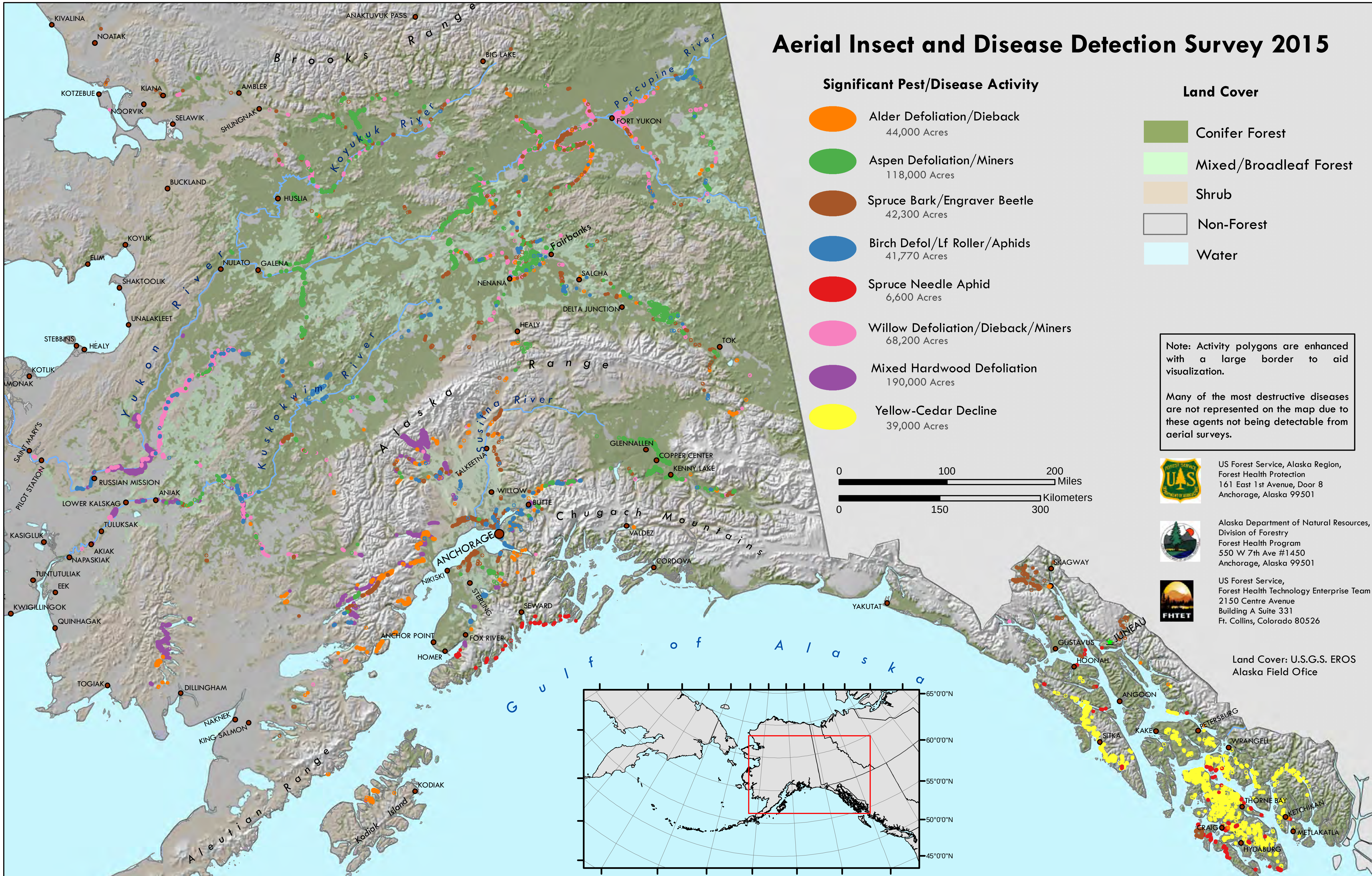
Figure 5. Frass filled amber-marked birch leaf miner gallery in birch foliage, with larvae still visible in the leaf.

Airport Invasive Species Panel

In 2014, Alaska FHP received special project funds to design an invasive species display for the Anchorage International Airport. In a cooperative effort between the US Fish and Wildlife Service and FHP, a 12-by-4.5-foot display titled "Unwanted arrivals: invasive species are damaging Alaska's ecosystems" was developed (Figure 6). The backlit panel highlights eight species that are invading, or are considered likely to invade the state. Because no invasive forest pathogens have been detected in Alaska, white pine blister rust and sudden oak death were shown as examples of what invasive forest pathogens can do. The panel was installed in January, 2015, will be on display through December, 2017. Passenger traffic at Anchorage International Airport averages five million people per year.

Figure 6. Invasive species panel located in the Anchorage International Airport. The panel will be on display through December of 2017.

Map 1. Alaska aerial insect and disease detection survey, 2015.



Map 2. Alaska aerial insect and disease detection survey flight paths, 2015.

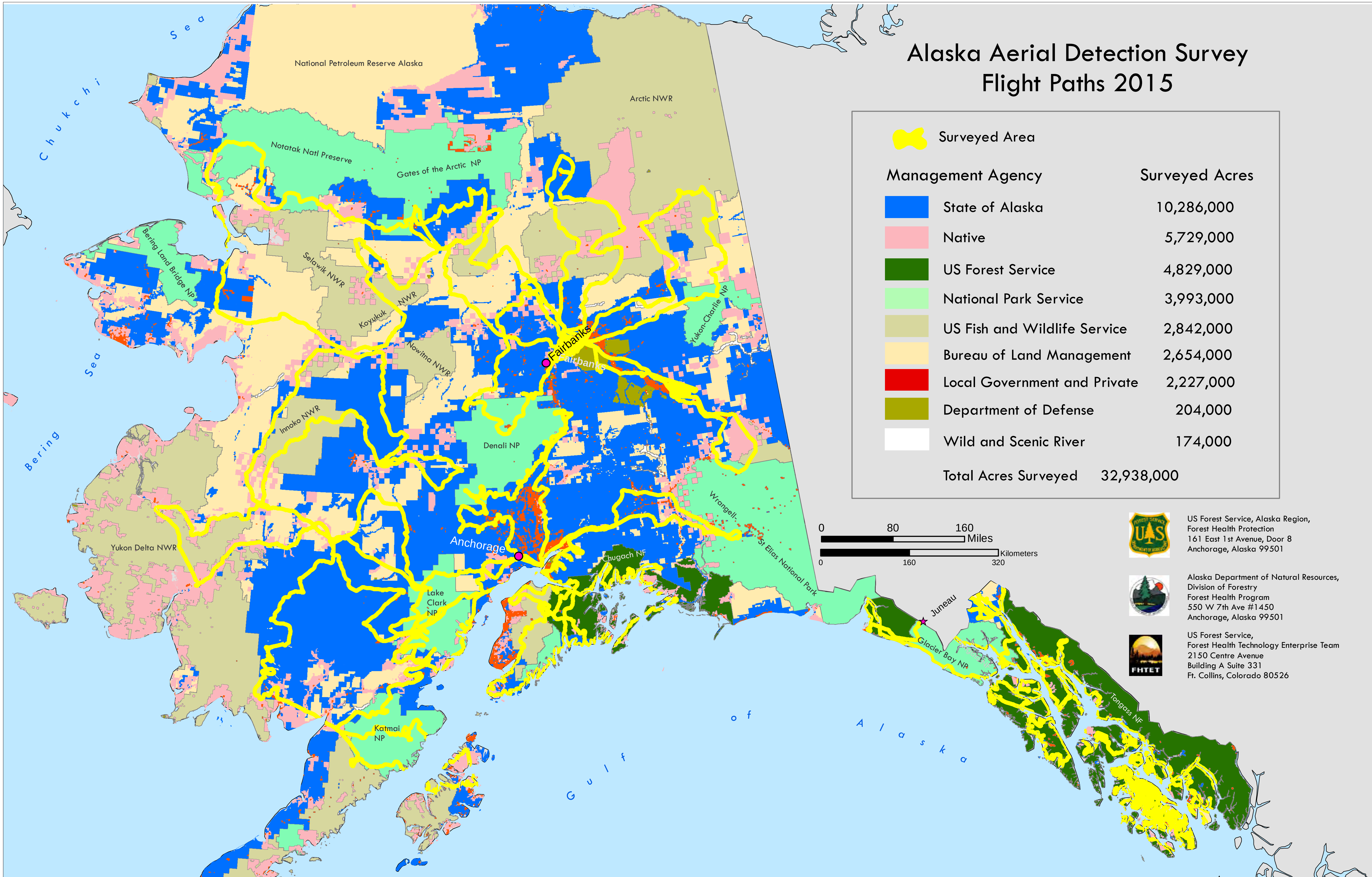


Table 1. Forest insect and disease activity detected during aerial surveys in Alaska in 2015 by land ownership[1] and agent. All values are in acres[2].

Category	Agent	*Total Acres*	*National Forest*	*Native*	*Other Federal*	*State & Private*
Forest Diseases	Alder dieback	12,000	354	5,013	3,021	3,655
	Dothistroma needle blight	2,800	223	196	642	1,783
	Willow dieback	1,200		142	323	782
	Spruce broom rust	490		185	69	238
	Pine dieback	550	531	20		3
	Hemlock canker	200	96	101		3
Defoliators, Miners, Aphids	Hardwood defoliation	190,000	68	53,668	76,123	56,444
	Aspen leaf miner	82,000		26,461	17,018	38,109
	Willow leafblotch miner	38,000		22,296	12,403	2,990
	Birch defoliation	39,000		7,534	14,921	16,083
	Alder defoliation	26,000	26	5,871	14,158	6,324
	Willow defoliation	29,000	10	10,772	13,109	5,604
	Large aspen tortrix	20,000		773	6,932	12,772
	Aspen defoliation	16,000		1,768	7,091	6,901
	Cottonwood defoliation	9,200		3,510	3,694	1,989
	Spruce needle aphid	6,600	3,365	738	166	2,293
	Conifer defoliation	3,100	2,398	108		582
	Spruce defoliation	1,700	1,536	202		
	Birch leaf roller	1,600		15	243	1,344
	Birch aphid	630			620	10
	Birch leaf miner	540			20	519
	Dwarf birch defoliation[3]	190				189
	Hemlock defoliation	120	116			6
Insect Mortality	Spruce beetle	33,000	1,493	4,999	5,244	21,365
	Northern spruce engraver	9,300		2,533	3,292	3,495
	Hemlock mortality	250	71			176
	Western balsam bark beetle	24	1			23
Abiotic and Animal Mortality	Yellow-cedar decline[4]	39,000	34,143	3,472	46	1,816
	Flooding/High-water damage	9,700	445	2,446	1,819	5,007
	Porcupine damage	1,000	131	799		95
	Windthrow/Blowdown	820	768		19	35
	Drought	320		23		298
	Landslide/Avalanche	110	44	19		51
Total	Total damage acres	574,444	45,818	153,666	180,974	190,984

[1] Ownership derived from the 2014 version of Land Status GIS coverage, State of Alaska, DNR

[2] Acre values are only relative to survey transects and do not represent the total possible area affected. Table entries do not include many diseases (e.g. decays and dwarf mistletoe), which are not detectable in aerial surveys.

[3] Defoliation of birch trees and dwarf birch has been reported separately. "Dwarf birch defoliation" primarily represents defoliation of dwarf birch, but also includes defoliation of woody shrubs by several external leaf-feeding insects.

[4] Acres represent only areas with actively dying yellow-cedars. More than 400,000 acres of cedar decline have been mapped over the years in Southeast Alaska.

Table 2. Affected area (in thousands of acres) for each host group and damage type from 2011 to 2015. Note that the same stand can have an active infestation for several years. For detailed list of species and damage types that compose the following categories, see Appendix II on page 74.

Host Group / Damage Type[1]	2011	2012	2013	2014	2015
Abiotic damage	16.3	15.8	6.2	13.6	11.0
Alder defoliation	123.0	58.5	83.9	51.5	26.0
Alder dieback	142.0	16.4	15.7	125.4	12.0
Aspen defoliation	145.6	82.7	53.4	138.6	118
Birch defoliation	76.7	177.8	278.2	586.7	42.0
Cottonwood defoliation	23.4	27.1	9.4	53.4	9.2
Fir mortality	0.0	0.0	0.0	0.2	0.0
Hardwood defoliation	5.5	2.7	2.8	42.1	190
Hemlock defoliation	11.1	5.5	13.3	46.0	0.1
Hemlock mortality	6.2	0.0	0.0	0.0	0.5
Porcupine damage	0.2	0.0	0.5	1.8	1.0
Shore Pine damage	0.0	2.9	4.8	4.5	3.4
Spruce damage	5.5	14.2	7.5	60.1	8.8
Spruce mortality	55.5	19.8	35.1	22.1	42.3
Spruce/hemlock defoliation	0.0	0.0	121.2	4.1	3.1
Willow defoliation[2]	63.9	47.7	16.2	146.1	67.0
Willow dieback	0.3	0.0	0.0	3.4	1.2
Yellow-cedar decline	26.8	17.4	13.4	19.9	39.0
Total damage acres	**702**	**488.5**	**661.6**	**1320**	**574.6**
Total acres surveyed	31,392	28,498	31,497	32,172	32,938
Percent of acres surveyed showing damage	2.2%	1.7%	2.1%	4.1%	1.7%

[1] Values summarize similar types of damage, mostly from insect agents, by host group. Disease agents contribute to the totals for spruce defoliation, hemlock mortality and alder dieback. Damage agents such as fire, wind, flooding, slides and animal damage are not included.

[2] Although these acreage sums are due to defoliating agents, a large portion of the affected area has resulted in mortality.

STATUS OF DISEASES

Paul Hennon has worked as a forest pathologist in Southeast Alaska for more than three decades.

Discovering Root Rot Pathogens In Alder Riparian Forest Ecosystems

Gerry Adams, Associate Professor, University of Nebraska Plant Pathology; Loretta Winton, USDA Forest Service

Figure 7. Dr. Gerry Adams sampling for root rot pathogens in a stand of dead and dying thin-leaf alder on the Kenai Peninsula.

Widespread mortality of alder in Europe and western North America has caused forest pathologists worldwide to more closely examine alder riparian ecosystems (Webber et al. 2004, Aguayo et al. 2013, Navarro et al. 2015). Such work has been ongoing in Europe and the UK since the end of the 1990s. The cause of alder mortality there has been found to be two new root rot pathogens resulting from hybridizations among introduced (exotic) pathogens in the genus *Phytophthora*. These pathogens have now been named as the hybrids *Phytophthora* × *alni* and *Phytophthora* × *multiformis.* Fortunately, our surveys have not found the hybrids in Alaska or the southern Rocky Mountains, nor have surveys by others found them in Oregon (Navarro et al. 2015).

Following the characterization of alder mortality and determination of the causal agents, as the "alder Phytophthora" in Europe, the sudden oak death pathogen, *Phytophthora ramorum*, was discovered in Europe. Forest pathologists then received funding for a region-wide effort to discover all *Phytophthora* pathogens that might be associated with decline of major forest tree species (European Commission action COST FP0801), a similar funding effort was established in Australia (Hüberli et al. 2013). These initiated survey efforts in the UK, Germany, Belgium, France (Jung & Burgess 2009), Spain, Italy, Poland (Jankowiak et al. 2014), Hungary (Nechwatal et al. 2013), Turkey (Balci & Halmschlager 2003), and Western Australia (Hüberli et al. 2013). Western Australia has contributed much to the understanding of new species arising from hybridizations between native *Phytophthora* species and their close relatives that were introduced through international movement of plants (Burgess 2015). North American efforts to better delineate the presence of *Phytophthora* species began with the discovery of sudden oak death.

As part of this larger effort we have been surveying and identifying *Phytophthora* species in Alaska and the southern Rocky Mountains (Figure 7). It turns out that many species of *Phytophthora* and species of the related (i.e. – "water mold") root pathogens *Pythium* we have discovered were only recently described and named. European scientists named many of these but Canadian and USDA scientists have named several as well. For example, Dr. Gloria Abad (Oomycetes-Fungi Program Leader USDA-APHIS-PPQ-Center of Plant Health Science & Technology) has named a new genus (*Phytopythium*) and several new species from the forest surveys.

We have discovered 15 species of *Phytophthora* in Alaska and nine species in southern Rocky Mountain riparian alder ecosystems. At least two new species, *Phytophthora riparia* and *Phytophthora borealis*, were discovered and named as a result of our cooperative studies with scientists at Oregon State University. We are currently discussing with Dr. Abad the possible discovery of new *Phytopythium* species in Alaska.

Some of the species of *Phytophthora* and *Pythium* we have discovered are not as yet named; these have also been discovered in Canadian studies. The pathogens will be named after more is known about their distribution and ecological role in the northern forests. All of these studies throughout the western world are unraveling the ecological role of specific pathogens in the riparian forests.

The more aggressive root rot pathogens of alder in Alaska are *Ph. uniformis* (formerly named *Ph. alni* subsp. *uniformis*) and *Ph. gallica.* Our surveys indicate that *Ph. uniformis* is widely distributed in Alaska from the Kenai Peninsula to north of Fairbanks. *Phytophthora gallica* was present only in urban Fairbanks and may have been introduced by movement of plant materials into Alaska. *Phytophthora gallica* has also been found in Oregon and appears to be native in some of the lower states and in Europe, but it was not found in surveys of the southern Rocky Mountain riparian alder ecosystem. Other Alaskan species capable of causing less serious root rot or bole canker disease in alder include the most abundant species, *Ph. gonapodyides*, the also common *Ph. lacustris and Ph. pseudosyringae*, as well as a new unnamed Alaskan species, *Ph.* species 1 (Navarro et al. 2015).

Our surveys in Alaska did not find the alder-pathogenic species *Ph. siskiyouensis* and *Ph. chlamydospora*, which are perhaps the native *Phytophthora* species most virulent on alder in the lower 48 (Navarro et al. 2015). These two species are common in Oregon and other states. We did find *Ph. siskiyouensis* on alder in the southern Rocky Mountains but *Ph. chlamydospora* was not present in higher altitude (2000-3000 meter or ~6500-9800 feet) alder stands there.

Do these other *Phytophthora* and *Pythium* species pose a future threat to alder health in Alaska? Presumably, *Ph. siskiyouensis* and *Ph. chlamydospora* are absent from Alaskan riparian alder

Do these other *Phytophthora* and *Pythium* species pose a future threat to alder health in Alaska?

forest stands because they do not tolerate cold temperatures; however, since an introduced species like *Ph. gallica* is surviving in Fairbanks, then our assumptions may be wrong. Nevertheless, these species are not nearly as virulent as *Ph.* ×*alni* in inoculation trials, therefore we would assume they could not cause the extensive mortality like that witnessed in Europe. It is this latter hybrid species that remains a true threat to alders in North America (http://www.fs.fed.us/foresthealth/technology/invasives_phytophthoraalni_riskmaps.shtml).

Seventeen *Pythium* species were identified within the root zones of alder in Alaska, while 13 were identified in the southern Rocky Mountains. *Pythium* pathogens are generally not thought of as specific to particular host plants and mostly cause seedling diseases known as "damping-off". However they may be important actors in North American (temperate) forest ecosystems. *Pythium* species can be instrumental in increasing diversity of tree species in the forest because the abundance of their populations can influence host root exudates released into the rhizosphere (Packer & Clay 2003). The accumulating *Pythium* populations differentially increase seedling mortality of host seeds germinating beneath the older parent plants while being less virulent on non-host tree seedlings (Packer & Clay 2000, 2004). It is proposed that *Pythium* species act as host-specific, density-dependent, and distance-dependent pathogens driving higher tree diversity in the maturing forest following early succession, the Janzen-Connell hypothesis (Connell 1971).

Pythium intermedium is one Alaskan species involved in increasing tree species diversity in forest stands following early succession. We know little about *Pythium* species individually but assume that some may be simple saprophytes colonizing senescing feeder rootlets and alder leaf litter. Forest *Pythium* species are particularly poorly known because attention has focused so far on the species important in agricultural systems. Some of the species of *Pythium* discovered in Alaska are new and will need to be named and their role in forest dynamics elucidated in future studies.

We have managed so far to determine baseline rhizosphere information by characterizing the native community of *Phytophthora* and *Pythium* species in alder root zones in Alaska and the southern Rocky Mountains prior to the arrival of exotic and invasive species. Such studies have seldom been accomplished, as interest and funding have generally come about only after a destructive *Phytophthora* species, such as *Ph. ramorum*, has been introduced. If unusual mortality within alder ecosystems becomes noticeable again, we will be able to more easily determine if an introduced root pathogen has arrived, or whether environmental changes are responsible for allowing a native species to cause increased damage. ⌘

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2015 Pathology Species Update

Most forest pathogens are not conducive to aerial detection and do not change much from one year to the next. Therefore, this year we began constructing distribution maps (Map 3, page 16) of forest pathogens from georeferenced and verified observations from 2013-2015 in Southcentral and Interior Alaska. These ground observations are recorded annually by FHP specialists as well as collaborative surveys with the forest inventory permanent plot networks administered by the Cooperative Alaska Forest Inventory (CAFI), the Bonanza Creek Long Term Ecological Research (LTER) program, and the Department of Defense Forest Management program. These maps represent documented pathogen locations as of 2015 based on over 2,700 observations. These maps are expected to be continually refined as new data is added each year. We have also included other data, where available, such as that from the Aerial Detection Survey and journal articles.

Foliar Diseases

Dothistroma Needle Blight
Dothistroma septosporum (Dorog.) M. Morelet

There was pronounced Dothistroma needle blight activity on shore pine (*Pinus contorta* subsp. *contorta*) in Southeast Alaska in 2015. The ongoing outbreak near Gustavus and Glacier Bay National Park (GBNP) has been mapped on 7,700 cumulative acres since 2012 and has caused >50% mortality of shore pine in monitoring plots installed in 2013. A new 600 acre outbreak was detected along the Chilkat River between Haines and Klukwan and northeast to the Canadian border. The total mapped acreage in 2015 was 2,850 acres, down from 4,150 acres in 2014. Ground observers in Gustavus noted significant needle shed and no apparent reduction in disease extent or severity; the reduction in mapped acreage may be due to needle drop from dead and dying trees, which will limit their detectability from the air. As in 2014, small pockets of Dothistroma needle blight were mapped north of the main outbreak in GBNP, suggesting some intensification and spread in the flatland pine-spruce-cottonwood forests.

The combination of mortality and limited regeneration is likely to reduce the abundance of shore pine in the flatland pine-spruce-cottonwood forests near Gustavus. Monitoring plots were installed near Haines to track disease severity and tree survival, and the long-term impacts will depend on the duration of the outbreak. Severe Dothistroma disease activity was also reported in scattered peatland bogs in Southeast Alaska, especially on Prince of Wales and Mitkof Islands.

Dothistroma needle blight affects a wide range of pine hosts worldwide. It occurs throughout the range of shore pine in Southeast Alaska, where wet, mild summers are conducive to many conifer foliage diseases. The causal fungus produces black, pimple-like fruiting bodies and orange-red banding symptoms on needles in spring and early summer. Diseased trees may have sparse crowns (Figure 8) and reduced growth from premature needle shed (Figure 9). Under normal circumstances this disease does not kill trees; however, multiple years of severe disease can cause significant mortality, as we have observed near Gustavus. This year, Irene Barnes from the University of Pretoria in South Africa confirmed with molecular techniques that the *Dothistroma* species in Haines, GBNP, and Juneau is *Dothistroma septosporum*, the same species present in British Columbia.

Figure 8. Thin shore pine tree crowns affected by Dothistroma needle blight.

Figure 9. Shore pine branches with only current-year foliage due to premature needle cast of all older needles from Dothistroma needle blight.

Spruce Needle Casts/Blights
Rhizosphaera pini (Coda) Maubl.
Lirula macrospora (Hartig) Darker
Lophodermium piceae (Fuckel) Höhn

Rhizosphaera needle cast is currently the most widespread disease of spruce mapped in Interior and Southcentral Alaska (Map 3a). However, damage to white and black spruce has been minor in recent years, as mainly the oldest, least active needles have been significantly infected.

In contrast, the disease has been severe on Sitka spruce in Southeast Alaska from 2013–2015 (Figure 10). It was particularly evident in the Mendenhall Valley and farther north of Juneau. An epidemic that occurred in 2009 remains the largest and most intense recorded outbreak of spruce needle cast in Southeast Alaska. There have been several consecutive years of notable disease activity in localized areas in Southeast Alaska without resulting in tree mortality. In coastal forests, symptoms can appear similar to those caused by spruce aphid.

Lirula needle blight and Lophodermium needle cast are two rather common, if less widespread, foliage diseases of spruce (Map 3b-c). Although not unusual on older needles of white and black spruce in the boreal forest, damage is usually minor as mainly the least active needles are affected. However, in 2014 and 2015, pronounced Lirula needle blight damage was observed near Juneau and other locations in Southeast Alaska (e.g., Kake road system). Lophodermium needle cast has not caused significant damage in recent years.

Spruce Needle Rust
Chrysomyxa ledicola Lagerh.

Records of spruce needle rust from boreal forest plots and aerial survey data is shown (Map 3d). No damage from this disease was mapped in the 2015 Aerial Detection Survey. Although this disease is common in Southeast Alaska (Figure 11), it was the third consecutive unremarkable year for spruce needle rust compared to previous years. This may be linked to record-setting dry weather in coastal Alaska in May (http://climate.gi.alaska.edu/). Large outbreaks were reported in Southcentral Alaska in 2012, Western Alaska in 2011, Southeast Alaska in 2007, and Interior Alaska in 2008. This disease rarely results in tree mortality since only current-year needles are affected, and conditions for severe infection usually do not occur in the same location in consecutive years.

Shoot Blights

Sirococcus Shoot Blight
Sirococcus tsugae Rossman, Castlebury, D.F. Farr & Stanosz

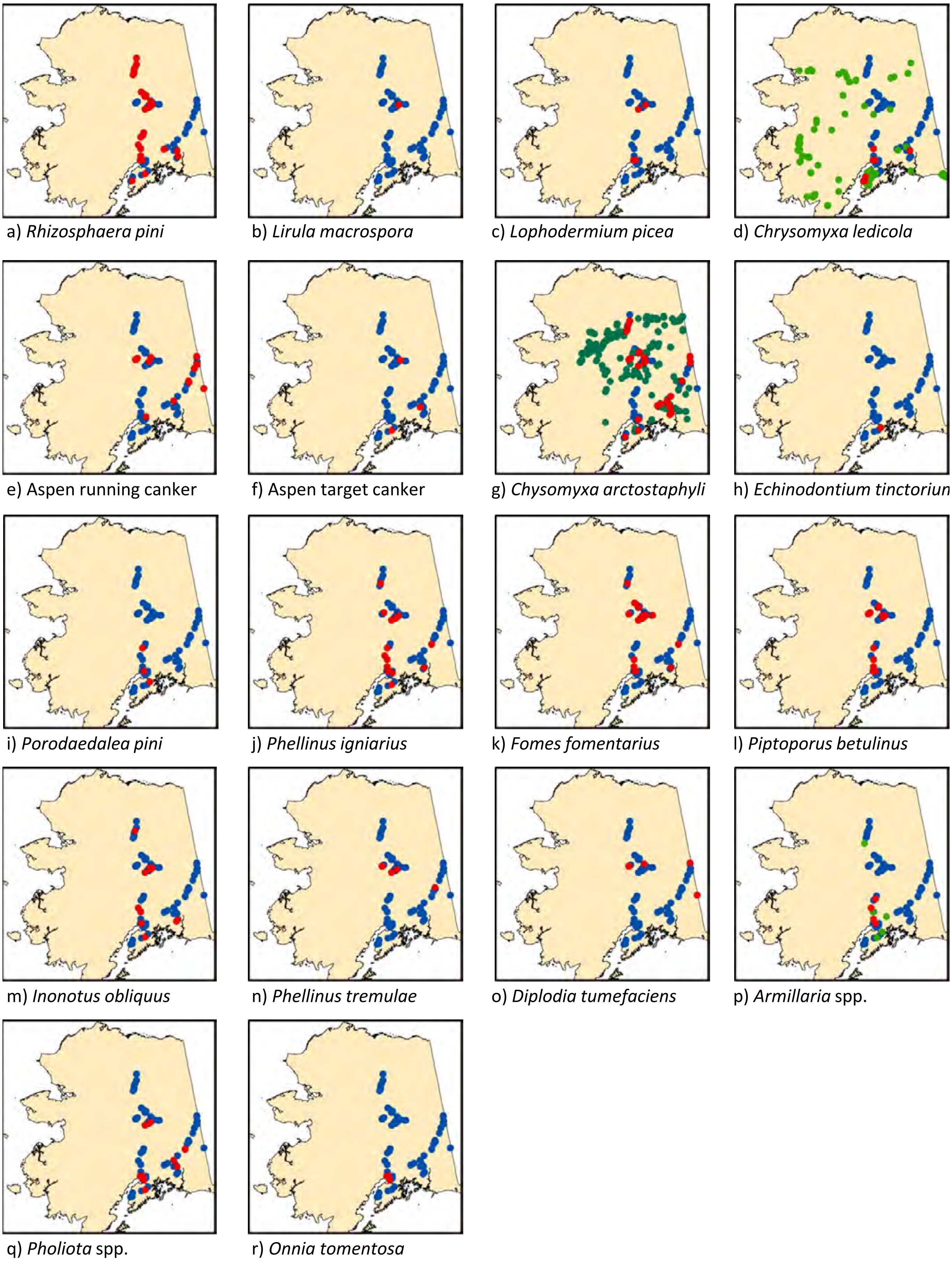
Damage to new growth of western and mountain hemlock from Sirococcus shoot blight was pronounced in 2014 and 2015 in Juneau, Yakutat, Kake, and other locations in Southeast Alaska. Shoots killed in 2014 were still noticeable in 2015, and more shoots died in 2015 (Figure 12). This disease of young lateral or terminal shoots occurs in Southeast Alaska on western and mountain hemlock (rarely spruce). Mountain hemlock is considered more susceptible, but shoot symptoms have recently been widespread on both hemlock species. Riparian zones with apparently conducive infection conditions, such as Montana Creek and Eagle River near Juneau, often show evidence of repeated years of shoot dieback resulting in compromised tree form. Ornamental mountain hemlocks are sometimes chronically diseased; this may be due to the genetic source of landscape trees conferring greater susceptibility. In natural stands, damage is most severe along rivers and creeks.

Figure 10. R*hizosphaera pini* causes yellowish to red-brown foliage discoloration and premature needle shed of older needles in fall. Symptoms are most severe in the lower crown and older, interior needles of Sitka spruce.

Figure 11. Spruce needle rust (*Chrysomyxa ledicola*) on current-year needles of Sitka spruce. Heavily infected spruce trees often have a distinctive orange tinge when the rust is fruiting on the needles in summer.

Figure 12. Sirococcus shoot blight (*Sirococcus tsugae*) of western hemlock.

Map 3. Locations where each agent has been found to be present (red dots) or absent (blue dots) on boreal forest plots surveyed in 2013-2015. For *Chrysomyxa ledicola* and *C*. *arctostaphyli*, green dots represent observations mapped in the Aerial Detection Survey from 1989-2015. For Armillaria, green dots represent sites where *A*. *sinapina* was found in a survey conducted in 2007 to evaluate potential impacts of climate change. Note that these maps do not show the known presence of some disease agents in Southeast Alaska.



a) *Rhizosphaera pini*
b) *Lirula macrospora*
c) *Lophodermium picea*
d) *Chrysomyxa ledicola*
e) Aspen running canker
f) Aspen target canker
g) *Chysomyxa arctostaphyli*
h) *Echinodontium tinctoriun*
i) *Porodaedalea pini*
j) *Phellinus igniarius*
k) *Fomes fomentarius*
l) *Piptoporus betulinus*
m) *Inonotus obliquus*
n) *Phellinus tremulae*
o) *Diplodia tumefaciens*
p) *Armillaria* spp.
q) *Pholiota* spp.
r) *Onnia tomentosa*

Yellow-cedar Shoot Blight

Kabatina thujae Schneider & Arx

Shoot blight of yellow-cedar regeneration in Southeast Alaska was observed again in 2015. Terminal and lateral shoots on seedlings and saplings become infected and die during late winter or early spring. Symptoms of this disease are sometimes confused with spring frost damage. Dieback may extend 4 to 10 inches from the tip of the shoot. Sometimes entire seedlings up to 2 feet tall are killed. The long-term tree structure of taller saplings is not thought to be compromised by leader infections. In 2013, some infections were observed on deer-browsed shoots. Jeff Stone at Oregon State University confirmed the identity of the causal fungus as *Kabatina thujae* from collections made in 2013. This pathogen is known to damage natural and ornamental yellow-cedar saplings in British Columbia. More work is needed to determine if this is the only shoot blight pathogen that causes widespread damage to yellow-cedar young-growth in Southeast Alaska.

Stem Diseases

Alder Cankers

Valsa melanodiscus Otth.
Valsalnicola spp. D. M. Walker & Rossman
Melanconis sp. Tul. & C. Tul.
And other fungi

Alder dieback was only mapped on 12,000 acres (Map 1), an order of magnitude less than the 125,000 acres mapped in 2014 and about half the acreage mapped in 2013. The most concentrated damage was mapped in and around Lake Clark National Park near the Tlikakila River, northcentral Kodiak Island, southwestern Wood-Tikchik State Park, and along the southern boundary of Denali National and State Parks. Significant alder dieback was first observed in Southcentral Alaska in 2003 and the fungus *Valsa melanodiscus* was determined to be the main pathogen involved. The pathogen causes girdling cankers on branches and main stems. More recently, fungal pathogens other than *V. melanodiscus* have been found to cause very similar girdling cankers and subsequent branch dieback of alder in Interior and Southcentral Alaska, including a species in the newly recognized genus *Valsalnicola*. Damage from alder canker has been mapped across more than 380,000 cumulative acres since 2008 and continues to be a significant concern. Drought stress has been shown to increase susceptibility to this pathogen in greenhouse experiments; therefore, climate trends may impact disease incidence and severity. This may explain why this presumably native pathogen has caused unprecedented damage in the past decade.

Most alder canker damage occurs within 1,600 feet of streams. The most susceptible alder species is thin-leaf alder (*Alnus tenufolia*), although Siberian/green alder (*A. fruticosa*) and Sitka alder (*A. sinuata*) are also susceptible. The incidence of alder canker on Sitka alder throughout Southcentral Alaska, especially on the Kenai Peninsula, has increased in recent years.

In 2014, alder canker was confirmed for the first time in Southeast Alaska on Sitka alder near Haines. Alder canker damage was mapped along the Stikine River in 2013. This damage to Sitka alder was ground-confirmed in 2015 (Figure 13) and found to be locally common but not severe. Alder canker was also observed along Taku Inlet and River. Another canker disease caused by *Melanconis* spp. caused scattered damage to red alder on Prince of Wales, Etolin, Zarembo, and Wrangell Islands, and near Sitka (Figure 14). The causal fungus was identified with help from Gerry Adams at University of Nebraska. The finding was significant because we have never observed an aggressive pathogen of red alder in Southeast Alaska. Widespread damage to red alder may have been triggered by abnormally warm, dry weather in May (http://climate.gi.alaska.edu/), stressing alder hosts and increasing susceptibility to an otherwise weak pathogen that has been previously detected in Alaska.

Seen from the air, alder defoliation (see page 56) and dieback are challenging to differentiate. Ground surveys are necessary to discern the cause of dieback and whole stem mortality, but extensive surveys in Alaska have found that most alder dieback is caused by canker fungi.

Figure 13. Siliviculturist Greg Roberts of Wrangell holds a Sitka alder branch with alder canker (*Valsa melanodiscus*) along the Stikine River. This disease is less common in Southeast Alaska than other parts of the state.

Figure 14. A red alder stem in Sitka affected by *Melanconis* spp. (likely *M. stilbostoma*) with bark intact and stained, bleeding cankers (left) and bark removed, revealing dark tissue killed by the pathogen (right).

Aspen Cankers
Unknown fungal species

Several canker-causing fungi infect hardwoods in Alaska and trembling aspen is particularly susceptible (Table 3). Due to increased use of permanent plot networks, we have documented significant mortality caused by cankers on trembling aspen. The appearance and aggressiveness of the cankers vary significantly depending on the causal fungi. A very aggressive diffuse, running canker (Figure 15) has been mapped in many locations in the boreal forest (Map 3e). This canker is rather subtle in appearance and can kill trees within a single season. At four permanent plots in the Ray Mountains, it has affected 5% to 20% of aspen trees on the plots and about 30% of infected trees died within the past year.

In addition, small pockets of distinctive target-shaped cankers with flaring bark have been found on trembling aspen near Cooper Landing, Fox, and Thompson Pass (Map 3f). The disease has been killing trees in these areas for many years (Figure 16). We have isolated a new pathogen from these cankers (*Cytospora notastroma*) that has also been found as a major contributor to Sudden Aspen Decline in the Rocky Mountains. Further work is needed to explore the role of this pathogen in the health of trembling aspen in Alaska.

Figure 15. Aggressive, elongated running canker on aspen; the dark line on the bark shows a crack between the live and dead tissue. The inset shows a debarked area of live greenish-white tissue and successive advances of brown tissue killed by the causal fungus.

Table 3. Common canker fungi of live hardwood trees in Alaska with hosts, modes of infection, and identifying characteristics. Includes the hardwoods: birch (*Betula neoalaskana* and *B. kenaica*), trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), black cottonwood (*Populus trichocarpa*), and red alder (*Alnus rubra*).

Canker Fungus	Hosts in Alaska	Mode of Infection/ Characteristics
Ceratocystis fimbriata	trembling aspen	through wounds and is often insect-vectored; grows slowly over many years and seldom kill trees directly; causes grey-black diamond-shaped cankers with flaring bark
Cryptosphaeria ligniota (=*C. populina*)	trembling aspen, balsam poplar, black cottonwood	through wounds and exists as saprot and heartrot before causing canker; smaller trees may be killed rapidly; predisposes trees to bolesnap; causes long, gray sunken cankers and woodstain
Cytospora chrysosperma (=*Valsa sordida*)	trembling aspen, balsam poplar, black cottonwood, willow	usually affects stressed trees and causes mortality; colonize dead tissue, wounds, or sometimes healthy bark and buds; causes orange, weeping cankers
Encoelia pruinosa	trembling aspen, balsam poplar	through wounds; aggressive cankers may develop rapidly and kill trees; cankers appear similar to fire scars and give tree barber-pole appearance due to patterns of bark retention
Nectria galligena	paper and Kenai birch, occasionally red alder & other hardwoods	usually affects stressed trees; infects through wounds and natural openings (leaf scars); causes a target-shaped canker; may kill stressed trees

Figure 16. An aspen stand near Fox, Alaska (10 miles northeast of Fairbanks) that is severely impacted by a target canker.

Hemlock Canker
Unknown fungus

An outbreak of hemlock canker has been ongoing in western hemlock stands along roadways on Prince of Wales Island since 2012 (Figure 17). The most severe disease activity is between Thorne Bay and Coffman Cove, and Staney Creek and Whale Pass. This outbreak was thought to be abating, but disease activity was severe again in 2015. The disease has been ground-mapped along more than 70 miles of the Prince of Wales road system (Map 4), with new activity along paved roads between Hollis and Klawock Lake. Elsewhere in Southeast, hemlock canker symptoms were pronounced along Harbor Mountain and Blue Lake Roads in Sitka, and in scattered patches on Zarembo Island, Hobart Bay, near Auke Lake in Juneau, and Cordova.

Outbreaks of hemlock canker disease have been documented a couple of times per decade on Prince of Wales, Kosciusko, Kuiu, and Chichagof Islands in Southeast Alaska. The outbreak on Price of Wales has persisted longer than historic outbreaks, and this was the first time the disease has been reported as far north as Juneau and Cordova. Disease symptoms have been observed in old-growth and second-growth forests and extending several hundred feet from roadways, as long as lower branches are present to infect.

In 2012 and 2013, cankered branches were collected and sent to Gerry Adams at the University of Nebraska. Several potential canker pathogens were identified from these samples (Table 4). Inoculation trials were conducted with these fungi in spring 2013 and 2014 to determine if any were the cause of hemlock canker disease of western hemlock in Alaska. Of trees inoculated in 2013 and 2014, *Discocainea treleasei*, *Pezicula livida*, and *Collophora hispanica* generally caused the largest lesions to develop at inoculation sites on tree boles. *Discocainea treleasei* was also used to inoculate freshly-cut hemlock logs in Juneau in 2015 (Figure 18), resulting in consistently larger lesion development than the control treatment. It is considered the most likely causal pathogen, but more work is needed for definitive confirmation.

Hemlock canker causes synchronized mortality of western hemlock lower branches and small trees. This disease is most often seen along roads, rivers, and occasionally shorelines. Road dust was once thought to contribute to disease, but outbreaks continued to occur along gravel roads that were subsequently paved. Although hemlock canker outbreaks cause showy symptoms along roadways, this disease is not considered a serious concern. Resistant tree species may benefit from reduced competition with hemlock, and wildlife habitat may be enhanced where hemlock mortality promotes understory vegetation.

Figure 17. Hemlock canker has killed small to medium western hemlock trees and lower branches, while adjacent spruce is healthy along this road on Prince of Wales Island.

Figure 18. Robin Mulvey inoculates a western hemlock log with *Discocainia treleasei*.

Map 4. Road surveys have detected more than 70 miles of road on Prince of Wales Island in Southeast Alaska with western hemlock trees affected by hemlock canker disease since 2012.

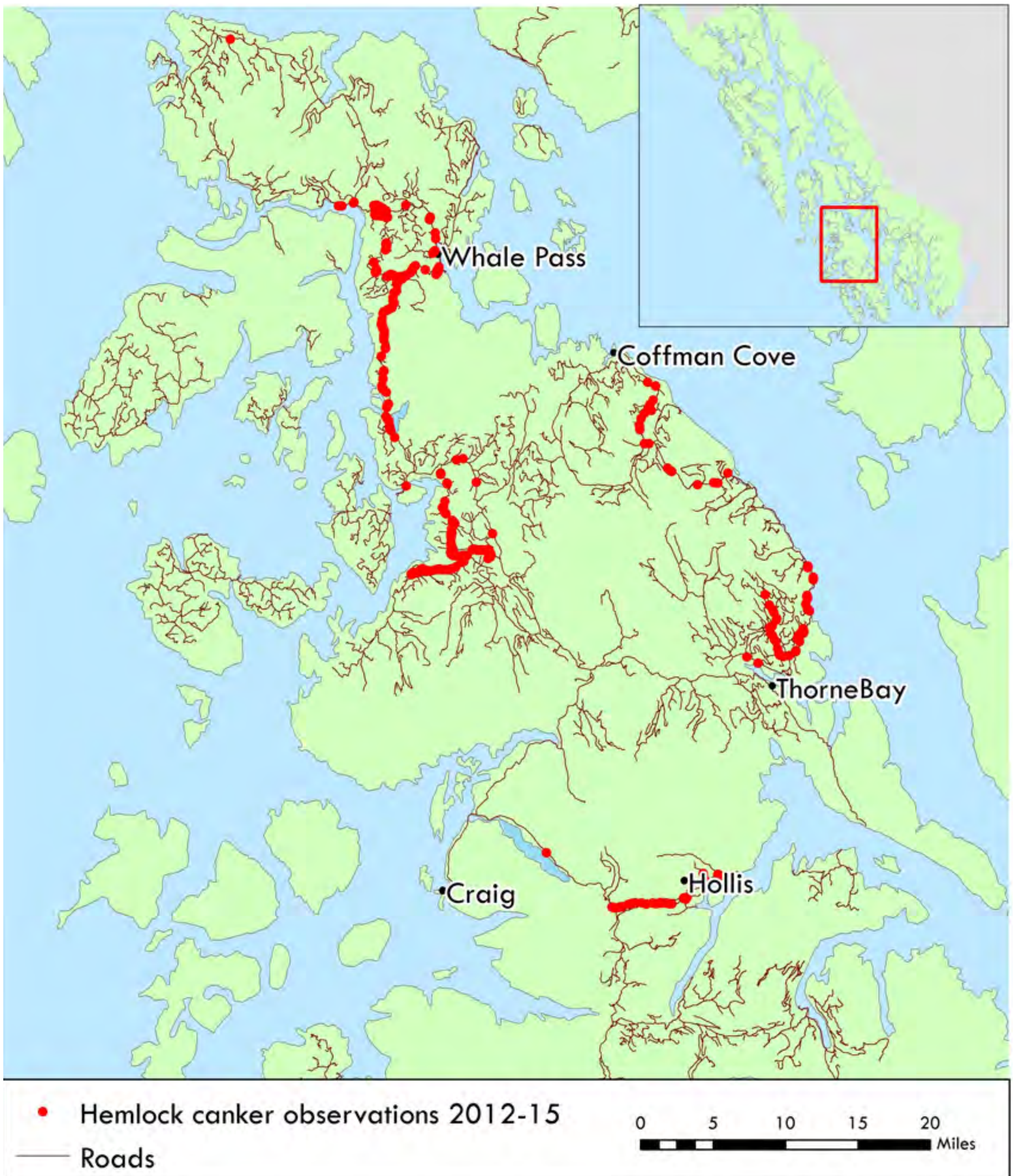


Table 4. Fungi isolated from diseased western hemlock trees, then used in an inoculation trial on Prince of Wales Island in 2013 and 2014.

	Fungi/Treatment
2014	*Discocainia treleasei*
	Dermea abietinum
	Pestalotiopsis sp.
	Pezicula livida
	Sarea resinae
	Zolerion arboricola
2013	*Alternaria porri*
	Collophora hispanica
	Pezicula livida
	Sydowia polyspora

Hemlock Dwarf Mistletoe
Arceuthobium tsugense (Rosendhal) G.N. Jones

Hemlock dwarf mistletoe, a parasitic plant, is the leading cause of disease of western hemlock in unmanaged old-growth stands in Southeast Alaska. Hemlock dwarf mistletoe brooms (prolific branching) provide important wildlife habitat. Suppression and mortality of severely affected trees contributes to canopy gap creation. Bole infections (Figure 19) serve as infection courts for decay fungi and can result in bole breakage. Clear-cutting reduces dwarf mistletoe in second-growth timber stands, but managers can choose to retain some mistletoe-infected trees in second-growth stands for wildlife benefits without significant growth losses.

Figure 19. A large hemlock dwarf mistletoe bole infection of western hemlock.

Dwarf mistletoe incidence, severity and distribution changes little over time without active management. Forest Inventory and Analysis (FIA) plot data was used to estimate the incidence and distribution of mistletoe across Southeast Alaska; hemlock dwarf mistletoe infests approximately 12% of the forested land area and causes growth loss, top kill and mortality on an estimated 1 million acres. These estimates are conservative, because dwarf mistletoe may not always have been recorded when present.

Hemlock dwarf mistletoe is apparently limited by climate (elevation and latitude), becoming uncommon or absent above 500 feet in elevation and 59°N latitude (Haines, AK). Dwarf mistletoe is conspicuously lacking from Cross Sound to Prince William Sound despite the continued distribution of western hemlock. It is thought that short growing seasons or snow loads on trees may limit hemlock dwarf mistletoe fruiting, seed dispersal, germination, infection, or survival. Climate-envelope models have been used to predict changes in mistletoe distribution under various climate change scenarios using three modeling techniques. All models predict that both hemlock and hemlock dwarf mistletoe will be favored by a warming climate, although actual migration rates will be limited by the biology and spread rates of the host and pathogen.

Spruce Broom Rust
Chrysomyxa arctostaphyli Diet.

Broom rust is common and widespread on white and black spruce branches and stems throughout Southcentral and Interior Alaska (Map 3g). Spruce broom rust has been found on Sitka spruce in Glacier Bay and near Halleck Harbor on Kuiu Island, but is absent throughout most of Southeast Alaska. The causal pathogen also completes lifecycle stages on bearberry (*Arctostaphylos uva-ursi*).

Less than 500 acres of broom rust were mapped in 2015, approximately half the acreage mapped by aerial survey in 2014. However, the annual fluctuation in mapped acreage represents differences in detection methodologies and areas flown rather than differences in disease distribution over time. While conditions for infection may be particularly favorable during specific years, the incidence of the perennial brooms changes little from one year to the next. Spruce broom rust may cause crown and bole deformation, spike tops, dead branches, or growth loss, but usually does not kill trees unless infection and breakage occur low on the bole.

Stem Decays of Conifers
Several fungal species

In mature forests of Southeast Alaska, conifer stem decays cause enormous wood volume loss. Approximately one-third of the old-growth timber volume in Southeast Alaska is defective, largely due to stem decay. There is very little decay in young-growth stands unless there is prevalent wounding. By predisposing large old trees to bole breakage and windthrow, stem decays are key disturbance agents in the coastal rainforest, where fire and other large-scale disturbances are uncommon. Stem decays create canopy gaps, influence stand structure and succession, perform essential nutrient cycling functions, increase biodiversity, and enhance wildlife habitat. Trees with stem decay can be hazardous in managed recreation areas.

A variety of different fungi cause stem decay in Alaskan conifers (Figure 20, Table 5). In 2015, we confirmed that the paint fungus (*Echinodotium tinctorium*), thought to be absent in Southeast Alaska south of Skagway, is locally abundant on western and mountain hemlock in one stand on Mitkof Island. We will continue to survey to better-understand its distribution; it is not often that we make a new stem decay finding! In Southcentral Alaska, we have only found it on mountain hemlock in the boreal-coastal transition zone (Map 3h). *Porodaedalea pini* is widespread in coastal forests. Less common in the boreal forest, we have also detected it on white spruce, black spruce, and mountain hemlock in the boreal forest and boreal-coastal transition forest (Map 3i).

Many stem decay fungi cause heart rot of living trees, others decay the wood of dead trees, and some grow on dead tissue of both live and dead trees. Most stem decay fungi do not interfere with normal tree growth and physiological processes since the vascular system is unaffected, but some may attack the sapwood and cambium after existing as a heart rot fungus (Figure 21).

Classic cull studies in Southeast Alaska have shown that brown rots are the most significant source of cull for Sitka spruce, while white rots are the most significant for western hemlock and western redcedar. Western redcedar is the most defective species, followed by western hemlock and Sitka spruce.

Yellow-cedar and western redcedar wood products are prized for their decay resistance. Paradoxically, large, live cedars often have extensive stem decay. Defective cedars usually lack

Laetiporus sulphureus, Chicken-of-the-woods

Phellinus hartigii, Hartig's conk

Fomitopsis pinicola, Pinicola/red-belt conk

Porodaedalea pini, Pini conk

Echinodontium tinctorium, Paint fungus

Phaeolus schweinitzii, Cow-pie/velvet-top

Ganoderma applanatum, Artist conk

Ganoderma tsugae, Varnish conk

Onnia tomentosa, Tomentosus Root Disease

Figure 20. Conks of common stem decay fungi of Alaskan conifers.

Table 5. Stem, butt, and root 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* ssp. *contorta*), larch (*Larix laricina*) and Sitka, Lutz, white, and black spruce (*Picea sitchensis*, *P. lutzii* [*glauca* x *sitchensis*], *P.glauca*, *P. mariana*).

Decay Fungi	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, possibly yellow-cedar	likely through root-to-root contact & subsequent spread into butt
Coniophora sp.	brown	spruce, hemlock, larch (occasionally hardwoods)	through wounds
Echinodontium tinctorium	brown	mountain hemlock (occasionally western hemlock)	through branch stubs or live branches
Fomitopsis pinicola	brown	spruce, hemlock, pine, larch; sometimes redcedar & birch	through wounds
Fomitopsis officinalis	brown	Sitka spruce, hemlock, larch	through wounds, broken tops
Ganoderma spp.	white	spruce, 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/black spruce (occasionally Sitka spruce & shore pine)	through root-to-root contact
Phaeolus schweinitzii	brown	spruce, pine western redcedar, larch, 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, larch	through branch stubs or live branches
Phellinus weirii	white	western redcedar (possibly yellow-cedar)	likely through root-to-root contact & subsequent spread into butt

obvious outward indicators of decay, such as conks, swelling, or seams. There is a desire to learn how the type and incidence of decay varies by cedar species and location and whether there are any reliable external indicators of decay; this information could improve the timber valuation process. A project is underway to identify the primary fungi causing stem decay of both cedar species in Southeast Alaska (Figure 22).

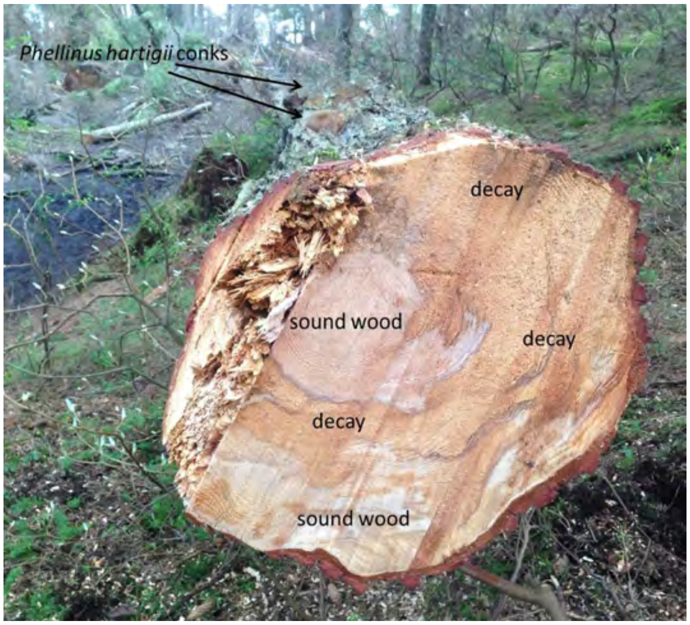


Figure 21. *Phellinus hartigii* infected this western hemlock through a mistletoe swelling on the main stem. Unlike most stem decays, this fungus is not restricted to the heartwood; its movement into the sapwood killed the tree and the decay extended >40ft above the conks.

Figure 22. R.D. Parks of the Petersburg Ranger District collects a sample from a decayed yellow-cedar stump on Kupreanof Island in June 2015.

Stem Decays of Hardwoods
Several fungal species

A number of fungi cause heart rot in paper birch, trembling aspen, balsam poplar, cottonwood, and other hardwood species in Alaska (Table 6). *Phellinus igniarius* is extremely widespread and common on both live and dead paper birch (Map 3j). Both *Fomes fomentarius* and *Piptoporus betulinus* are also widespread and common on paper birch, but are found on dead trees and dead parts of live trees (Maps 3k-l). *Inonotus obliquus* is a stem decay fungus that is also found on live paper birch, but is not often found on dead trees because it dies soon after its host tree dies (Map 3m). There has been a marked increase in birch trees damaged by Chaga (*Inonotus obliquus*) collectors in recent years. *Phellinus tremulae* accounts for the majority of stem decay in trembling aspen (Map 3n).

Western Gall Rust
Peridermium harknessii J.P. Moore
(=*Endocronartium harknessii***)**

The incidence of western gall rust does not vary significantly over time. Our permanent shore pine monitoring network revealed that 85% of pines greater than 4.5 feet in height were infected with gall rust. Twenty-five percent of pines had dead tops associated with galls on the main tree bole (Figure 23), while 34% had at least one gall infection of the main stem that could lead to top kill or whole tree mortality. Western gall rust was the most important predictor of crown dieback.

Western gall rust is extremely common throughout the distribution of shore pine in Southeast Alaska. There is lower disease incidence and severity in relatively drier locations, such as Haines and Gustavus. This rust fungus does not require an alternate host to complete its lifecycle. Orange spores release from galls in spring infecting new foliage, eventually causing a spherical gall to form on boles or branches. It is thought that ideal infection conditions occur more regularly in Southeast Alaska compared to other regions. Secondary insects (*Pseudips mexicanus* beetles and *Dioryctria* sp. larvae) and fungi (*Nectria cinnabarina*) frequently invade gall tissue, killing infected boles and branches.

Diplodia Gall
Diplodia tumefaciens (Shear) Zalasky

Diplodia gall, widely distributed throughout North America on trembling aspen, balsam poplar, and other *Populus* species, has been mapped on aspen in Alaska for the first time (Map 3o). However, anecdotal reports with matching descriptions have been received previously. When occurring on the trunk it strongly resembles the cinder conk (*Inonotus obliquus*), but Diplodia gall has only been found on aspen in Alaska (Figure 24). The fungus is unsightly and can weaken trees and branches, but generally does not kill trees.

Table 6. Stem, butt, and root decay fungi of live hardwood trees in Alaska with decay type, hosts and common modes of infection. Includes the hardwoods: birch (*Betula neoalaskana* and *B. kenaica*), trembling aspen (*Populus tremuloides*), and black cottonwood (*Populus trichocarpa*).

Heart Rot Fungi	Type of Rot/Decay	Hosts in Alaska	Mode of Infection
Armillaria spp.	white	all hardwoods (& conifers)	vegetative spread (or spores) to stressed, dying, or dead trees
Fomes fomentarius	white	birch (occasionally other hardwoods)	through wounds, branch stubs
Ganoderma applanatum	white	all hardwoods (some conifers)	through wounds, broken tops
Inonotus obliquus	white	birch (occasionally aspen & cottonwood)	invades through wounds; a canker-rot fungus that produces sterile conks
Phellinus igniarius	white	birch	through wounds, branch stubs
Phellinus tremulae	white	aspen	through wounds, branch stubs
Pholiota spp.	white	all hardwoods	through wounds of lower stem & roots; also decays dead wood as saprophyte
Piptoporus betulinus	brown	birch	through wounds, branch stubs; abundant on dead trees

Figure 23. Western gall rust (*Peridermium harknessii*) on the main bole of shore pine is very common and frequently results in topkill.

Figure 24. Diplodia gall (*Diplodia tumefaciens*) causes unsightly black galls on aspen boles and branches.

Root and Butt Diseases

There are four notable root and butt diseases on trees in Alaska: Annosus/Heterobasidion root disease, Armillaria root disease, Pholiota butt rot, and Tomentosus root rot. 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. We are also working to identify the fungus that causes widespread butt rot of yellow-cedar. In Alaska, root diseases do not usually create canopy openings typically associated with root pathogens elsewhere in North America.

Armillaria Root Disease
Armillaria spp.

Armillaria root disease has been mapped on paper birch and white spruce in several locations in Interior and Southcentral Alaska (Map 3p). In Southeast Alaska, *Armillaria* species are common on all tree species, but are generally not considered destructive, merely hastening the death of stressed trees. However, aggressive disease behavior has been recently observed in a young-growth yellow-cedar stand with yellow-cedar decline symptoms on Kupreanof Island. John Hanna and Ned Klopfenstein from the Rocky Mountain Research Station have identified *Armillaria* collected from yellow-cedar in this stand and from western hemlock trees near Juneau as *Armillaria sinapina*. *Armillaria* collections made from hardwood and conifer hosts from the Kenai Peninsula to the Arctic Circle in 2007 were all also identified as *A. sinapina*.

Pholiota Butt Rot
Pholiota spp.

A species of *Pholiota* has been mapped in many locations (Map 3q). *Pholiota* mushrooms have primarily been observed fruiting on the base of trembling aspen, but are also fairly frequent on paper birch. It has also been found once each on black spruce and a willow species. Usually host trees have no symptoms until they fall over or snap near the root collar.

Heterobasidion/Annosus Root & Butt Rot
Heterobasidion occidentale sp. nov. Otrosina & Garbelotto

The spruce type of *Heterobasidion occidentale* causes root and butt rot in old-growth western hemlock and Sitka spruce forests in Southeast Alaska. This pathogen does not typically kill trees, and has not been documented in other parts of the state. Cut stumps are not treated during harvest because stump infection is not an important mode of disease spread in Alaska. The name of this pathogen has changed to reflect that the spruce and pine types of this disease are caused by two distinct species. The pine type of this pathogen (not present in Alaska) retained the original pathogen and disease names: *H. annosum*, the cause of Annosus root and butt rot.

Tomentosus Root Disease
Onnia tomentosa (Fr.) P. Karst. (=*Inonotus tomentosus*)

The pathogen *Onnia tomentosa* is apparently widespread throughout spruce stands of Southcentral and Interior Alaska (Figure 25), but to date has only been confirmed and mapped on white and black spruce in the boreal-coastal forest transition zone (Map 3r). However, as with most root diseases, comprehensive surveys have not been conducted due to obstacles to detection such as ephemeral fruiting bodies and the lack of distinctive above-ground features. In Southeast Alaska, this pathogen has been detected on Sitka spruce near Dyea (Skagway) and fruiting bodies have also been collected from dead shore pine near Hoonah. The annual conk has a velvety, yellow-brown cap, tubular pores, and often a brown felt on the underside close to the stalk.

Figure 25. Jack-strawed black spruce in a forest where *Onnia tomentosa* is present. Trees falling in a haphazard manner are a symptom of root diseases at work.

Invasive Pathogens

No serious exotic tree pathogens are known to have established in Alaska. The hosts for many of the most devastating invasive plant pathogens in North America (e.g., white pines, chestnuts, elms) are not native to Alaska. However, Alaska is not safe from invasive pathogen introductions. Importation of live plant material (nursery plants, Christmas trees, and greens for wreaths) and firewood are the most likely modes of invasive pathogen introduction. Many of the same factors that have protected Alaska from pathogen introductions in the past heighten its vulnerability. Low tree species diversity translates to potentially substantial, statewide impacts if introduced pathogens cause damage or mortality to any of the few dominant tree species. Symptoms may not be detectable by aerial detection survey until a serious epidemic is underway with notable tree mortality. Many pathogens are difficult to identify and have the capacity for long-distance spread through microscopic spores; pheromone trapping or similar techniques employed by entomologists cannot usually be applied to invasive pathogen detection. For these reasons, there is frequently a lag between introduction and detection.

Worldwide, there are no examples of successful eradication of invasive plant pathogens established in forest ecosystems. Preventing invasive pathogens from entering Alaska must be a top priority. The primary roles of FHP related to prevention are to 1) compile and communicate a list of pathogens that are major potential threats to Alaska's forests, 2) communicate the most likely introduction pathways to other federal agencies that govern product importation and travel such as Customs and Border Protection and Animal and Plant Health Inspection

Service, 3) monitor forests to detect damage from native and introduced pests, and 4) collaborate with and provide expertise to federal and state agencies when introductions are detected.

A thorough assessment of exotic tree pathogens requires a comprehensive list of native species for context. Field surveys and identification of tree pathogens should be a long-term goal and an ongoing effort of the forest health program. Plant pathogens that are inconspicuous and minor in their native range can have major impacts in new habitats due to differences in host susceptibility and climate; this can make new introductions difficult or impossible to predict. Importation and movement of live plant material is known to be a major introduction pathway for invasive plant pathogens, particularly movement of plants closely related to our native species.

Forest Health Protection and cooperators in Alaska have been working on a review of worldwide literature to identify potential invasive tree pathogens and to gain detailed information that can be used to rank their possible impacts in Alaska (Table 7). Our approach is to identify pathogens that infect close relatives of Alaskan tree species. "ExFor" (Exotic Forest Pest Information System North America) is a national database to catalogue potential invasive forest insects and pathogens (http://spfnic.fs.fed.us/exfor/index.cfm). We have only added four species to this database and should revitalize this effort.

Table 7. Potential invasive pathogens and diseases with susceptible Alaskan host species, presence/absence information and invasive-ranking for Alaska.

Pathogen Name	Disease Name	Host/s Species Alaska	In AK?	Invasive Ranking
Chrysomyxa abietis (Wallr.) Unger	Spruce needle rust	spruce	no	high
Phytophthora austrocedrae Gresl. & EM Hansen	Mal del ciprés	yellow-cedar	no	high
Bursaphelenchus xylophilus	Pine wilt nematode	lodgepole pine	no	moderate
Chrysomyxa ledi var. *rhododendri* (de Bary.) Savile	Rhododendron-spruce needle rust	spruce & rhododendron	no	moderate
Cistella japonica Suto et Kobayashi	Resinous stem canker	yellow-cedar	no	moderate
Didymascella chamaecyparidis (JF Adams.) Maire	Cedar shot hole	yellow-cedar	no	moderate
Lophodermium chamaecyparissi Shir & Hara.	Cedar leaf blight	yellow-cedar	no	moderate
Melampsora larici-tremulae Kleb.	Poplar rust	aspen, larch & pine	no	moderate
Seiridium cardinale (Wagener) Sutton & Gibson	Seiridium shoot blight	yellow-cedar	no	moderate
Erwinia amylovora (Burrill) Winslow	Fire blight	mountain-ash & ornamental fruit trees	yes	low
Phytopthora ramorum Werres deCock Man in't Veld	Sudden oak death	Pacific yew, larch & understory spp. [1]	no	low
Phytophthora alni subsp*. uniformis* Brasier & SA Kirk	Alder Phytophthora	alder	yes	low[2]
Taphrina betulae (Fckl.) Johans.	Birch leaf curl	birch	no	low
Taphrina betulina Rostr.	Birch witches broom	birch	no	low
Valsa hariotii	Valsa canker	aspen, cottonwood, willow	no	low
Phytophthora lateralis Tucker & Milbrath	Phytophthora root disease	Pacific Yew (yellow-cedar v. low)	no	low
Apiosporina morbosa (Schwein.:Fr.) Arx	Black knot	bird cherry (invasive/ornamental)	yes	very low
Cronartium ribicola JC Fisch.	White pine blister rust	white pines (not native/ornamental)	yes	very low

[1] Rhododendron, highbush-cranberry, western maidenhair fern, mountain laurel, false Solomon's seal, western star flower, salal, ninebark, salmonberry and Lingon berry. Only hosts native to Alaska that are on the APHIS host list for P. ramorum are listed. Susceptibility to P. ramorum varies significantly by species/genus and many highly susceptible hosts in CA, OR and WA are not present in AK.
[2] *P. alni* was detected in Alaska in 2007. High genetic diversity within the pathogen population in AK and lack of damage to native alder species from this pathogen suggest that *P. alni* has long been established and is not an invasive species.

STATUS OF NONINFECTIOUS DISEASES & DISORDERS

Forest Health Protection staff examine a dying yellow-cedar tree in a young-growth stand on Kupreanof Island.

A Special Aerial Survey of Yellow-cedar Decline on Prince of Wales Island

Robin Mulvey, Tom Heutte, Melinda Lamb, Paul Hennon, USDA Forest Service

Yellow-cedar decline has affected over a half million cumulative acres in Southeast Alaska. The large acreage of standing dead yellow-cedar trees (snags), the high value of yellow-cedar wood, and its long-term retention of wood properties suggest promising opportunities for salvage. The Tongass National Forest has partnered with the Alaska Coastal Rainforest Center and the University of Alaska Southeast to conduct economic feasibility studies of yellow-cedar salvage. In some settings, salvage recovery of yellow-cedar snags may yield valuable wood products and economic, social and ecological benefits. Yellow-cedar snags could supply local mills with valuable timber and potentially offset harvests in healthy, old-growth yellow-cedar stands.

Forest Health Protection conducted a special two-day aerial survey in October to comprehensively map active yellow-cedar decline (very recently dead trees) on Prince of Wales Island and parts of Zarembo and Etolin Islands. This survey was prompted by observations of elevated active yellow-cedar mortality in 2015 following two mild winters with lower than average snowpack. In particular, the winter of 2013-2014 had the combination of low winter snow and cold spring temperatures needed to kill shallow, exposed yellow-cedar roots. Portions of Prince of Wales Island were flown during the July survey, but visibility and flight time were limited by poor weather conditions.

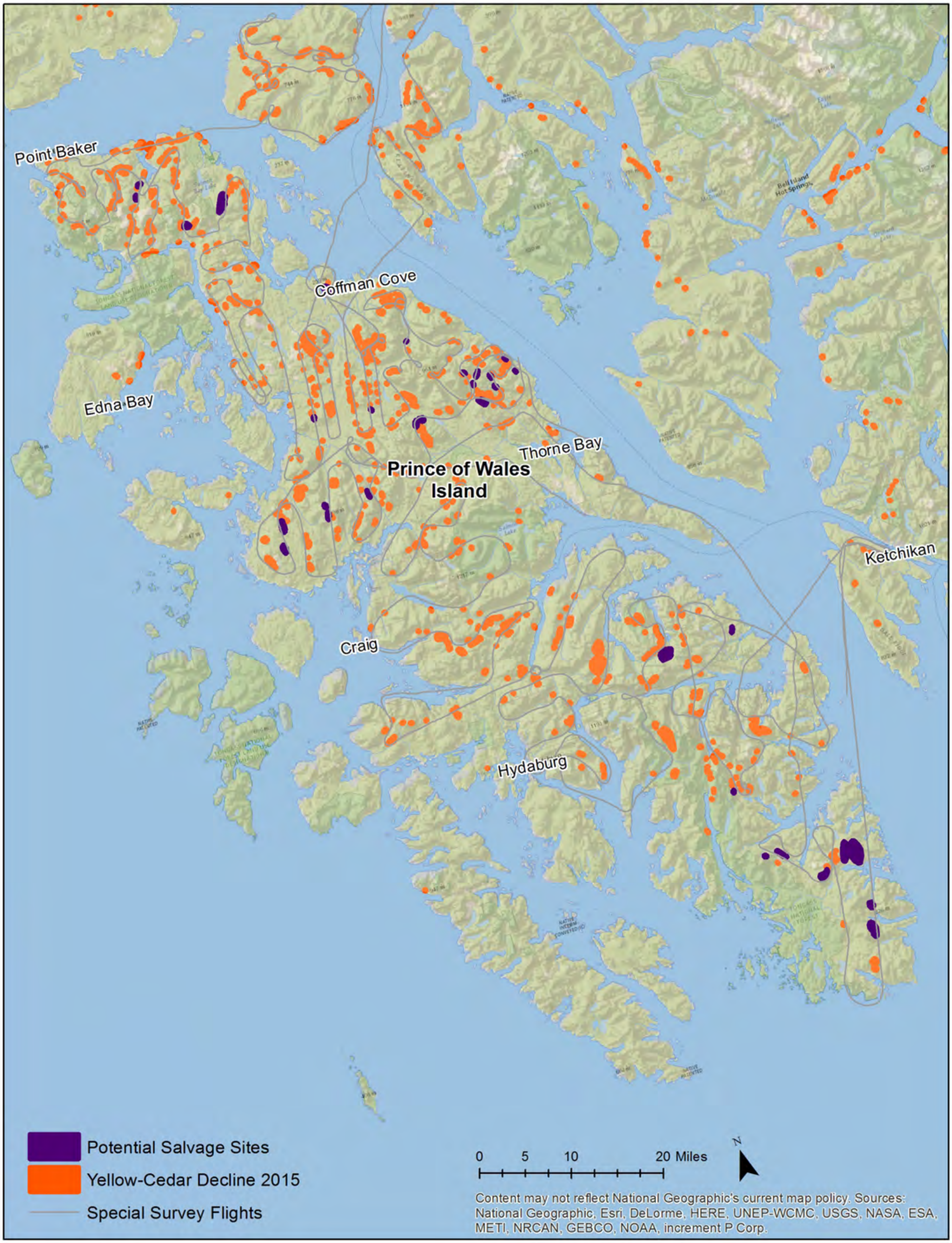
In July 2015, we mapped 11,200 acres of active decline, lower than any of the preceding six years; the total active decline acreage increased to 39,500 acres following the intensive survey (Map 5). See page 32 for more detailed information about the distribution of decline in 2015. It can be complicated to interpret differences in mapped acreage over time. Annual variation is linked to a) real fluctuations in root-freezing injury and symptom development, b) the amount of yellow-cedar forest flown, and c) the flight line pattern and density (e.g., flight lines frequently follow coastlines rather than dissecting inland valleys during our standard survey). Overlaying the July survey flight lines with modeled yellow-cedar forest revealed that yellow-cedar forests were under-surveyed during the July survey compared with the previous year. Only 166,000 acres of yellow-cedar forest were surveyed during regular-season work in 2015; significantly less than the sixteen-year average of 272,000 acres. Tongass silviculturists and land managers requested a more comprehensive survey of active decline to inform potential salvage project development.

In some settings, salvage recovery of yellow-cedar snags may yield valuable wood products and economic, social, and ecological benefits.

The extensive survey of Prince of Wales Island in October tripled the active decline acreage detected in 2015 and made the total acreage of yellow-cedar forest flown comparable to past surveys. Much of the active decline mapped during our special survey had never been previously mapped, indicating that the areas in which this activity was detected are not typically flown during our annual survey and/or that this activity is in previously unaffected forests. Aerial surveyors also made observations about the size class and density of snags. For salvage operations to be economically feasible, harvested trees must be large, concentrated, and sufficiently close to maintained roads (<1 miles). Much of the active decline appeared to affect forests with yellow-cedar trees too small to support salvage operations. However, more than 30 areas were identified with large snags with fine and/or coarse branches, indicating that they have been dead for less than 30 years and are still merchantable. Salvage is permitted on lands in certain management categories, as described in Chapter 3 of the Tongass National Forest Plan. Potential salvage areas will be further evaluated by Tongass silviculturists to determine their suitability for harvest.

Yellow-cedar snags retain desirable strength and decay resistance properties for decades after tree death and remain standing for 80-100 years. Studies of mill-recovery and wood properties of snags have shown that all wood properties are retained for the first 30 years after tree death. Even after the bark has sloughed off and the outer rind of sapwood (<1 inch) has begun to decay, the heartwood remains sound and merchantable. Decay resistance is altered somewhat 30 to 80 years after tree death; remarkably, wood strength of 80 year old snags is the same as live trees. Large pulses of mortality occurred in the 1970s, 80s and 90s; many trees that died during this time period are still merchantable, but as the sapwood continues to deteriorate and heartwood chemistry begins to change, the window of merchantability will close. Yellow-cedar salvage may be one management activity that helps the Tongass National Forest to produce valuable wood products and sustain local economies while transitioning away from clearcut harvest of old-growth forests. ⌘

Map 5. The distribution of active yellow-cedar decline and areas identified to have salvage harvest potential during a special survey flight of Prince of Wales Island (southern Panhandle) in October 2015.



2015 Noninfectious Diseases & Disorders Updates

Windthrow, flooding, drought, winter injury, and wildfires affect forest health and structure to varying degrees. Hemlock fluting, though not detrimental to tree health, reduces economic value of hemlock logs in Southeast Alaska. Several animal species damage forest trees throughout the state; porcupines, bears, and beavers can be particularly destructive. Wildfire causes extensive tree mortality in Alaskan boreal forests, and may be especially severe after bark beetle outbreak or in times of drought or high wind. Nationwide, 2015 was a significant year for wildfire, one of only 4 years since 1960 in which more than 9 million acres burned. The National Interagency Fire Center reported that 770 fires burned across 5.1 million acres in Alaska in 2015, affecting 4% of the state's 107 million acres of boreal forest. Historically, the 2015 fire season in Alaska was surpassed only by 2004, in which 6.6 million acres burned; other significant fire seasons occurred in 1957 and 2005.

Birch trees in most of Southcentral and Interior Alaska experienced a mast year (heavy seed production) in 2014, contributing to the poor appearance of Alaska birch throughout much of the region. Many trees exhibited short new growth, small, sparse leaves, and extremely high catkin density. In 2014, we mapped more than half a million acres of thin-crowned birch forest, with no single biotic agent identified as the consistent cause. In early spring 2015, many birch forests were completely carpeted with birch seeds. Thin birch crowns were uncommon during 2015 aerial and ground surveys, indicating that there was little long-term negative effect from last year's investment in reproduction (although leaf miner caused late-season damage to birch in some areas). Birch catkin production was notably low in 2015.

Abiotic Damage

Hemlock Fluting

Hemlock fluting is characterized by deeply incised grooves and ridges that extend vertically along boles into tree crowns of western hemlock (Figure 26). Hemlock fluting reduces the merchantable volume of hemlock logs because bark is imbedded in the outer wood, but does not negatively impact tree health. 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. The cause of fluting is not fully understood, but it is associated with increased wind-firmness and sites with shallow soils. Fluting may be triggered during growth-release following pre-commercial thinning or natural disturbances that increase exposure to wind. Trees may also be genetically predisposed to fluting. Planting seed from severely fluted trees on protected, productive sites with stable soils could help to discern genetic versus environmental causes of fluting.

Figure 26. Deep grooves characteristic of hemlock fluting. This condition is often widespread within a forest stand.

Windthrow

In 2015, 820 acres of windthrow were mapped by aerial detection survey, more than twice the acreage mapped in 2014, but far less than the thousands of acres mapped in 2013 and over a million acres affected in 2012. In 2012, there was an enormous windthrow event in the upper Tanana Valley and a moderate event on the Kenai Peninsula. Although windthrown trees can create ideal breeding conditions for bark beetles, there have been no large-scale outbreaks as a result of these events. However, small outbreaks of engraver beetles have developed in some locations (see the essay on page 52). In 2015, all but 40 acres were mapped in Southeast Alaska in patches up to 160 acres (Nichols Bay on southern Prince of Wales Island). Windthrow was also concentrated along the Behm Canal and Burroughs Bay in the Misty Fiords Wilderness Area, as well as Admiralty Island's Glass Peninsula and nearby mainland.

Wind is a common and important small-scale disturbance in Alaskan forests. It contributes to bole snap of individual trees with stem or butt rot, or trees that are tall and skinny. Wind can also result in complete failure of trees (or clumps of trees) rooted on shallow, saturated soils (Figure 27) or trees with root disease. Stand-level windthrow may occur on exposed sites when heavy rain is followed by extreme wind. Windthrow potential is predicted by stand characteristics (tree height to diameter ratios, tree density, exposure and slope), as well as mechanical properties (tree height, diameter, crown size and rooting depth). Although larger diameter trees are more wind firm, they are also more likely to have stem decay.

Figure 27. An uprooted tree on a site with shallow, rocky soil.

Flooding

Flooding can be caused by rainfall and snowmelt or by stream channel disruption (e.g., beaver activity, windthrow, landslide, etc.), and the cause can sometimes be difficult to distinguish from the air. Therefore, this type of damage overlaps the abiotic damage and animal damage categories. Flooding and high-water damage were mapped on nearly 10,000 acres in 2015. There was only a slight decrease from the acreage mapped in 2014 despite the lower rainfall; one possible explanation is that stands stressed by flooding in 2014 were unable to recover. The bulk of this year's damage (>7,000 acres) was mapped in Western and Southcentral Alaska. Approximately 4,500 acres of damage were observed in Western Alaska, while over 700 acres were observed on the Kenai Peninsula and in Prince William Sound. Nearly 1,500 acres were mapped in the Matanuska-Susitna Valley, including 1,200 acres along the Alaska Range near the Kahiltna River and outwash from the Kahiltna Glacier. Flooding damage in the upper Tanana and Yukon River Valleys of the Interior decreased from roughly 2,700 acres in 2014 to about 1,600 acres in 2015. Damage was observed in roughly the same areas (i.e., the Minto and Tanana Flats) both years. In Southeast Alaska, 650 acres of flooding damage were widely scattered in small patches (most less than 20 acres) along the Chilkat and Klehini Rivers near Haines and Klukwan, and on Admiralty, Kuiu, Mitkof, Etolin and Prince of Wales Islands.

Animal Damage

Brown Bears on Yellow-Cedar
Ursus arctos L.

Yellow-cedar trees on Baranof and Chichagof Islands are often wounded in the spring by brown bears. Surveys conducted in the 1980s found that over half of the yellow-cedar trees in some stands were scarred while other tree species were unaffected. The incidence of bear damage tends to be greatest in productive stands with deep soils that are less likely to experience yellow-cedar decline. Brown bears use their teeth to rip away bark from lower tree boles, usually on the uphill side of the tree, apparently to feed on the inner bark tissue. Bear damage does not typically kill trees and callus tissue slowly develops around wounds, but bear scars serve as entry points for stem decay fungi that reduce wood volume.

Porcupine Feeding
Erethizon dorsatum L.

In 2015, about 1,000 acres of porcupine damage were mapped, less than the 1,800 acres mapped in 2014. The most extensive damage was observed in young-growth stands on the mainland, Wrangell Island (along the Zimovia Highway to Nemo Point), Kupreanof Island, and Etolin Island (South Anita Bay). Most of the mapped damage (800 acres) occurred on lands managed by Native Corporations, particularly around Hobart Bay. Last year, pronounced porcupine damage was mapped on North Kupreanof Island and it was observed as being severe there again this year. Porcupine damage must be severe enough to girdle and kill trees to be visible from the air (Figure 28), and is therefore under-mapped during the aerial survey. Variation in mapped acreage is also affected by differences in surveyor focus on this type of damage and the specific locations flown.

Figure 28. An aerial survey view of porcupine-caused mortality in a young-growth stand on Anita Bay, Etolin Island.

Porcupine feeding damage commonly occurs in winter, when tree branches, twigs, and inner bark become a diet staple. Feeding damage to spruce, hemlock, and birch boles causes bole scarring, top-kill, or tree mortality, reducing timber values but enhancing 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 4 to 10 inches in diameter. Porcupine feeding typically tapers off over time; surviving, damaged trees often have forked tops and develop internal wood decay. Porcupines feed only sparingly on western redcedar or yellow-cedar. Young stands with a cedar component provide more thinning treatment options. Where porcupines are problematic, managers can prescribe a tighter thinning spacing and favor tree species that are less attractive to porcupines.

Porcupines are absent from several islands in Southeast Alaska, including Admiralty, Baranof, Chichagof and Prince of Wales. Their distribution suggests historic points of entry and migration along the major river drainages in Interior British Columbia to mainland Alaska and nearby islands.

Forest Declines

Yellow-cedar Decline

Forest Health Protection and colleagues from the Forest Service Alaska Regional Office and National Forest System have developed a comprehensive conservation strategy for yellow-cedar in Southeast Alaska to account for yellow-cedar decline. In four sections and multiple appendices, this report focuses on what is known about: the ecology, cultural and commercial values, taxonomy, and silvics of the tree; the mechanism and risk factors of yellow-cedar decline; guidance and opportunities for the active management of yellow-cedar; the development of models to spatially display and estimate the distribution of yellow-cedar and the risk factors for decline now and into the future; and the current and projected future status of yellow-cedar in 33 management zones in Alaska. The report is available for download at: http://www.fs.fed.us/pnw/pubs/pnw_gtr917.pdf and the citation is:

Hennon, P. E., C. M. McKenzie, D. V. D'Amore, D. T. Wittwer, R. L. Mulvey, M. S. Lamb, F. E. Biles, and R. C. Cronn. 2016. A climate adaptation strategy for conservation and management of yellow-cedar in Alaska. PNW-GTR-917. Portland, OR: U.S. Dep. Agric., For. Serv., Pacific Northwest Research Station. 382p.

Yellow-cedar decline functions as a classic forest decline and has become a leading example of the impact of climate change on a forest ecosystem. The term forest decline refers to situations in which a complex of interacting abiotic and biotic factors leads to widespread tree death, usually over an extended period of time. It can be difficult to determine the mechanism of decline, and the causes of many forest declines throughout the world remain unresolved.

Yellow-cedar decline is linked to climate change. Yellow-cedar trees are killed by freezing injury to fine roots where there is insufficient snowpack to insulate them from lethal cold temperatures (< -5°C, 23°F). Since yellow-cedar is a long-lived tree, many affected yellow-cedar forests established under the colder, more favorable climate of the Little Ice Age (1400-1850). An abnormal rate of yellow-cedar mortality began around 1900, spiked in the 1970s and 1980s, and continues today. On wet sites, where yellow-cedar faces less competition from western hemlock and Sitka spruce and is more abundant, yellow-cedar trees with shallow fine roots are particularly vulnerable to freezing injury. Research into root and foliar cold tolerance has shown that yellow-cedar roots are more vulnerable to this type of injury than associated conifers. Impacted forests tend to have mixtures of old dead, recently dead, dying, and living trees, indicating the progressive nature of tree death. From the time crown symptoms appear, it often takes 10 to 15 years for trees to die, making it difficult to associate observations from aerial surveys to weather events in particular years. Yellow-cedar is extraordinarily decay resistant and tree often remain standing for 80 to 100 years after death.

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. These losses may be balanced by yellow-cedar thriving in other areas, such as higher elevations and unimpacted parts of its range to the northwest. Yellow-cedar is preferred deer browse, and deer may significantly reduce regeneration in locations where spring snowpack is insufficient to protect seedlings from early-season browse.

Distribution of Yellow-Cedar Decline

The mapped acreage of active yellow-cedar decline (dying trees with yellow to red crown symptoms) increased from about 20,000 acres in 2014 to almost 40,000 acres in 2015. Although this was considered a dynamic year for yellow-cedar decline, the elevated acreage also resulted from more intensive surveys; we mapped decline during our annual aerial survey in July and an additional survey focused on Prince of Wales Island in October. The objective of the October survey was to comprehensively map active yellow-cedar decline to gather information on forests with salvage harvest potential (see the essay on page 28 for more information). Local expert observations and mapped data suggest that active decline has increased from recent years despite the relatively low acreage value of our initial July survey. Much of the active decline mapped during our special survey had never been previously detected, indicating that these areas are not typically flown during our annual survey and/or this activity is new.

In 2015, active decline was mapped as far north as Yakobi Island and was most intense on Chichagof and Baranof Islands in the vicinity of Hoonah Sound, Deep Bay and Poison Cove along Peril Strait (Map 6; Table 8). Abundant active decline was also mapped in Crawfish Inlet, just south of Redoubt Lake on Baranof Island and scattered throughout Kupreanof, Kuiu, and Etolin Islands. Our comprehensive yellow-cedar decline survey on Prince of Wales Island showed widespread active decline, particularly at mid and high elevations over the northern half of the island. Yellow-cedar forests along the coast of Glacier Bay and in Prince William Sound remain healthy.

Over 614,000 acres of decline have been mapped in Alaska through aerial detection survey since surveys began in the late-1980s, with extensive mortality occurring in a wide band from the Ketchikan area to western Chichagof and Baranof Islands. This cumulative estimate has been refined using GIS filters to exclude certain decline-mapped areas based on the distribution of yellow-cedar forest. For this reason, it is problematic to compare the cumulative acreage of decline across consecutive years to detect trends in yellow-cedar decline activity.

Recent Projects & Publications

In 2013, staff from the Wrangell Ranger District and Alaska Region Forest Health Protection examined dead and dying yellow-cedars in young-growth on Zarembo Island. This was the first observed instance of yellow-cedar decline in managed young-growth forests. *Phloeosinus* beetle galleries, Armillaria root disease, and staining of the coarse roots associated with fine root-freezing injury were common on affected trees, the same signs and symptoms observed in affected old-growth forests. We have worked with the Tongass National Forest to compile a list of young-growth stands known to contain yellow-cedar to facilitate monitoring (Figure 29). In 2015, several additional young stands with decline symptoms were identified by ground

Map 6. Current (2015) and cumulative cedar decline mapped by aerial detection survey in Southeast Alaska.

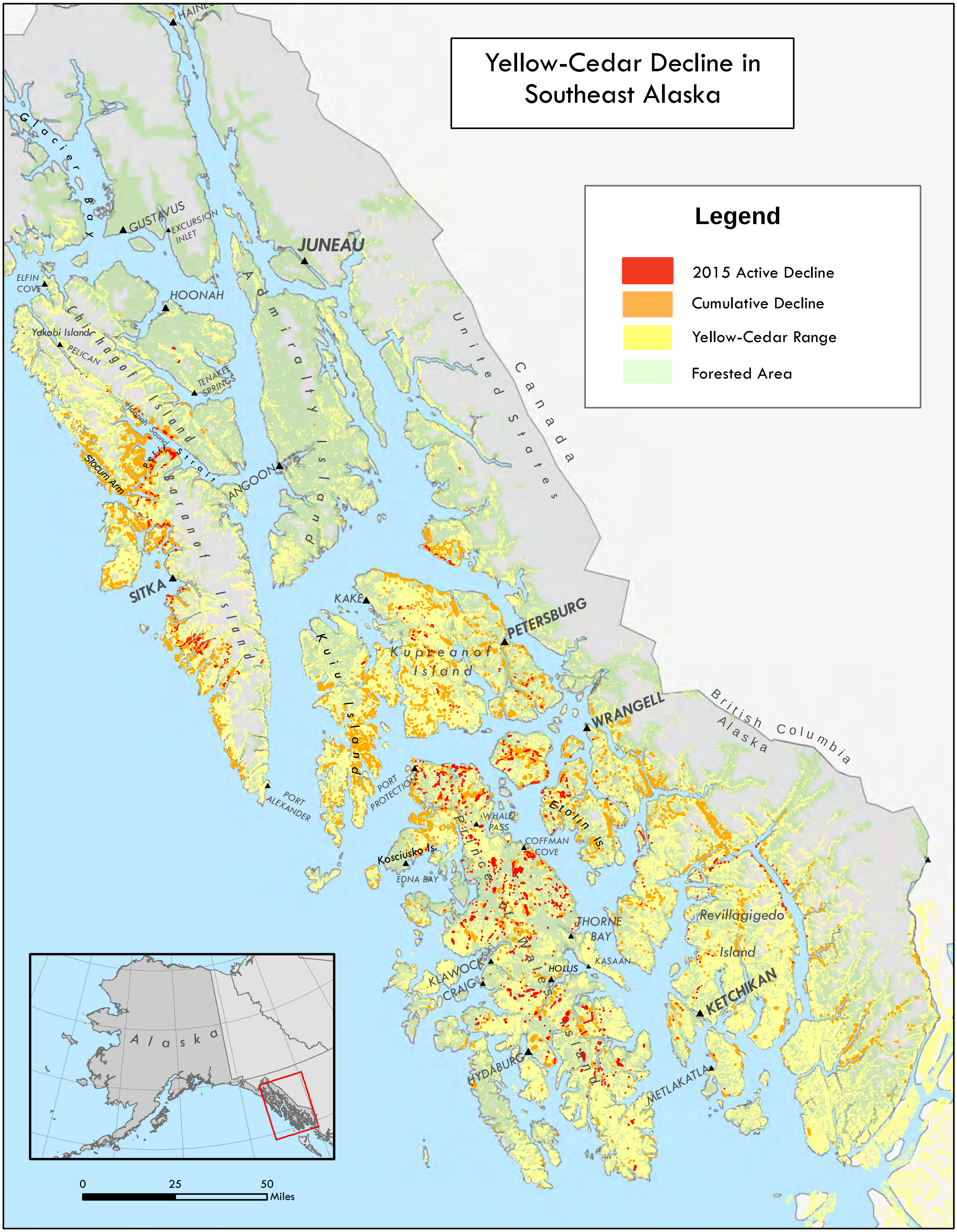


Table 8. Cumulative acreage affected by yellow-cedar decline as of 2015 in Southeast Alaska by ownership.

National Forest	**562,545**
Admiralty Monument	**4,537**
Admiralty Island	4,537
Craig Ranger District	**40,152**
Dall and Long Islands	1,573
Prince of Wales Island	38,579
Hoonah Ranger District	**504**
Chichagof Island	504
Juneau Ranger District	**992**
Northern Mainland	992
Ketchikan Ranger District	**41,290**
Annette & Duke Islands	2,162
Gravina Island	1,765
Mainland	17,960
Revillagigedo Island	19,403
Misty Fjords Monument	**34,420**
Mainland	23,952
Revillagigedo Island	10,468
Petersburg Ranger District	**177,028**
Kuiu Island	76,676
Kupreanof Island	79,999
Mainland	10,120
Mitkof Island	7,533
Woewodski Island	2,700
Sitka Ranger District	**122,019**
Baranof Island	56,419
Chichagof Island	40,803
Kruzof Island	24,797
Thorne Bay Ranger District	**71,056**
Heceta Island	1,520
Kosciusko Island	13,998
Prince of Wales Island	55,538
Wrangell Ranger District	**70,547**
Etolin Island	25,164
Mainland	20,895
Woronkofski Island	1,380
Wrangell Island	11,259
Zarembo Island	11,849

Native	**21,671**
Admiralty Island	55
Baranof Island	321
Chichagof Island	957
Dall and Long Islands	1,220
Heceta Island	6
Kruzof Island	135
Kuiu Island	606
Kupreanof Island	4,047
Mainland	1,100
Prince of Wales Island	11,151
Revillagigedo Island	2,073
Other Federal	**337**
Baranof Island	20
Chichagof Island	2
Etolin Island	31
Kuiu Island	176
Kupreanof Island	60
Mainland	1
Prince of Wales Island	47
State & Private	**29,915**
Admiralty Island	21
Baranof Island	3,905
Chichagof Island	1,085
Dall and Long Islands	51
Etolin Island	48
Gravina Island	1,809
Heceta Island	64
Kosciusko Island	215
Kruzof Island	394
Kuiu Island	855
Kupreanof Island	2,370
Mainland	3,904
Mitkof Island	2,044
Prince of Wales Island	7,049
Revillagigedo Island	4,264
Wrangell Island	1,697
Zarembo Island	140
Grand Total	**614,468**

and air on Zarembo (Figure 30), Kupreanof (Figure 31), and Mitkof Islands. Many stands identified during the aerial survey will be ground verified in 2016. We will continue to monitor this emerging issue, which will likely influence yellow-cedar management in some young stands with risk factors.

This year, Lauren Oakes completed her PhD at Stanford University and published about the distribution and ecological, cultural and social views around yellow-cedar and yellow-cedar decline (Oakes et al. 2015). She mapped and studied healthy yellow-cedar in Glacier Bay National Park and assessed the future risk of these populations to yellow-cedar decline. She also examined the social views and perceptions around the acceptability of active management intervention (planting and salvage) inside and outside National Parks and National Forest Wilderness Areas.

Last year, Lauren Oakes published her work quantifying changes in forest community structure in yellow-cedar forests (Oakes et al. 2014). The primary ecological effects of yellow-cedar decline are changes in stand structure and composition. Lauren's key findings were that succession favors other conifer species, especially western hemlock, and that understory functional plant diversity and composition changed.

A large team of specialists from the US and Canada initiated a project in 2015 to evaluate the climate vulnerability for yellow-cedar throughout its entire range, from northern California to Prince William Sound in Alaska. This project includes the production of a new high resolution map of yellow-cedar's occurrence, analysis of elevational trends for both yellow-cedar and existing forest decline, and incorporation of climate models related to freezing injury, drought, and fire to predict

Figure 29. A yellow-cedar stand on Zarembo Island is monitored for yellow-cedar decline symptoms and found to be healthy.

Figure 30. A yellow-cedar tree with a thin, discolored tree crown, consistent with yellow-cedar decline, in a young-growth stand on Zarembo Island.

Figure 31. An aerial survey view of yellow-cedar decline crown discoloration symptoms of crop trees in a thinned 34-year-old stand on Kupreanof Island.

future mortality. University of Alaska Southeast, University of Alaska Fairbanks, and the Forest Service have initiated a project to understand the establishment, migration and spread of yellow-cedar populations near Juneau. Graduate student John Krapek is mapping all known yellow-cedar populations in the area and establishing plots at population boundaries (Figure 32) to examine regeneration success and stand expansion into existing plant communities. His project may determine why yellow-cedar is so rare around Juneau, and whether populations are expanding.

The Alaska Coastal Rainforest Center, US Forest Service, State of Alaska, and University of Alaska Southeast initiated a project to evaluate the economic feasibility of salvaging dead yellow-cedar. Monitoring plots have been installed on Kupreanof Island to compare forest composition, structure, seedling regeneration, and damage to residual trees from logging equipment in salvaged and unsalvaged stands impacted by yellow-cedar decline. Salvage recovery of standing dead yellow-cedar trees in declining forests can help produce valuable wood products and offset harvests in healthy yellow-cedar forests. For more information on salvage logging, see the essay on page 28.

Figure 32. John Krapek and Alex Botelho adjust survey equipment used to stem-map trees, saplings and seedlings in yellow-cedar stands near Juneau. Photo credit: Mark Rainery, University of Alaska Southeast.

References:

Oakes, L., P. Hennon, K. O'Hara, and L. Dirzo. 2014. Long-term vegetation changes in a temperate forest impacted by climate change. Ecosphere 5(10): 135, pp. 1-27.

Oakes, L., P. E. Hennon, N. M. Ardoinc, D. V. D'Amore, A. J. Ferguson, E. A. Steel, D. T. Wittwer and E. F. Lambin. 2015. Conservation in a social-ecological system experiencing climate-induced tree mortality. Biological Conservation 192: 276–285.

STATUS OF INVASIVE PLANTS

This jumble of flowers on a Fairbanks hillside consists of two invasive plants: birdvetch (the purple flowers, *Vicia cracca*) and Siberian alfalfa (the yellow flowers, *Medicago sativa* var. *falcata*). Both of these nitrogen- fixers crowd out and grow over native understory species.
Photo credit: Darcy Etcheverry.

A GIS-based Approach to Prioritizing Surveys for Invasive Aquatic Plants in Southeast Alaska

Tom Heutte and Tricia Wurtz, USDA Forest Service

Elodea is a genus of freshwater aquatic plants that is often used in aquariums. First recorded in the 1980's in Eyak Lake in Cordova; it has since been found in more than 20 locations in Southcentral and Interior Alaska. At some of these locations, Elodea was likely introduced by aquarium dumping; at others, the plant was unintentionally introduced by floatplane traffic coming from an infested waterbody. When released to the wild, Elodea can spread aggressively, and has the potential to degrade fish habitat, alter stream flow and sedimentation and displace native plants and animals. Additionally, it can reduce property values, hamper navigation and be a hazard to floatplane operation. Elodea is Alaska's first invasive aquatic plant. The State of Alaska is currently developing a state-wide management plan for Elodea. To date, no infestations of Elodea have been found in Southeast Alaska.

There are over 22,000 lakes and ponds in Southeast Alaska. In 2015, FHP staff conducted a geographic information system (GIS) analysis to prioritize lakes for survey. Use of GIS software for decision support ensures a logical process to decide where to look for invasive species. GIS stores and displays geographic data as a series of layers allowing users to analyze spatial relationships among elements (Figure 33).

The first step was to define risk factors. We know Elodea grows only in freshwater, and the water must be still or slow-moving. We then considered ways Elodea could be introduced to lakes and ponds, and how plant material could be transported from one lake to another. We also know people will sometimes dump aquariums into lakes and ponds when they can no longer maintain them. Elodea is also sold to science teachers by educational supply companies, and sometimes classroom plants or animals are released into the wild at the end of the school year. For instance, in 1982, a schoolteacher in a small Southeast Alaska community purchased some red-legged frog (*Rana aurora*) eggs from an educational supply company (red-legged frogs are not native to Alaska). Students watched the eggs hatch into tadpoles in their classroom, and watched as the tadpoles turned into frogs. At the end of the school year, the teacher released about two dozen adult frogs into a nearby pond. Twenty years later, red-legged frogs have spread widely from that one site, occupying all suitable amphibian habitats in more than 12,000 acres. Native amphibians have been completely displaced in those locations; not a single native frog or toad could be found. Thus, the possibility of an aquarium dump sent us on a virtual hunt for lakes in southeast Alaska where people would be most likely to empty out home or classroom aquariums.

Once Elodea has infested a lake, it can be spread to other waterbodies by floatplanes. Dispersal by this route can be widespread and rapid. While there are numerous floatplanes landing on freshwater lakes all over Southeast Alaska, commercial operators start and end their day on saltwater, brackish water or hard-surfaced runways. Because salt water is inhospitable to Elodea, we focused on the lakes most at risk for aquarium dumping in our analysis. If Elodea is found in a Southeast Alaska lake experiencing any amount of floatplane activity, our approach to prioritizing lakes for survey will change.

We used GIS software to show overlap among features like lakes, population centers, roads, and recreation sites. In the first elimination round, we looked for lakes near population centers, selecting lakes in a ten-mile radius around the 19 communities in Southeast Alaska having a population of at least 250 people. This step reduced the lakes under consideration from 22,000 to 3,000. A limitation of this approach is the rugged topography of southeast Alaska. Many lakes located within the ten-mile radius of a community are virtually inaccessible from that community (unless you happen to be a mountain goat) (Map 7).

To eliminate close-but-still-inaccessible lakes, we settled on a maximum distance of 50 yards from road to lake. In southeast Alaska there are 135 lakes meeting these criteria. We further narrowed down the list to a group of 26 very high-risk lakes using the Tongass National Forest data for recreation sites, looking for lakes near boat launches and public parking areas. Of these 26 lakes, 12 are inside the Tongass National Forest or share a boundary with it.

The knowledge of local land managers and community members should be a component in any survey design.

GIS is a powerful tool for decision support. But in a complicated world, we shouldn't let the computer make all the decisions. The knowledge of local land managers and community members should be a component in any survey design. Our approach sets up a logical framework we can supplement with local knowledge to further refine this prioritization.

In 2016, FHP staff, Tongass National Forest staff, and representatives of other land management agencies will work together to survey those 26 lakes for Elodea. Keep your fingers crossed that we don't find it.

For more information about the lake surveys, please contact Tom Heutte at theutte@fs.fed.us ⌘

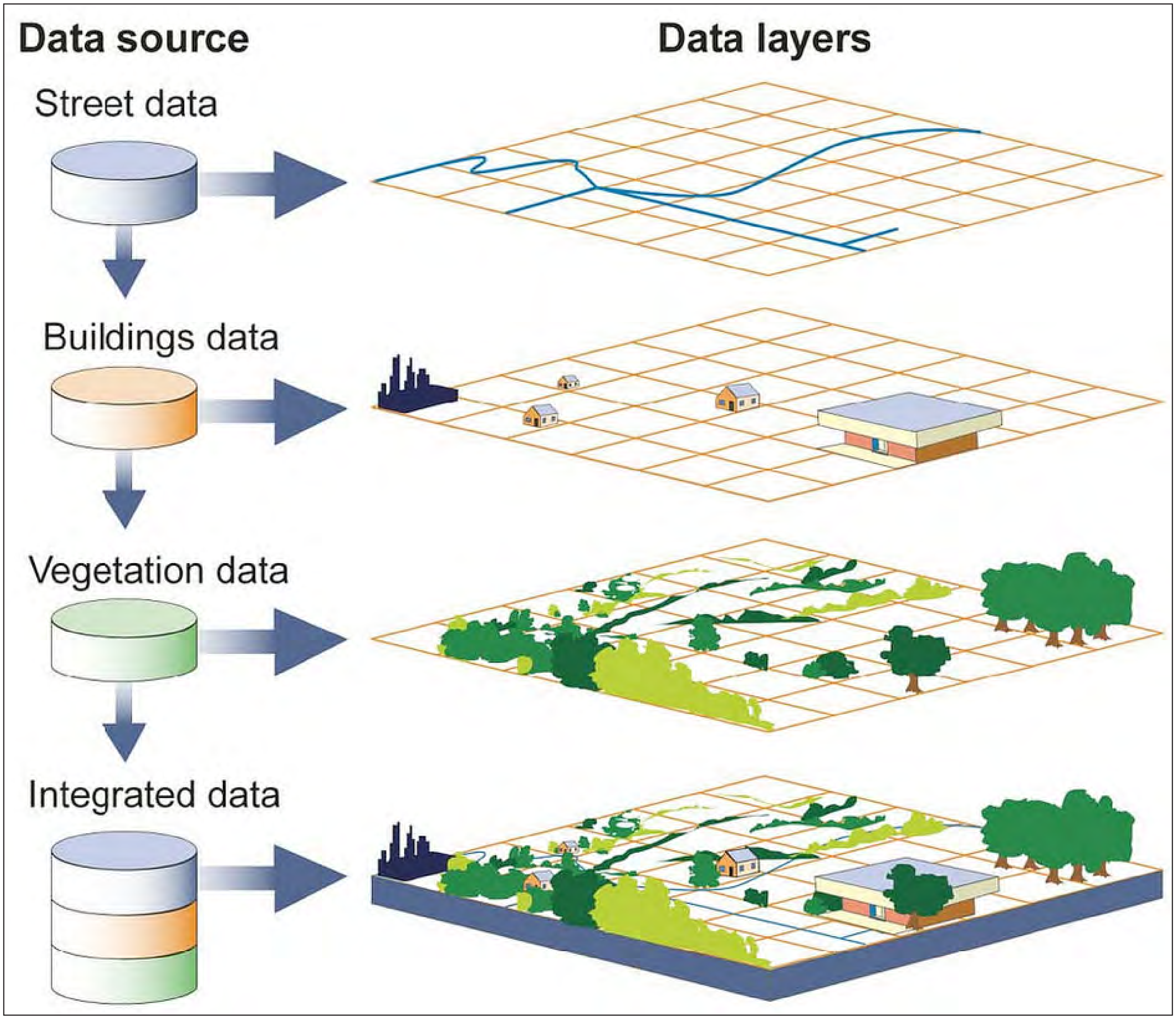
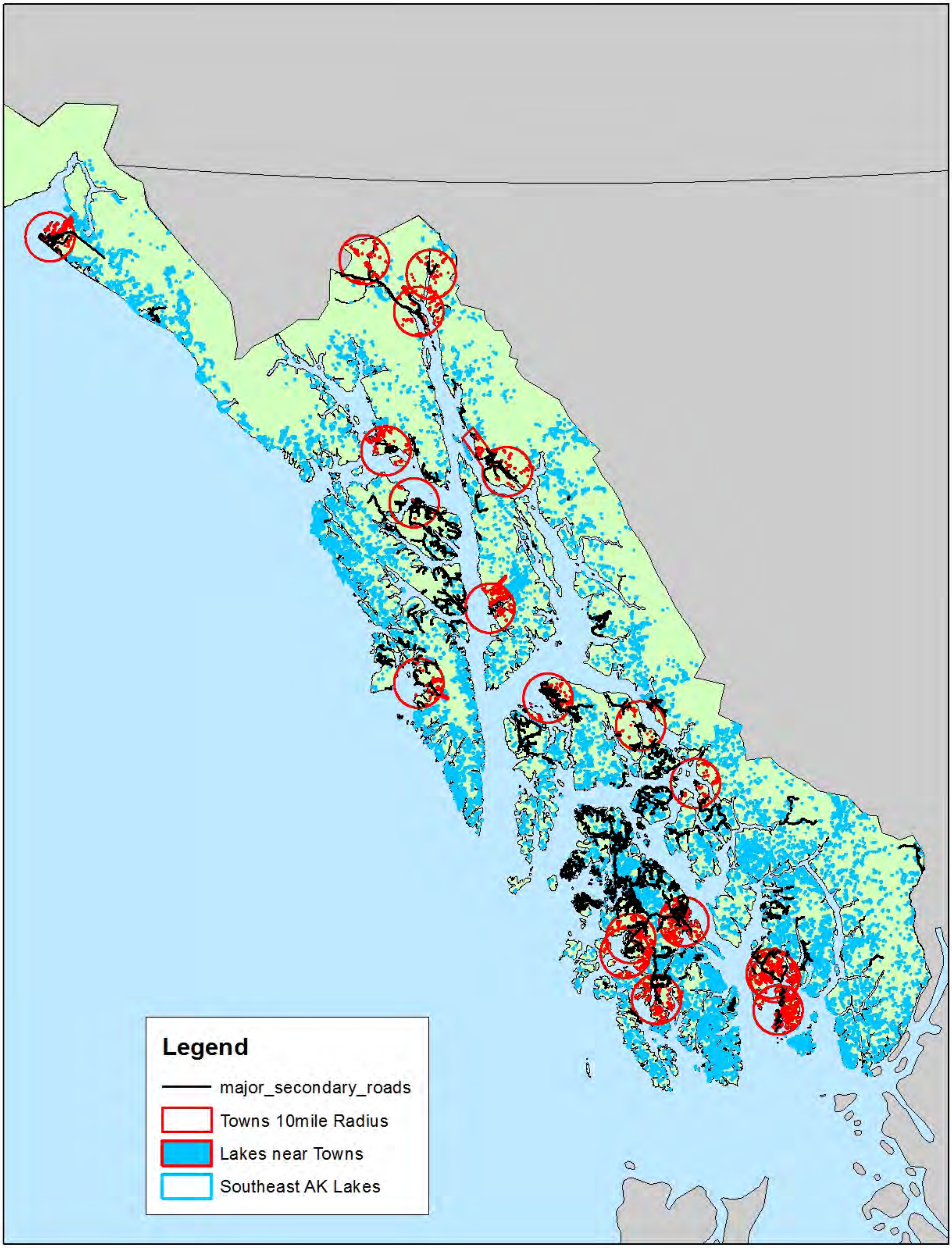


Figure 33. Schematic diagram showing how GIS data is stored, visualized and integrated for analysis as map layers.

Map 7. Southeast Alaska lakes and population centers.



Best Management Practices (BMPs) for Preventing the Spread of Invasive Plants During Road Maintenance: Online and Print Education

Gino Graziano, University of Alaska Fairbanks, Cooperative Extension Service

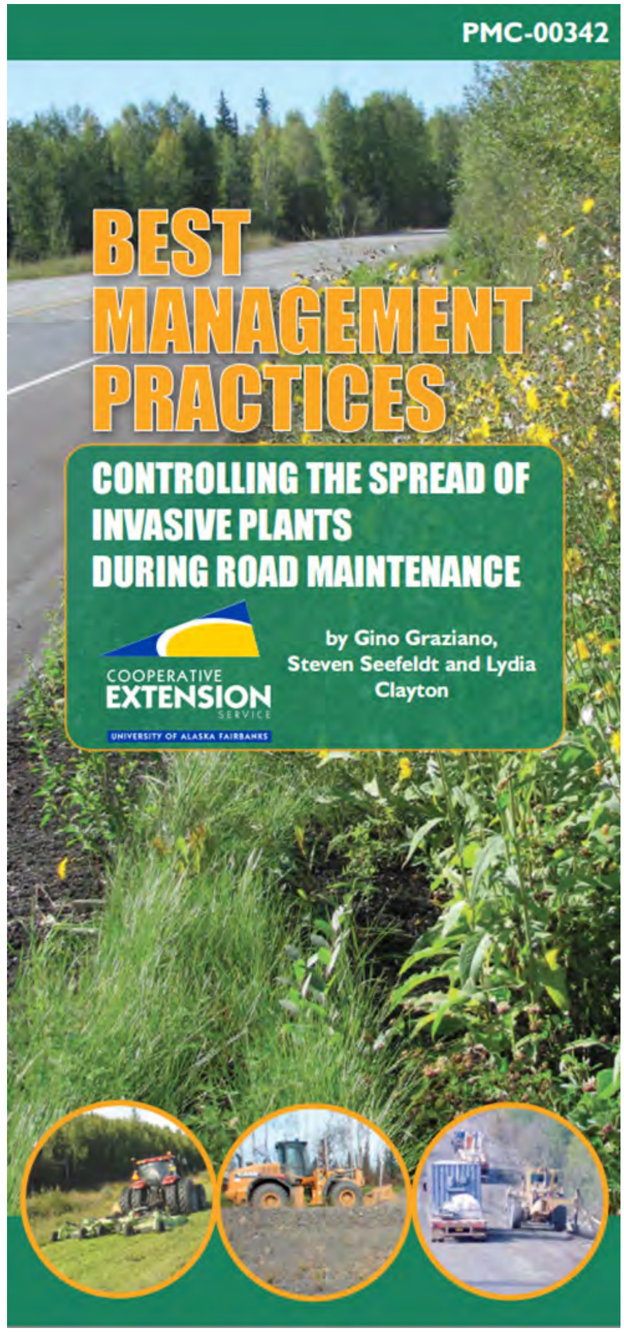


Figure 34. The new BMP manual was a joint effort of the Cooperative Extension Service and AKDOT&PF.

Roads and rights-of-way are widely recognized as primary pathways for the movement of invasive plants, making the managers of those roads and rights-of-way key regional players in invasive plant management. In Alaska, recent changes to pesticide-use regulations ease the process for the application of herbicides on state lands, including rights-of-way. The regulation changes have resulted in the Alaska Department of Transportation and Public Facilities (ADOT&PF) adopting an Integrated Vegetation Management Plan, defining how they and others will use herbicides in the rights-of-ways they manage.

These developments spurred the University of Alaska Fairbanks Cooperative Extension Service (CES) to work with ADOT&PF in developing a Best Management Practices (BMP) manual and an online course on preventing the spread of invasive plants during road maintenance (Figure 34). Online training is available through a self-paced web course that provides a certificate of completion after successfully passing section quizzes and a final test. The BMPs are intended for people who perform routine maintenance activities such as vegetation clearing on roads, trails, railways, and utility corridors.

Prevention is the first step in any integrated vegetation management program. Cleaning equipment regularly to ensure weed seeds are not transported is an ideal measure. Other measures include using certified weed-free gravel, topsoil, and erosion control tubes.

Planning to avoid spreading known infestations is important, too. Many of the invasive plant infestations on Alaska's roadsides are already recorded in the Alaska Exotic Plant Information Clearinghouse (AKEPIC) database. The manual and course guide highway managers in the use of AKEPIC to locate known infestations. AKEPIC has an interactive web map allowing users to download documented invasive plant location data for the whole state, for specific species, and for user-defined areas. But the existence of the AKEPIC database does not replace the need to scout work areas regularly, or the need to coordinate with local invasive plant managers.

Highway maintenance workers may be the first to spot new infestations of high-priority plants. The new mobile application (see "There's and app for that…" page 48) makes reporting new infestations quick and easy.

The BMP manual and course take an "integrated vegetation management" approach to the topic. **Physical (mechanical) methods** such as mowing, grading, and hand pulling are often used in conjunction with other control methods. Mowing considerations include timing and frequency (Figure 35). **Biological weed control** is the use of insects, grazers and pathogens to control a weed population. Currently there are no weed species in Alaska with both an approved biocontrol agent and large enough weed populations to sustain the agent. While grazing animals can be valuable for biocontrol, their use on rights-of-way can be problematic. **Cultural methods** include keeping areas mowed prior to weed seed development and promoting desirable vegetation. Promoting desirable vegetation can help prevent weed establishment by eliminating bare ground where weeds are likely to invade. For more information on practices to promote desirable vegetation, course participants are directed to the "Revegetation Manual for Alaska" (http://dnr.alaska.gov/ag/RevegManual.pdf). **Chemical methods** of control are covered in the manual, providing species-specific chemical control information and recommended application rates.

Figure 35. An example of a BMP, or best management practice, is paying attention to the timing of roadside weed mowing. Mowing just before seeds are produced reduces the likelihood of weed spread. Photo credit: Brett Nelson.

Some best management practices described in the manual include:

Use certified weed-free materials such as gravel, topsoil, hay/straw and erosion control tubes

Identify the location of known invasive plant infestations prior to work in the field

Scout for invasive plants prior to performing maintenance activities

- Record and report locations of invasive plants
- Avoid working in infested areas, if possible
- Clean vehicles and equipment regularly
- Revegetate with native, local, and/or noninvasive plant species
- Work from uninfested areas toward infested areas
- Time mowing to prevent seed production
- Coordinate with local groups that manage invasive plants

The new manual and course encourages users to learn to identify invasive plants, report where they are found, take steps to prevent their spread, and to actively control those species. CES will continue to promote the widespread adoption of these BMPs in Alaska.

The BMP manual can be accessed here: http://www.uaf.edu/files/ces/publications-db/catalog/anr/PMC-00342.pdf.

The online course can be accessed here: https://weedcontrol.community.uaf.edu/. ⌘

2015 Invasive Plant Program Updates

Invasive Plant Program Activities

Elodea update

Elodea (Figure 36) has now been found in more than 20 locations around Alaska. The invasive aquatic plant was likely first introduced to Alaska's wild waterways by aquarium dumping; since then it has been spread by downstream water flow, boats and floatplanes. A range of government agencies and NGOs are collaborating on efforts to eradicate the species from the state, but this remains a daunting prospect. The situation took a dramatic turn on June 10, 2015, when Elodea was discovered growing in Lake Hood by a National Park Service (NPS) pilot/biologist.

Figure 36. The invasive waterweed Elodea was likely first introduced to Alaska waterways by aquarium dumping. Since then it has been spread by downstream water flow, by boats and by floatplanes.

Lake Hood

Anchorage's Lake Hood is the busiest seaplane base in the world. It has more than 300 floatplane slips and in 2012 there were more than 67,000 flight operations (take-offs or landings) there. More than 25 remote lodges, and many more private cabins and remote lakes are served by Lake Hood. Thus, there is enormous potential for Elodea to be spread inadvertently from Lake Hood to remote locations.

Lake Hood had been inspected several times in recent years for the presence of Elodea, and the plant was not found. Whether those earlier inspections missed it, or it was only recently introduced, is not known. Either way, news of its discovery in June caused the State's Invasive Plant and Agricultural Pest Coordinator to leap into action. By July 24, just 44 days later, she had received the required permits and had begun a treatment program in Lake Hood using two aquatic herbicides: diquat and fluridone. Kudos to the State of Alaska, Division of Agriculture and their cooperators for this fast and coordinated response. Funding for this effort came from Anchorage International Airport.

Following the discovery of Elodea in Lake Hood, the float pond of Fairbanks International Airport and the seaplane base of the Juneau Airport (Figure 37) were surveyed, by Fairbanks Soil and Water Conservation District (FSWCD) and FHP staff, respectively. No Elodea was found in either location.

Figure 37. Satellite image of the Juneau, Alaska seaplane base. Green triangles show locations of aquatic plant sampling by FHP staff in summer, 2015.

Other Anchorage Lakes

Three small lakes, Sand, DeLong, and Little Campbell, were found to be infested in 2011. In September, 2015, the State Division of Agriculture began treating them with fluridone.

Mat-Su

Sixty waterbodies in the Mat-Su Borough have been surveyed, and Alexander Lake has the only known infestation. Funding from the Mat-Su Fish Habitat Partnership will allow the Alaska Division of Agriculture to treat Alexander Lake with fluridone beginning in 2016.

Kenai Peninsula

More than 100 lakes were surveyed on the western Kenai Peninsula, and only three infestations were found. Led by the US Fish and Wildlife Service (USFWS), the Kenai Peninsula Cooperative Weed Management Area came together on this issue, quickly acquiring permits and funding. The three lakes were treated with herbicides in 2014 and 2015, and surveys conducted in fall, 2015 detected no Elodea remaining. More intensive surveys will be done in spring of 2016, to determine whether further herbicide applications are needed.

Fairbanks area

Chena Slough and Chena Lake were found to be infested in 2009 and 2011. Chena Slough empties into the Chena River, which joins the Tanana River and later the Yukon. The Chena Slough infestation thus has great potential to spread plant fragments to downstream waters. This concern was substantiated in August, 2015, when foresters with the Tanana Chiefs Conference reported a previously unknown infestation, about sixty miles downriver of Fairbanks. Totchaket Slough is a slow-moving, spring-fed tributary of the Tanana River, twelve miles downriver of Nenana. Although the source of this infestation is not certain, Elodea was likely introduced to Totchaket during a flood event, with plant material originating in Chena Slough.

Following the discovery of the infestation in Totchaket Slough, teams made up of NPS, USFWS, FSWCD, UAF and FHP staff surveyed all likely sloughs and oxbows of the Tanana River from Fairbanks downriver to Minto, a total of 127 sites. No additional infestations were found. With funding from the USFWS, the FSWCD is working on permit applications to treat the Fairbanks-area infestations. A source of funds for the proposed treatment effort has not yet been identified.

Cordova/Copper River Delta

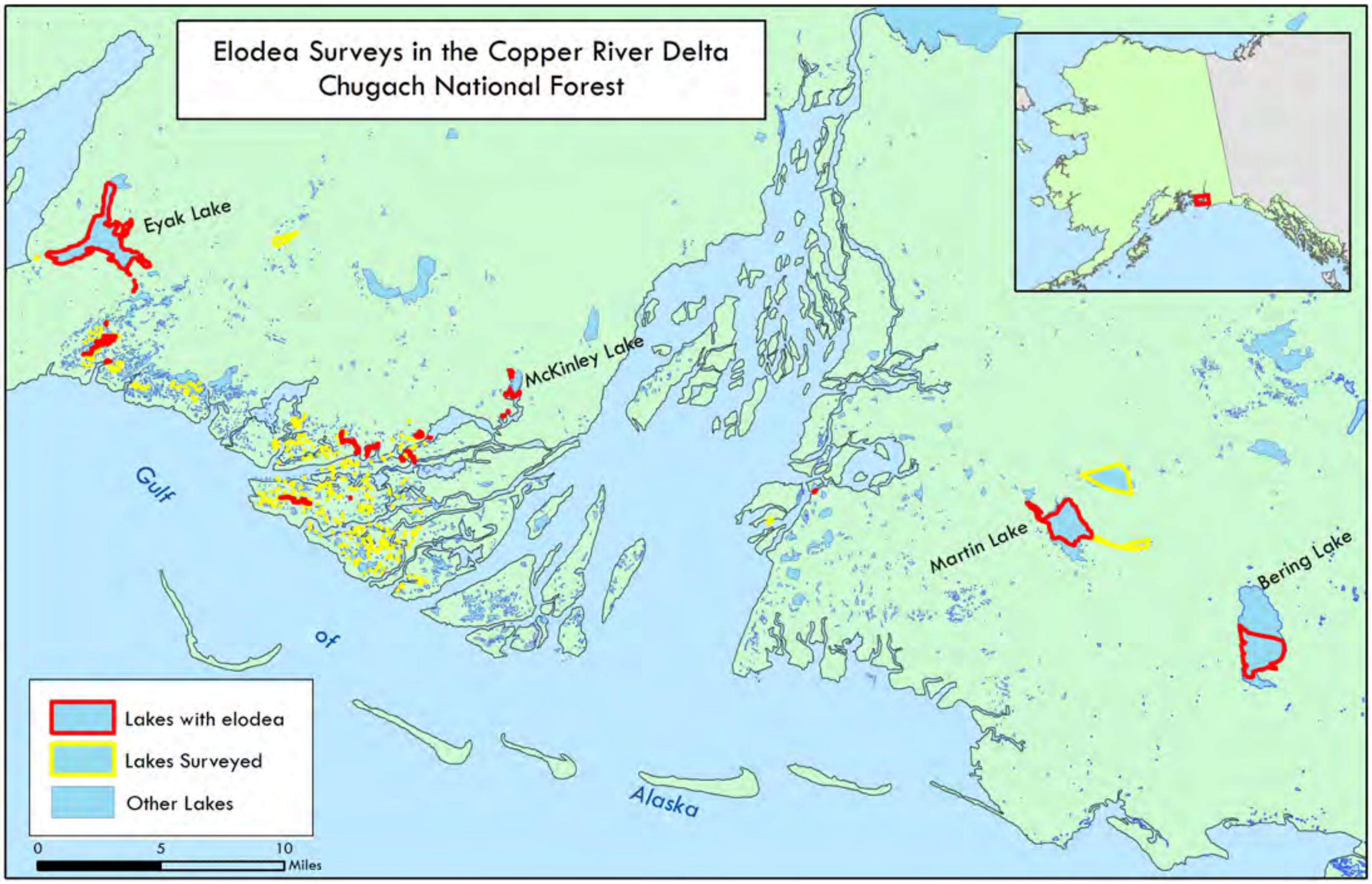
Elodea was first recorded in Eyak Lake in 1982. Since 2011, the Chugach National Forest has put substantial effort into determining the current distribution of Elodea on the national forest, surveying dozens of likely sites. By the end of 2015, a fairly complete picture had emerged (Map 8). It appears that after being introduced to Eyak Lake in the 1970s or early 1980s, Elodea's extent in the lake gradually increased. It spread downstream from Eyak Lake into Eyak River, and appears to have been carried into nearby ponds during flood events. Jet and air boats travelling from Eyak Lake likely spread Elodea in the western delta. Floatplanes carried it to at least two large lakes in the eastern delta, and may have dropped some in smaller lakes along the flight path.

Cordova and the Copper River Delta currently have more Elodea-infested waterbodies and the largest infestations of any region in the state. For comparison, the three successfully-treated lakes on the Kenai Peninsula cover a total of roughly 1100 acres. In contrast, Eyak Lake alone is 2400 acres, and the total infested area in the Cordova/Copper River region is more than 7200 surface acres. In addition to the size of the lakes, much of the infested area is remote and challenging to access. Finally, the Copper River Delta is unique among areas with Elodea in that it supports essential rearing grounds for ecologically and economically important salmonids, and provides significant shorebird resources.

For these reasons, the Cordova Ranger District is laying the groundwork for a pilot study of the use of fluridone to treat Elodea. The plan involves treating three of the smaller infested ponds in 2016. The chemical applications will be done in collaboration with a team from USFS Pacific Northwest Research Station, Oregon State University, Loyola University, and University of Notre Dame. These researchers began examining the role of Elodea in the Copper River Delta ecosystem this past year, and are asking some key questions that have not been addressed in other parts of the state: How does the distribution and abundance of Elodea change during the growing season? Has the introduction of Elodea changed native plant community composition or fish habitat quality? Could Elodea be filling what was a vacant ecological niche?

The team is studying the aquatic vegetation community in Eyak, McKinley and Martin Lakes and in three smaller ponds. In 2015, snorkel surveys were conducted to estimate percent

Map 8. Known distribution of Elodea in the Cordova / Copper River Delta area.



plant cover, both Elodea and 30 native aquatic plant taxa, using 1m² plots (Figure 38). The team also collected over 600 macroinvertebrate samples from benthic habitat and vegetation for use as bioindicators of aquatic habitat condition. Fyke nets were employed to compare fish use of Elodea-dominated plant beds to plant beds comprised of native vegetation. Water temperature and dissolved oxygen data were collected.

Figure 38. Chugach National Forest technician, Elizabeth Camarata, uses a packraft, snorkel and mask to survey the aquatic vegetation in Wrongway Pond, in the western Copper River Delta. In shallow ponds, the packraft functions as a portable platform for the surveyor. Plot frames can be viewed from above and the surveyor can avoid getting tangled up in the dense aquatic vegetation. Photo credit: Alanna Gotshall.

This research is a multi-year effort, and full analysis of the data will take time. But it will provide valuable insights for assessing the effects of potential management actions. An understanding of both spatial extent and functional implications of widespread infestation will inform cascading management decisions now, as well as in future confrontations with invasive aquatic species.

Alaska Association of Conservation Districts continues its mini-grant program

FHP's invasive plant program has worked closely with the Alaska Association of Conservation Districts (AACD) for many years. AACD uses FHP funding to run an invasive plant "mini-grant" program, substantially increasing the number of groups engaged in invasive plant projects around the state. In 2015, AACD's mini-grant program awarded more than $88,000 to 10 different organizations.

One of them, Metlakatla Indian Community, continued its efforts to eradicate two small infestations of orange hawkweed (*Hieracium aurantiacum*) and tansy ragwort (*Senecio jacobaea*), the only infestations of those species on Annette Island. Both infestations have declined substantially in size since being targeted. The director of Metlakatla's invasive species program wrote "Preservation of our traditional culture and subsistence lifestyle is important and heavily influences the management decisions we make in controlling invasive species on Annette Island….We consider public outreach to be one of our greatest tools in invasive weed control. In addition to planning multiple community outreach events, we make a concerted effort to hire youth as our team members in control work, thus 'infecting' them with the passion to continue being stewards of their island."

Homer Soil & Water Conservation District (HSWCD) conducted invasive plant surveys in the remote village of Nanwalek on the south side of Kachemak Bay. This project was an extension of the previous season's work in the village of Port Graham, where similar surveys were conducted. Alaska DOT & PF is planning to construct a road that connects the two villages, as well as a new airport that will be shared by the residents. HSWCD's surveys have provided baseline data on existing invasive plants in these two isolated communities. The surveys found distinct differences in the invasive plant populations between the two villages: six species occurred in Port Graham but not in Nanwalek, and two species occurred in Nanwalek but not in Port Graham. The new road will increase the likelihood of cross contamination. In addition to surveys, HSWCD held workshops in the village of Nanwalek, led native plant hikes, and prepared an invasive plant management plan for the village council. The HSWCD intends to maintain a healthy relationship with both villages as this project continues and opportunities arise.

Progress made in Anchorage parks

Anchorage is Alaska's largest city and its center of shipping, transportation and commerce. Unsurprisingly, the city has a large number of invasive plant species; many are widely spread throughout urban areas, road rights-of-way, private property, and public parks. Anchorage thus functions as a source of invasive plant propagules to the rest of Alaska, via a variety of pathways. A partnership between FHP, the Anchorage Park Foundation and private industry has led to substantial progress in controlling invasive plants in some of the city's public parks. In 2015, this partnership led to 22 volunteer weed-pull events, involving 1560 volunteer hours. Twenty-one acres of bird vetch (*Vicia cracca*) was controlled (Figure 39) and more than 70 acres of European bird cherry (*Prunus padus*) infestations were treated, using both mechanical and chemical means. Presentations were made at meetings of six different Anchorage Community Councils about the problematic European bird cherry, with three of the councils voting to support chemical control work in their local park (Figure 40).

Alaska Division of Mining, Land, and Water begins to monitor for invasive plants

The Alaska Department of Natural Resources (DNR) Division of Mining, Land, and Water Northern Region Office (NRO) has increased its attention to invasive plants within its managed lands. With the DNR Division of Agriculture's Weed-Free Gravel Program now officially underway, the NRO recognizes its potential contribution to decreasing the spread of invasive plants. The NRO has begun to document the presence of invasive plant species on land where it authorizes activities, specifically at material sale sites and leased land, during routine site visits. In 2014, the NRO began to train staff on the issues associated with invasive plant infestations and to develop protocol for identifying and surveying for invasive plants. In 2015, the NRO continued along the learning curve with protocol refinement and additional staff training on invasive plant ID.

The NRO's protocol for surveying includes identifying invasive plants present based on a reference list designating species as "high priority" [e.g. white sweet clover (*Melilotus alba*), bird vetch] or "low priority" [e.g. foxtail barley (*Hordeum jubatum*), prostrate knotweed (*Polygonum aviculare*)]. The list was developed in consultation with the DNR Division of Agriculture.

In 2014, the focus was on the Elliot Highway and south Tok areas. Twenty-three material sites were visited, of which 15 were found to have invasive plants. In 2015, 26 material sites and 18 lease tracts were visited in the Delta Junction and north Tok areas. Invasive plants were found only at seven material sites, meaning 19 material sites and all 18 lease tracts were completely weed-free.

Figure 39. Lovely Carr-Gottstein Park is a gateway for people and invasive species into the Anchorage Coastal Wildlife Refuge. Bird vetch, European bird cherry, and reed canarygrass were treated there over the last year. Before treatment, the area behind and beneath these signs was covered with bird vetch. Photo credit: Tim Stallard.

Figure 40. Tikishla Park in Anchorage is overrun with European bird cherry trees despite previous manual and mechanical efforts to control this aggressive invader. Some residents report being afraid to use the overgrown northern trail in the park. Photo credit: Tim Stallard.

Table 9. Select Invasive Plants of Interior Alaska. Species listed in this table are pictured on the next page, left to right, top to bottom.

Species	Growth Form	Annual/ Perennial	Primary Mode of Spread	Primary Mode of Introduction	Distribution in Interior Alaska	AKEPIC ranking[1]
European bird cherry (*Prunus padus*)	Small tree	Perennial	Seed (bird dispersed)	Planted as an ornamental tree; cherries consumed and widely spread by birds	Very common in Fairbanks parks and gardens; being spread to wildlands	74
Waterweed (*Elodea spp.*)	Submersed aquatic herb	Perennial	Vegetative fragments	Common aquarium plant, likely introduced via aquarium dumping. Spreads with water flow and when caught on boats, trailers and floatplanes	Currently known to occur in Chena Slough, the Chena River, Chena Lake and in Totchaket slough, downstream of Nenana	79
Reed canarygrass (*Phalaris arundinacea*)	Tall grass	Perennial	Seed and rhizomes	Introduced for forage and for erosion control in many road-building projects	Very few small infestations in the Fairbanks area	83
Sweetclover (*Melilotus alba*)	Tall herb	Biennial	Seed	Formerly sown in revegetation efforts and for erosion control. Likely still used for soil enhancement and as a nectar source for honeybees	Widespread on roadsides and in gravel pits over much of interior Alaska. On floodplain of lower Nenana river	81
Bird vetch (*Vicia cracca*)	Low-climbing herb	Perennial	Seed	Originally introduced as a research crop; seeds spread by snowplows and other vehicles	Widespread on roadsides in much of the Fairbanks area. Epicenter is UAF experimental farm	73
Perennial sowthistle (*Sonchus arvensis*)	Tall herb	Perennial	Seed and rhizomes	Likely introduced in horticulture products, contaminated hay	Widespread on portions of the Fairbanks-area road system	73
Yellow hawksbeard (*Crepis tectorum*)	Moderate-height herb	Annual	Seed	Likely introduced in horticulture products, contaminated hay	Widespread on roadsides in interior Alaska	56
Siberian peashrub (*Caragana arborescens*)	Tall shrub	Perennial	Seed	Planted as an ornamental shrub or hedge	Widespread in yards and gardens in Fairbanks; appearing in adjacent forest land	74
Butter and eggs (*Linaria vulgaris*)	Low herb	Perennial	Seed	Introduced as an ornamental garden plant, shared among gardeners	Widespread in yards and gardens in Fairbanks	69

[1] The Alaska Exotic Plant Information Clearinghouse (AKEPIC) is a collaboratively managed GIS database for tracking invasive plants, administered by the Alaska Natural Heritage Program (University of Alaska). Invasiveness rankings (0-100) are assigned based on the species' potential for establishment and spread, perceived impacts to resources, and biological characteristics. For more information visit aknhp.uaa.alaska.edu/botany/akepic/.


European bird cherry


Waterweed


Reed canarygrass


Sweetclover


Bird vetch


Perennial sowthistle


Yellow hawksbeard


Siberian peashrub. Credit: Andrew Butko


Butter and eggs

The fact that many sites visited were presently weed-free, and that high-priority invasive plants were found on relatively few sites, is an enviable situation. But the occurrence of low-priority plants demonstrates that invasive plants are beginning to move into these disturbed sites. From these initial inspections, it's clear that NRO-managed material sites may contribute to the spread of invasive plants through the movement of gravel. In time, high-priority weeds will likely follow the same pathways low-priority species utilize, and begin to contaminate material to be harvested at these sites with seed.

These efforts represent the beginning steps toward one day integrating with the Division of Agriculture's weed-free gravel program.

There's an App for that! Invasive weeds identification and reporting, that is

Alaskans can now identify invasive weeds using a new, free mobile application for both Android and IOS devices, thanks to a project spearheaded by the University of Alaska Fairbanks Cooperative Extension Service (CES). The application allows users to browse species by name, or identify species using an interactive key with photos of key characteristics at each couplet. Species tentatively identified by users can be reported directly from the app to CES for confirmation of identification, information about control options, and inclusion in the statewide exotic plant database when appropriate. Since the mobile application was released in late August, 2015, 788 users have downloaded the application on their devices. CES has received 13 reports, and interest is building for next field season. Land management agencies are interested in the app because new infestations can be identified and reported quickly by field staff without taking time from other field work obligations. The app includes 56 invasive plants with high invasiveness rankings, and CES is seeking funding to add more species. The app was developed by the University of Alaska Fairbanks, Cooperative Extension Service and the University of Georgia, Center for Invasive Species and Ecosystem Health with support from the Western Alaska Landscape Conservation Cooperative and funding from the US Fish and Wildlife Service and US Geological Survey. Download the Alaska Weed ID app today!

Alaska Region of the Forest Service convenes its Invasive Species Issue Team

The Forest Service's 2013 National Strategic Framework for Invasive Species Management (http://www.fs.fed.us/foresthealth/publications/Framework_for_Invasive_Species_FS-1017.pdf) guides and prioritizes invasive species management. In concert with Forest Service policy, this Framework provides broad strategic direction for the Forest Service's programs, spanning the National Forest System, Research and Development, and State and Private Forestry Deputy Areas, as well as International Programs. The Framework describes how Regional Invasive Species Issue Teams (RISIT) will coordinate activities within the Forest Service and with Federal, State, and local partners.

Members of the Alaska Region's RISIT represent an array of disciplines including: fish & wildlife, ecology, watershed, timber, wilderness, entomology, plant pathology, recreation, geology and botany. In accordance with the Framework's action items, the Alaska RISIT is reviewing the 2006 Alaska Region invasive strategy along with current Forest Service strategic direction, policy and guidance. A new, updated invasive species strategy for the Alaska Region will be the result of the review. The strategy identifies invasive species priorities and action items, which will provide guidance and highlight priorities for the Alaska Region invasive species program.

Alaska Invasive Species Meeting held in Juneau for the first time

The Alaska Committee for Noxious and Invasive Plant Management (CNIPM) has held annual meetings since 1999. Over the years, these events have become the go-to opportunity for people concerned with invasive plants in Alaska to interact and coordinate their efforts. Several years ago, the Alaska Invasive Species Working Group (AISWG, an all-taxa group) began to meet in conjunction with CNIPM. In 2012, the meetings were combined into a single entity, the Alaska Invasive Species Meeting, and this year it was held in Juneau. Several FHP staff presented, on topics ranging from invasive forest pathogens to a GIS analysis of lakes at risk for *Elodea* infestation (see page 38). Because the event occurred during Halloween week, one of the highlights was an invasive-species-themed costume party/poster session (Figure 41).

Figure 41. Attendees at the Alaska Invasive Species Meeting Halloween costume event included, from left, Bohemian knotweed (with a touch of zombie thrown in), an exotic insect that was shipped into Alaska in shrink-wrapped firewood from the lower 48, an overzealous master gardener who insists on sowing non-native seeds everywhere, and a bat with white nose syndrome. So far Alaska doesn't have white nose syndrome, but it definitely has the other three.

STATUS OF INSECTS

Live spruce tree with spruce beetle damage.

Sitka Spruce Weevil: a Non-Native Pest Detected Again in 2015

Jessie Moan, University of Alaska Fairbanks, Cooperative Extension Service

The Alaska Integrated Pest Management (IPM) program within the University of Alaska Fairbanks-Cooperative Extension Service is a statewide program to address the public need and demand for pest management education and pest control options in Alaska utilizing non-biased, research-based information. In Anchorage, the IPM program is heavily focused on issues relating to urban tree pests, urban tree health, and invasive species (plants, insects, and disease).

The IPM program has two main focuses: engagement with the community and emphasis on early detection of pests. This puts us in a unique position to receive reports of potential new pests or abnormally high pest populations from individuals within the community and respond accordingly. During the summer of 2015, this was demonstrated with the detection of the non-native Sitka spruce weevil, *Pissodes strobi*, in Anchorage.

It has been believed that SSW would not survive in Alaska; however, changing climate conditions may make Alaska more vulnerable to non-native pests such as the Sitka spruce weevil.

IPM staff responded to a request regarding dieback in the top of a young, recently planted Colorado blue spruce (Figure 42). The tree was imported to Alaska from the Pacific Northwest and purchased from a local retailer. IPM staff inspected the tree and found the top to be wilted and curled. Weevil pupae were also found within the damaged top. The top was removed from the tree (Figure 43) and the pupae were reared to adulthood (Figure 44). In total, 48 adult weevils emerged from approximately 11 inches of the infested stem between August 26 and September 18. The weevils were tentatively identified as the non-native *Pissodes strobi* and several adults were submitted to insect taxonomists with the Oregon Department of Agriculture who confirmed the identification. The IPM program is working with the Alaska Division of Agriculture and Alaska Division of Forestry to monitor the affected tree and take appropriate steps to minimize the impact of this weevil. The Division of Agriculture is also working with the retailer to reach additional customers who may have purchased infested trees in order to identify and monitor any other infestations.

Sitka spruce weevil (SSW) is native to the lower 48 and parts of Canada. It is not native to Alaska, but has the potential to be harmful in our native and ornamental spruce and pine trees. Sitka spruce weevils attack and kill the main shoots of young trees. Heavy attacks can result in the loss of 3 to 4 years of height growth and lead to heavy branching and bushy trees. Common hosts of SSW include native species such as Sitka spruce, white spruce, and black spruce and several popular ornamental species, including Norway spruce, Colorado blue spruce, Scots pine, and limber pine. In addition to the detection in 2015, the IPM program has responded to reports of SSW on several additional occasions:

1995: This appears to be the earliest known detection of SSW in Anchorage. IPM technicians collected adults and infested shoots from Colorado blue spruce in a nursery setting. Those trees were brought to Alaska in the late summer of 1994.

- 1996: Adult weevils and infested shoots were collected from spruce planted in south Anchorage in 1995. It was not determined at the time if this detection was a new introduction or a continuation of the 1994 population.

- 1999: SSW was found in landscape plantings near Tudor and C Street. No information regarding control measures or follow up could be found.

- 2004: A local arborist discovered SSW on imported Colorado blue spruce in Anchorage. A report mentions that “Control measures were administered immediately to prevent the spread of this insect”, though no details were given regarding the nature of the control measures.

- 2006: One report of SSW in landscape trees in Anchorage was recorded. The trees had been planted in 2004 and beetles were no longer present. A report of this detection indicated that “The trees were to be removed and replaced with live trees.”

- 2007: There were multiple detections of SSW infestation. Large mature blue spruce trees as well as young trees still in the nursery were affected. Little additional information regarding control measures or follow up was available for any of these detections.

Each of these detections appears to be the result of individual introductions, though confirmation of that remains unclear. There does not appear to be rapid spread of this pest within the landscape. To the best of our knowledge and observations, residual populations of SSW appear to die out after several years. Additional surveys and monitoring are needed to determine if SSW has established in Anchorage. Several questions remain regarding the fate of SSW in Anchorage and elsewhere across the state. It has been believed that SSW would not survive in Alaska; however, changing climate conditions may make Alaska more vulnerable to non-native pests such as the Sitka spruce weevil. ⌘

Figure 42. Photo taken by a concerned homeowner of a young Colorado blue spruce exhibiting wilting and curling of the top main shoots. Photo credit: Irmtraud Wiegel.

Figure 43. The damaged Colorado blue spruce top clipped by CES exhibiting wilting and curling. Photo credit: M.J. Moan.

Figure 44. An adult *P. strobi* that was reared from samples clipped from the affected Colorado blue spruce. Photo credit: M.J. Moan.

Northern Spruce Engraver Beetle (*Ips perturbatus*) Monitoring Near Quartz Lake, Alaska

Jason Moan, Alaska Department of Natural Resources, Division of Forestry; Nicholas Lisuzzo, USDA Forest Service

Figure 45. Blown down timber in the state forest at Bert Mountain. A Lindgren funnel trap is also shown.

Background

In September of 2012, a large scale wind event swept though the Tanana River Valley. As reported in the Forest Health Conditions in Alaska – 2012, the windstorm caused extensive damage to surrounding forests in the form of broken, uprooted, and leaning trees. An estimated 1.4 million acres of forests between Delta Junction and Tok were impacted including the Quartz Lake area near Delta Junction. In November of 2013, a smaller scale wind event again impacted the Quartz Lake area, causing further damage to stands in the area. These two consecutive years of disturbance created a large number of newly dead and dying trees within high value, mature white spruce stands within and adjacent to the Tanana Valley State Forest and Quartz Lake State Park. These conditions produced potentially ideal breeding habitat for pests like the northern spruce engraver (*Ips perturbatus*) (NSE), a tree killing bark beetle. Having experienced bark beetle damage in the past, local foresters expressed concern over the possibility of increasing beetle populations in the wind-impacted stands. As a result, a bark beetle monitoring effort was launched in 2014 to determine if bark beetle populations were high enough to warrant mitigation.

Northern spruce engraver activity is generally found in scattered pockets along the edges of wildfires, rivers, and other areas of weakened or damaged spruce, such as areas impacted by wind or heavy snow loading. Northern spruce engraver and other related *Ips* engraver species breed in these weakened and damaged trees. In general, windblown trees dry out relatively quickly and do not stay suitable for the engraver beetles for long. In the case of the most recent windstorm, however, many trees were left leaning but alive, potentially extending the length of time these trees were attractive to the NSE. Prolonged host suitability can allow beetle populations to build rapidly, eventually resulting in bark beetle attacks on residual trees.

Engraver beetle populations are elevated in portions of the surveyed areas.

The initial monitoring effort was coordinated through the Alaska Division of Forestry - Delta Area and Central Offices, USDA Forest Service – Forest Health Protection, and the Tanana Chiefs Conference. In 2015, Quartz Lake State Park was also added as a cooperator.

Methods

Initial monitoring consisted of 15 Lindgren funnel traps (Figure 45) baited with *Ips perturbatus* lures and placed in areas known to contain blown down timber; trapping efforts were expanded to include 21 monitoring locations in 2015. Monitoring traps were located across a spectrum of wind damage severities, ranging from light to heavy amounts of damage, based on assessments by local foresters. Traps were placed in sets of three in impacted areas, with each trap in the set at least 200 feet from the next. Traps were collected bi-weekly, or at slightly longer intervals, throughout the flight season of the NSE (generally early May-mid July). Collected specimens were then tallied for each trap by collection date. Although baited funnel traps can be useful in determining general trends in bark beetle populations, a wide variety of confounding factors such as temperature, wind speed and direction, and competition from natural attractants limit our ability to develop quantifiable relationships between trap catches and predicted tree mortality. Based on previous monitoring efforts (N. Lisuzzo, pers. obs.), we used the following guidelines to assess northern spruce engraver populations:

Total annual northern spruce engraver catches per trap:

# of NSE	Activity Level	
0-300	Low	Endemic population levels
>300	Moderate	Elevated population levels
>1000	High	Elevated population levels, tree mortality typically observed

Interim Results

The 2014 data suggest that engraver beetle population levels are moderate to high in several small concentrated pockets in the surveyed area, and endemic (low) immediately adjacent to those areas. Of the 15 sites monitored in 2014, eight indicated endemic population levels and the remainder indicated elevated population levels, including six which suggested high population levels (Figure 46).

The 2015 data is still being finalized, but early indications suggest that NSE activity remains high in several locations across the monitoring area including some areas that indicated endemic populations in 2014.

Discussion

Ideally, traps should be placed prior to the initial beetle flight each spring, however, in 2014 the traps were placed *during* the initial beetle flight. This likely resulted in overall lower trap catches as traps were not in place to attract as many of the initially emerging beetles. Evidence of fresh beetle attacks on blown down timber was visible on the day traps were installed (Figure 47). Regardless, the highest numbers of beetles were caught in areas with the heaviest blowdown, which was expected. Outside of these areas however, trap catches were highly variable and seemed to be very site specific. For example, in several cases one trap caught 1,000 or 2,000 total engraver beetles over the course of the season, while a trap only a few hundred feet away captured less than 100. These patterns emphasize the high level of variation associated with the monitoring technique and the attack dynamics of the NSE, and the need to use caution in interpreting results.

Because of the delayed trap placement in 2014 trap captures in 2014 and 2015 cannot be directly compared. Regardless, engraver beetle populations are elevated in portions of the surveyed areas in both years.

This area was also surveyed during the forest health aerial surveys in both 2014 and 2015. In 2014, the blown down timber was observed, but no insect damage to residual trees was apparent in the area. However, in 2015, approximately 75 acres of scattered low severity engraver beetle damage was observed in the area, on Bert Mountain and just southwest of Quartz Lake.

Monitoring will continue in 2016, as will the development of mitigation strategies to minimize the likelihood of NSE damage to high value stands in the area. ⌘

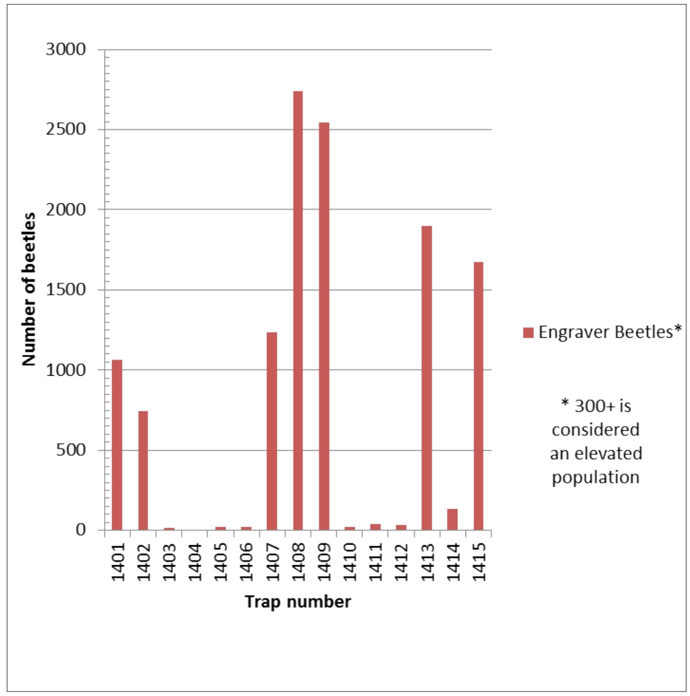


Figure 46. Quartz Lake area – northern spruce engraver trap catches 2014.

Figure 47. Fresh engraver beetle attacks on day of trap installation in 2014. Photo credit: J. Moan.

Warm Summers Prepare for Spruce Bark Beetle Return

Ed Berg, U.S. Fish & Wildlife Service (Retired)

If you lived in the woods on the Kenai Peninsula in the 1990s, you may not want to read this article. Those were the years when the spruce bark beetle outbreak killed most of the mature spruce forest on the Kenai, some 3.5 million acres. Living out Homer's East End Road my wife and I spent our weekends cutting down our beautiful old-growth Sitka spruce trees and burning the slash. Our view improved dramatically, but so did the cold wind coming up from Kachemak Bay, as well as the vehicle noise from the road.

Spruce bark beetles thrive on runs of warm summers, and the present 3-year run of sunny summers should trigger another burst of beetle activity. My research as an ecologist at the Kenai National Wildlife Refuge during the 1990s focused on the history and causes of bark beetle outbreaks. Using tree-ring analysis (dendrochronology), my colleagues and I developed a 250-year record of bark beetle outbreaks all around Cook Inlet. The last major outbreak was in the 1880s when many (but not all) stands on the Kenai and in Katmai and Lake Clark National Parks were heavily thinned, similar to the 1990s. There were smaller regional outbreaks in the 1970s, 1910s, 1850s and 1810s, as well as local outbreaks at other times.

Two factors control bark beetle outbreaks: adequate host material (enough large trees) and runs of warm summers

The peculiar ecology of spruce bark beetles allows them to kill only the larger trees; pole-sized trees are spared and are released from competition from neighboring trees to grow rapidly and rebuild a new forest. Bark beetles bore through the outer bark and lay their eggs in galleries within the sugar-rich inner bark (phloem). Small trees however produce a lot of pitch and can cement the mother beetles in their galleries, Mafia-style. Small trees also have thin phloem that can be too tight for a beetle. Big trees however are fat city for bark beetles. The strategy of mass attack allows thousands of beetles to completely overwhelm the tree's pitch defense and eat all the phloem, girdling the tree just as if the bark had been stripped off with an axe.

The phloem cylinder around a tree carries the sugar produced in the needles by photosynthesis down to the roots for storage over the winter. In the spring the sugar comes up as watery sap through the sapwood (the outer several inches of trunk wood) and the sugar feeds the new needles. If the phloem plumbing has been cut by girdling, the sugar never gets to the roots and only zero-calorie sap rises in the spring. The old needles turn red and the tree dies. After a year in the red-needle stage, the needles fall off and only a "gray ghost" of a tree remains.

Two factors control bark beetle outbreaks: adequate host material (enough large trees) and runs of warm summers. The forest gun must be loaded with mature trees, so to speak, and warm summers must pull the trigger. The natural growth of the forest loads the gun, and the El Nino climate cycle provides the runs of warm summers to pull the trigger. A run of cool summers (La Nina) will shut outbreaks down. My research found that there is a distinct temperature threshold for large outbreaks; average May-August temperatures in Homer must be at least 51^{o}F for two or more summers. The last 3 summers have been well above this threshold (2013 – 52.5^{o}, 2014 – 54.4^{o}, 2015 – estimated at 55.1^{o}), and the present El Nino is predicted to be one of the strongest on record.

The climate trigger has now been pulled, but is the gun loaded? The gun was very well loaded in the 1990s; foresters considered the forest "overmature," at least for timber harvesting. The present spruce forest has rebounded quite quickly, primarily through growth release of pre-outbreak understory poles (Figure 48), as well as recruitment of new seedlings. Today's forest is certainly not mature, but many trees have grown big enough, say 6 inches or more in diameter, to host bark beetles. So the gun is at least partially loaded. That said, however, it still may take several summers to build up enough beetles to the point where they can really use mass attack effectively.

Bark beetles are always present at low (endemic) levels in the forest; they can be monitored with pheromone traps, baited with the same chemicals that beetles use to attract more beetles to a tree that they have attacked. Homer sawmill operator Steve Gibson of Small Potatoes Lumber reports that his fresh-cut logs are acting in their typical role as bait logs for bark beetles and even some of their smaller cousins *Ips* beetles, but this occurs every spring with endemic beetles.

The USDA Forest Service flies annual aerial surveys for all kinds of forest pests and diseases. This summer's survey found spruce beetle mortality higher than the last couple of years, but still low, according to a preliminary report. Red needle acreage was mapped across Cook Inlet between the lower Susitna River and the east end of Lake Clark Pass. A slight increase was seen in the Point MacKenzie to Big Lake area and on the west side the Kenai Peninsula, but still the numbers were low compared to past outbreaks when several hundred thousand acres of fresh beetle-kill were reported every summer (Figure 49).

The future of spruce in southern Alaska seems grim, at least for the upland species of Sitka and white spruce, and the Sitka-white hybrid Lutz spruce. As Figure 49 shows, global climate models forecast generally rising summer temperatures. After 2030 these models indicate that May-August mean temps on the southern Kenai will consistently be above 51^{o} and suggest that there will always be beetles attacking any trees large enough to eat. If this turns out to be true, tomorrow's spruce trees could be harvested for pulp, but they would rarely grow to saw-timber size.

This dismal forecast presents a conundrum for landowners who want to replant their beetle-killed spruce forest. Fortunately, the warmer climate expands the silvicultural horizon beyond spruce. We can easily plant lodgepole pine, Siberian larch, hemlock (western and mountain), yellow cedar, red alder, fast-growing poplar hybrids for pulp, as well as native hardwoods like Sitka alder, birch, aspen, and cottonwood. If the 1990s spruce bark beetle outbreak has a take-home message, it would be to avoid single-species monocultures. Sooner or later every tree species has its attackers, and the only way to win the biological war is to plant a variety of species so that they don't all go down at once.

In the early stages of the 1990s bark beetle outbreak visiting experts from Anchorage and beyond advised us to defend our threatened spruce trees with plenty of watering, fertilizer, thinning, and pruning branches off the lower 10-30 feet of the trunks. As the outbreak intensified, spraying the lower 30 feet of the trunk with the insecticide Carbaryl was also recommended. These measures were designed to create healthy, vigorous trees with sunlit trunks which the beetles would avoid. They are suitable for low-intensity outbreaks, and they may well be adequate for the next outbreak. When a full-scale outbreak gets underway, however, these rules all go out the window. The strategy of mass attack allows the beetles to attack the healthiest trees pruned or unpruned, pole-sized trees, and the upper trunks. Many trees around Homer were sprayed up to 30 feet high, but the beetles simply went higher and killed the tops.

On a brighter note I don't expect the next outbreak to be anywhere as severe as the 1990s outbreak for the simple reason that we don't have the available breeding habitat, i.e., unlimited tree inner bark (phloem). Yes, we have some newly mature trees, but only a finite number of beetles can fit into that phloem. In the 1990s we had forests not substantially thinned since the 1880s, so there was plenty of phloem (and warm summers) to breed enough beetles for many years of mass attack. We'll likely have warm summers in the future, above the 51-degree threshold, but the endemic beetle population will act like a thermostat that keeps the spruce forest at a new, lower equilibrium. In place of spruce we can expect to see lots more hardwoods, resulting from increased fire activity, which in turn should provide more winter browse for the Giant Kenai Moose, to borrow a term from the 1890's. ⌘

Dr. Ed Berg is a retired ecologist with the United States Fish and Wildlife Service. He has worked on the Kenai Peninsula for a number of years, where he has studied spruce beetle activity and its possible relationship with climate change. We are excited to share this Op-Ed piece that is a reflection of his observations and thoughts. This piece was published in the Homer News in the September 3rd, 2015 edition."

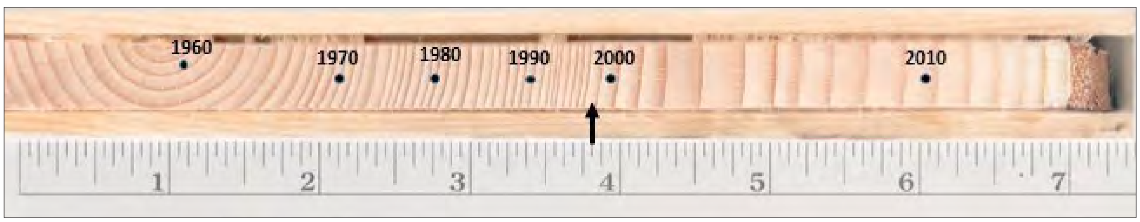


Figure 48. This tree core sample is from a live Sitka spruce that was too small (5 ½ inches diameter) to be killed by the spruce bark beetles in the 1990s. In the late 1990s its larger neighbors were killed and the canopy opened up, releasing the tree's growth in 1999 (arrow). At 13 inches today the tree is now growing vigorously and is prime fodder for the beetles. The corky-looking phloem layer (between the wood and the darker outer bark) is big enough for an adult beetle. Photo credit: Ed Berg.

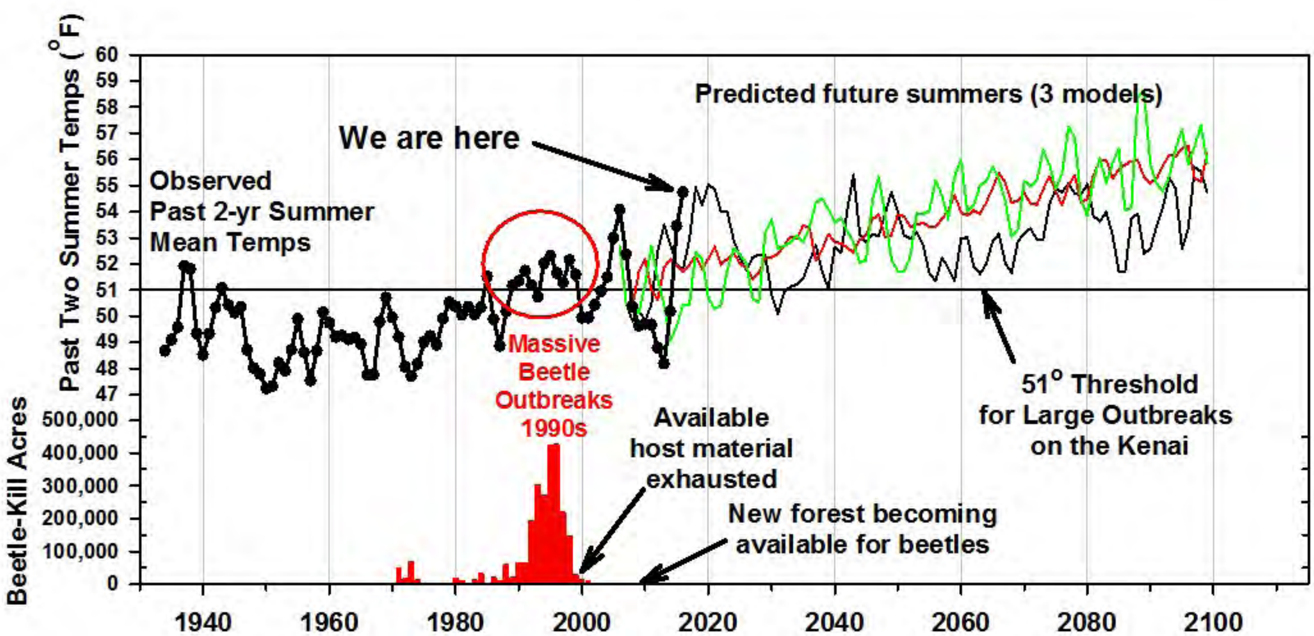


Figure 49. Global climate models scaled to the Kenai predict warmer summers throughout this century. The models predict that post-2030 mean summer temperatures will always be above the threshold for large spruce bark beetle outbreaks, if there are any trees available. Observed temperatures are from the Homer airport since 1932. Climate models are from Germany (green), Canada (red) and USA (black). Lower graph shows annual beetle-kill for southern Kenai since aerial surveys began in 1971 (US Forest Service). Graphic credit: Ed Berg.

INSECTS: ESSAY

2015 Entomology Species Update

Hardwood Defoliators - External Leaf Feeding

Alder Defoliation
Monsoma pulveratum (Retzius)
Hemichroa crocea (Geoffroy)
Eriocampa ovata (L.)
Lophocampa maculata Harris
Epinotia solandriana (L.)

Statewide, alder defoliation was down substantially from the last few years. Defoliated alders were mapped on approximately 32,500 acres, which included the following: north of Beaver along the Yukon River, the Yukon Flats, the Matanuska-Susitna Valley, the Anchorage area, from Iliamna Lake to Cook Inlet, and in parts of Lake Clark National Park and Preserve. The area between Iliamna Lake and Cook Inlet, including Lake Clark National Park and Preserve, contained most of the damage, and the National Park had roughly 7,000 damaged acres.

Alder defoliation can be caused by several agents, which often occur together in the same location. Fluctuations in defoliator populations can be attributed to multiple factors such as climate, predation, and disease. Three species of alder-feeding sawflies were found throughout the state. The green alder sawfly (*Monsoma pulveratum*) is a non-native species that has caused extensive damage in past years, but little activity in 2014, and even less in 2015. In Southeast and Southcentral Alaska, striped alder sawfly (*Hemichroa crocea*) activity was also low, whereas, the woolly alder sawfly (*Eriocampa ovata*) was most prevalent. Some insect species feed mostly after the aerial surveys have been completed and were not able to be assessed from the air. Late season feeding can look dramatic and alarming; however, impact on infested trees is usually minimal since damage occurs just before leaves drop in the fall. One such species, the spotted tussock moth (*Lophocampa maculata*), developed large populations this year in Southeast Alaska. Caterpillars of this moth are often called woolly bears, because of their bright color and furry appearance (Figure 50). There were many reports from Juneau and one report from Kake of hillsides of alder being completely defoliated by woolly bears.

Cottonwood Defoliation
Epinotia solandriana (L.)
Chrysomela spp. L.
Phratora spp. Chev.
Altica bimarginata bimarginata Say

Cottonwood defoliation was much less prevalent in 2015 with about 9200 affected acres mapped, which is approximately 16% of the over 50,000 acres mapped in 2014. Apparently, populations have returned to endemic levels. Most of the activity in 2015 was isolated to small patches averaging 30 acres in size, and found along the Koyukuk, Kuskokwim, and Teedriinjik (formerly Chandalar) Rivers, and in Lake Clark and Glacier Bay National Parks. Several large areas of damage ranging in size from 375 to 1,000 acres were found along the Knik and Skwentna Rivers. Cottonwood defoliation is caused by several different species of leaf rollers, leaf miners, and leaf beetles. Leaf beetles (*Chrysomela* spp., *Phratora* spp., and *Altica bimarginata bimarginata*) are the most common damage agent on cottonwood; the larvae are aggressive feeders and can skeletonize entire leaves by late summer (Figure 51).

Figure 50. Brilliantly colored woolly bear caterpillars were observed feeding on alder and other understory vegetation in Southeast during August and September. Because they do most of their feeding late in the season the damage to the tree looks worse than it appears.

Figure 51. Cottonwood leaf beetle larvae feeding does not consume the entire leaf rather only one layer leaving behind a characteristic "window."

Large Aspen Tortrix
Choristoneura conflictana (Walker)

Approximately 20,000 acres of damage caused by the large aspen tortrix (*Choristoneura conflictana*) was observed in 2015. During a light outbreak, partial defoliation of aspen trees is visible upon careful observation. During an intense outbreak, aspens are commonly denuded of leaves and larvae will feed gregariously on any other available vegetation (Figure 52). Most affected areas were scattered across the landscape in small pockets less than 100 acres in size. However, about one-third of the defoliation was concentrated in distinct outbreaks each over 500 acres in size. Forests experiencing the greatest large aspen tortrix impact were west of Allakaket (~9000 acres), near McGrath (~3000 acres) and the Nowitna River (~2400 acres). Several small infestations were highly visible in neighborhoods around Fairbanks, where stands were completely defoliated early in the growing season (Figure 53).

Figure 52. With no aspen leaves left, the large aspen tortrix larvae descend to the understory, covering the vegetation in webs as they try to feed on any plants they can find.

Birch Leaf Roller
Epinotia solandriana (L.)
Caloptilia spp. Hübner

Birch leaf rollers showed a dramatic decrease in area infested during 2015 with a total of about 1,600 acres affected. Most infested area occurred in the northern and eastern part of the range of its hosts. Roadside reconnaissance noted heavy leaf roller activity along the Taylor Highway between Tok Junction and Eagle. In addition to birch, leaf roller damage has been noted on alder and cottonwood. The incidence of leaf roller damage on alder was down from previous years throughout the state. The leaf roller outbreak along the Perseverance Trail in Juneau noted in 2014 seems to be diminishing. Minor alder mortality was observed after the heavy feeding of 2014 but that may have also been due in part to alder canker which was also observed in the area.

Figure 53. Heavy feeding from large aspen tortrix has left this stand of aspens devoid of leaves.

Hardwood Defoliators - Internal Leaf Feeding

Aspen Leaf Miner
Phyllocnistis populiella Chambers

Approximately 82,000 acres of aspen leaf miner (*Phyllocnistis populiella*) damage were observed across Alaska in 2015. Leaf miner galleries in the outer leaf layer can disrupt gas exchange by damaging guard cells surrounding stomates (Figure 54). The current outbreak of aspen leaf miner started in 2000, affecting hundreds of thousands of acres of aspen during many of the years. This year aspen canopies looked green and healthy in most parts of the state. In a few places, however, heavily infested stands were found, including: the Yukon River Valley near Ruby (~10,000 acres) and Rampart (~10,000 acres), the Tanana Valley State Forest west of Fairbanks (~8,000 acres), and the Copper River Valley near Glennallen (~25,000 acres).

Figure 54. An aspen leaf attacked by the serpentine aspen leaf miner. The thin brown line is frass within the leaf miner's gallery.

Willow Leafblotch Miner
Micurapteryx salicifoliella (Chambers)

Larvae of the willow leafblotch miner (*Micurapteryx salicifoliella*) feed in the interior of willow leaves, creating large brown areas of dead tissue. Approximately 38,000 acres of willow leafblotch miner damage was noted in 2015. Roughly 75% of the damage observed occurred on the Yukon Flats, and the rest was widely scattered across Interior Alaska from the Canadian border to the Holy Cross Hills. From 2005 to 2010 defoliation caused by this leaf miner was much more prevalent, occurring in many stands north of the Alaska Range. At its peak in 2010, over 500,000 acres were infested. In recent years, however, defoliation has been much more restricted, although the damage from these insects is still a common sight.

Birch Leaf Miners
Profenusa thomsoni (Konow)
Heterarthrus nemoratus (Fallén)
Fenusa pumila Leach

Injury to birch trees caused by invasive leaf miners, amber-marked birch leaf miner (*Profenusa thomsoni*) and the late birch leaf edge miner (*Heterarthrus nemoratus*) (Figure 55), was first reported in Alaska in 1989. Surveys of birch forests in Southcentral Alaska beginning 2003 found infested trees concentrated in Anchorage and at a few locations on the Kenai Peninsula (viz., Russian River Campground and the Soldotna Fred Myers parking lot). At the height of the outbreak in 2006, *P. thomsoni* caused the crowns of birch trees across entire city neighborhoods to turn brown. Outside Anchorage, however, this sawfly was mostly insignificant causing little or no noticeable impacts. Since then, the incidence of *P. thomsoni* progressively declined while that of *H. nemoratus* increased. By 2008, *H. nemoratus* had become the dominant leaf miner. In following years, both pests declined substantially reaching hardly noticeable levels by 2014 (Figure 56). However, in 2015, birch forests on the outskirts of Anchorage and in some localized neighborhoods of Soldotna exploded in *P. thomsoni* activity (Map 9). Some of these populations reaching widespread outbreak conditions, while severity levels within Anchorage remained very low. In contrast, *H. nemoratus* activity during the same time showed relatively low and consistent severity levels across both types of landscape (Map 10). While populations of birch leaf mining sawflies within Anchorage have decreased over the last decade, populations in Interior Alaska have continued to grow steadily in size. Damage is common within Fairbanks and North Pole, and has spread along the road system as far north as Livengood, and into intact natural stands east of Fairbanks. In Southeast Alaska leaf miners were prevalent on birch in the Haines area.

Softwood Defoliators

Hemlock Defoliation
Neodiprion tsugae Middleton
Acleris gloveranus (Walsingham)
Adelges tsugae (Annand)

Hemlock defoliation, which is caused by hemlock sawfly (*Neodiprion tsugae*), western blackheaded budworm (*Acleris gloveranus*), and several other species of caterpillars, was down in 2015. Most defoliation was mapped in the northern half of Southeast Alaska near Hobart Bay and on Douglas, Admiralty and Baranof Islands. Hemlock woolly adelgid (HWA) (*Adelges tsugae*) was found on Prince of Wales Island; however the population was at a low density and causing insignificant damage. HWA causes extensive and serious damage to eastern and Carolina hemlock, but it has less of an impact on western hemlock. It has been reported in Alaska before, however there are no specimens in FHP collections, or any other Alaskan collections (Figure 57).

Figure 55. Occurring in the same leaf are the frass filled galleries of the amber-marked birch leaf miner compared to the clean galleries with a reddish hibernaculum of the late birch leaf edge miner.

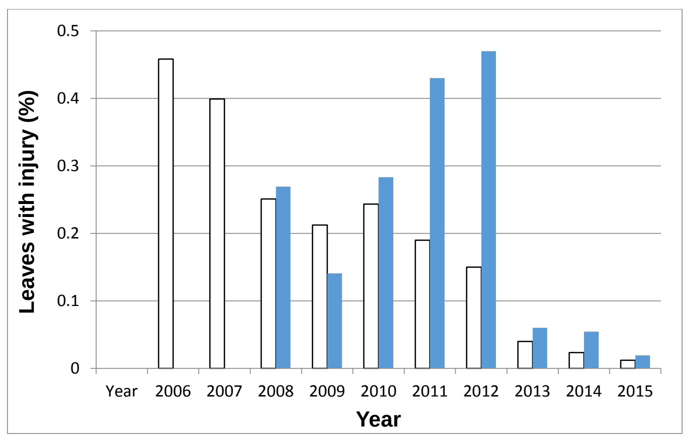
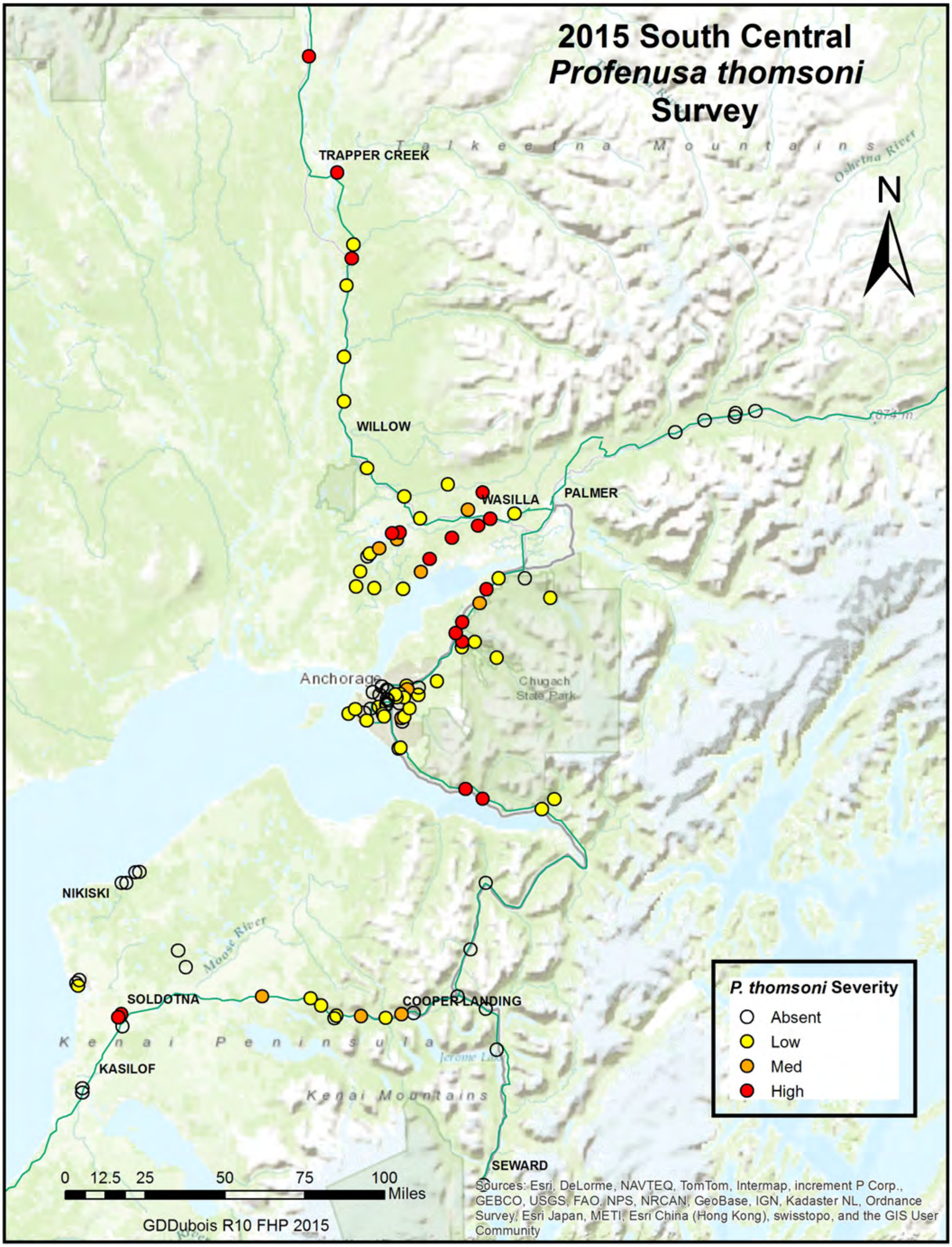


Figure 56. Average severity of injury caused by the amber-marked birch leaf miner (clear bars) and the late birch leaf edge miner (solid bars) to leaves (measured as percent of leaves with visible injury) of birch trees in Anchorage from 2006 to 2013.

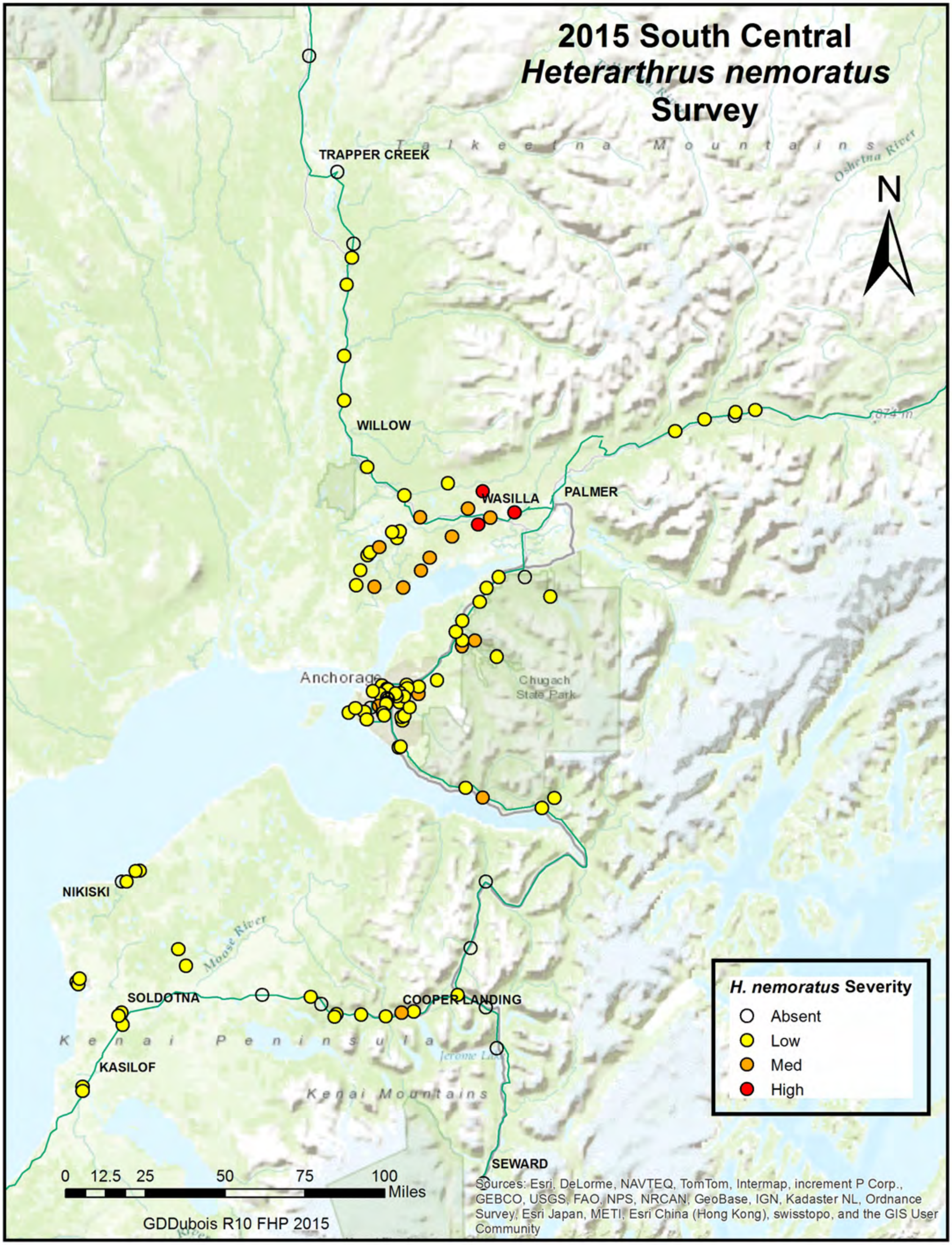
Figure 57. The hemlock woolly adelgid looks like cotton tufts stuck to branches. However this sap-sucking insect is a major pest of eastern and Carolina hemlock. Western hemlock is much more resistant to their feeding damage and it has never been an issue in Alaska.

Map 9. *Profensa thomsoni* distribution.



INSECTS

Map 10. *Heterarthrus nemoratus* distribution.



Spruce Aphid
Elatobium abietinum (Walker)

Originally from Europe, spruce aphid (*Elatobium abietinum*) (Figure 58) was introduced to the Pacific Northwest in 1910 and since has become established along the west coast infesting spruce trees especially along tidewater areas and other stressed environments. In Alaska, spruce aphid is well-known in Southeast forests, where it has damaged coastal Sitka spruce stands along marine shorelines and in urban areas since at least the early 1960s. Winter temperatures play a role in aphid population dynamics, warmer winters result in less mortality and therefore increased populations. Currently, spruce aphid activity is on the increase after repeated mild winters throughout Southeast Alaska (http://climate.gi.alaska.edu). In this regard, aphid activity was prevalent in Petersburg, Juneau, Sitka, and on Prince of Wales Island, especially near Craig. In contrast to Southeast Alaska, few reports have come from coastal Southcentral Alaska. This year, however, spruce aphid was reported and positively confirmed on the western Kenai Peninsula. Concerned citizens from Halibut Cove on the south side of Kachemak Bay and in Homer contacted multiple agencies about the alarming damage associated with these aphids (Figure 59). This is the first confirmation of spruce aphid on the Kenai Peninsula and represents a significant extension of its known distribution. An aerial pest survey of coastal areas neighboring Halibut Cove and along the coast lines of the Kenai Peninsula and Prince William Sound found occasional groups of trees showing the same symptoms, but not as severe. Areas with groups of trees showing similar symptoms include the Kenai Fjords National Park and east at Johnstone Bay, Auk Bay, Bainbridge Island and Latouche Island in Prince William Sound. FHP and State forest health professionals plan to investigate this range expansion further in 2016.

Spruce Budworm
Choristoneura fumiferana (Clemens),
Choristoneura orae Freeman

Populations of spruce budworm (*Choristoneura* spp.) in the Copper River Valley were higher than normal (Figure 60) (Figure 61). Long-term population monitoring in the Tanana Valley State Forest west of Fairbanks indicated that spruce budworm remain at background levels (Figure 62). Other parts of the state have not reported any signs of increased activity. No spruce budworm damage was mapped during insect and disease aerial detection surveys in Alaska in 2015.

Figure 58. Spruce aphid nymphs on spruce needles.

Figure 59. A view from Halibut Cove showing severely discolored spruce trees heavily infested with spruce aphid.

Figure 60. A spruce budworm larva feeding on the newly emerged needles of a white spruce tree.

Figure 61. Different color morphs of the spruce budworm moth.

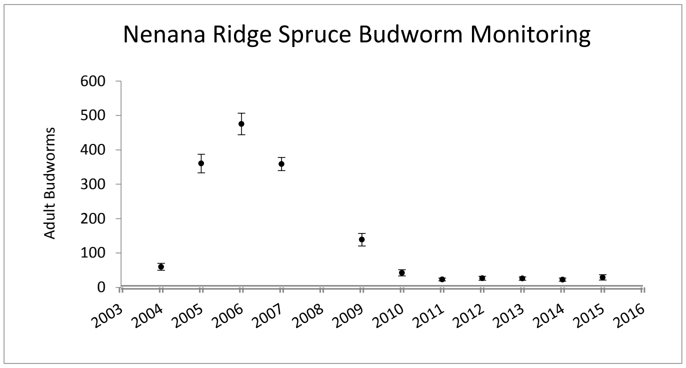


Figure 62. Spruce budworm populations are monitored each summer at 13 locations within the Tanana Valley State Forest. The last large-scale outbreak in Interior Alaska was from 2005-2007. The table below shows the mean number of adult spruce budworms caught per year (+/- 1 SE).

Bark Beetles and Woodborers

Spruce Beetle
Dendroctonus rufipennis (Kirby)

Spruce beetle (*Dendroctonus rufipennis*) activity was observed on 33,000 acres during aerial surveys in 2015 (Figure 63), roughly doubling that observed in 2014 for spruce beetle damage acreages since 2006. Although spruce beetle activity mapped in 2015 remains low compared to historical numbers, spruce beetle remains the leading non-fire cause of spruce mortality in the state.

Figure 63. Sitka spruce trees killed by spruce beetle adjacent to Chilkat Lake in Haines, AK.

The bulk of the increase in spruce beetle damage appears to be concentrated primarily in the Yentna and Susitna River Valleys and the northwestern Kenai Peninsula. Several new areas of activity were noted in these locations as well as in Western and Southeast Alaska. Widely scattered small pockets of spruce beetle activity continue to be observed in Northwestern Alaska, along the Noatak, Squirrel, Omar, and Kobuk Rivers (~165 acres total). In Southeast, the damage on Kupreanof Island, previously attributed to spruce beetle (2012-2014), was determined to have been in error. This damage was found to be yellow-cedar decline (See Ground-Truthing Summary: Southeast in Appendix I).

Surveyed areas experiencing notable spruce beetle activity are listed below. *General spruce beetle activity trends for the listed areas are shown as ↑ (Increasing) or ↓ (Decreasing) based on a comparison of the previous year's activity, with a percent difference shown in* ***blue-green for decreases*** *and* ***orange for increases****. New areas of activity are also identified below. New, in this case, describes damage in areas in which little to no damage was observed in 2014 or in areas that weren't flown in 2014.*

West and Southwest:

- Lake Clark National Park
  (4,256 acres ↓ -17% from 2014)
- Katmai National Park
  (398 acres, ↓ -87% from 2014)
- **NEW** Kuskokwim River at Deacons Landing
  (1,230 acres)
- **NEW** Kuskokwim River near Napaimiut
  (1,025 acres)

Southcentral and Kenai Peninsula:

- Beluga River north to Mount Susitna, east to Susitna River
  (9,926 acres, ↑ +266% from 2014)
- Skwentna and Puntilla Lake area
  (1,545 acres, ↑ +271% from 2014)
- Chulitna and Susitna Rivers near Byers Lake
  (543 acres, ↑ +735% from 2014)
- Chitina River area, near McCarthy
  (194 acres, ↓ -78% from 2014)
- **NEW** Northwestern corner of Kenai Peninsula, primarily northwest of Swanson River and Lakes
  (7,000 acres)
- **NEW** Susitna River from mouth east to Knik Arm, north to Big Lake
  (2,448 acres)
- **NEW** Western edge of Talkeetna Mountains from Caswell to Chase
  (340 acres)

Southeast:

- Haines area: Klehini River and Chilkat Lake area **(1,274 acres, ↓ -7% from 2014EW** Noyes Island **(1,357 acres*)**

- **NEW** Haines area: Upper Chilkat River **(304 acres)**

- **NEW** Taku inlet **(208 acres)**

- Kupreanof Island **(Null – Previous Data Error)**

* *It is possible that spruce beetle contributed to, but was not the primary cause of the spruce mortality observed on Noyes Island. The area was inaccessible from the ground.*

2015 statewide spruce beetle damage can be seen in Map 11.

Northern Spruce Engraver
Ips perturbatus (Eichhoff)

Northern spruce engraver, *Ips perturbatus* (NSE) (Figure 64), activity was observed on 9,300 acres in 2015, which represents a slight increase over the 7,340 acres mapped in 2014 (Map 11). Since 2011, NSE activity has remained fairly low and consistent (Figure 64). In 2015, most of the reported NSE activity occurred along or near the major river systems and their tributaries in the northeastern and central portions of Interior Alaska, which is consistent with historical patterns.

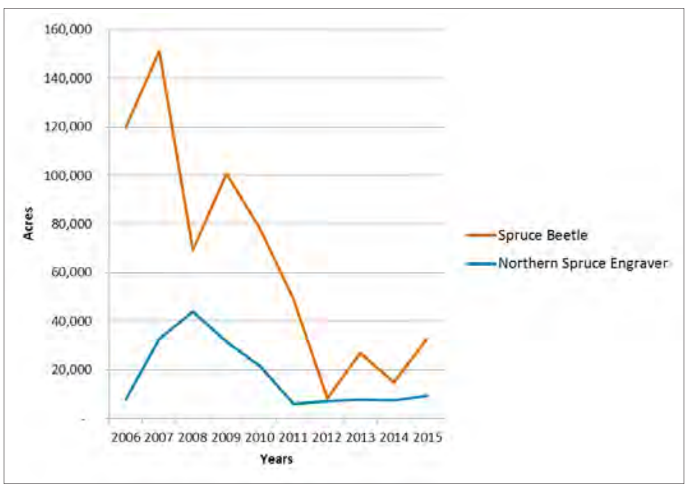


Figure 64. Cumulative observed acres of spruce beetle and northern spruce engraver damage 2006-2015. Note: Does not include acres mapped as containing both insects.

Although capable of widespread outbreaks, NSE activity is generally found in scattered pockets along the edges of wildfires, where trees have been fire-scorched and weakened. Chronic NSE activity also occurs along rivers subject to erosion, ice scouring, and silt deposition from flood events and less frequently in areas that have experienced spruce top breakage from heavy snow loading, timber harvest, high winds, or periodic wildfires. Work to monitor and mitigate damage from NSE in the Interior is ongoing in several locations (See Quartz Lake NSE monitoring essay on page 52 for more information).

Surveyed areas in Interior and Western Alaska experiencing notable NSE activity are listed below. *General NSE activity trends for the listed areas are shown as ↑ (Increasing) or ↓ (Decreasing) based on a comparison of the previous year's activity, with a percent difference shown in* ***blue-green for decreases*** *and* ***orange for increases****. New areas of activity are also identified below. New, in this case, describes damage in areas in which little to no damage was observed in 2014 or in areas that weren't flown in 2014, and* ***all acreages should be considered the total of several scattered small areas of damage unless otherwise noted.***

- 2012 Tanana River Valley windstorm area: Delta Junction to Tok, *low severity* **(895 acres, ↑ +111% from 2014)**

- Yukon Flats: Beaver Creek, *mostly low severity* **(478 acres, ↑ +9% from 2014)**

- **NEW** Koyukuk/Alatna River Valleys: approx. Evansville west to Akoliakruich Hills, *moderate to high severity* **(1,428 acres)**

- **NEW** Yukon River: Beaver to Deadman Island, *mostly low severity* **(1,679 acres)**

- **NEW** Nunivak Bar, *low severity* **(1,181 acres – 1 polygon)**

- **NEW** Denali National Park: Birch Creek/ McKinley River, *low severity* **(464 acres)**

Western Balsam Bark Beetle
Dryocoetes confusus Swain

Observed western balsam bark beetle damage (*Dryocoetes confusus*) tapered off considerably in 2015, with only 24 acres mapped along the Skagway River and White Pass Fork northeast of Skagway; 186 acres of damage were observed in this area in 2014. Western balsam bark beetle attacks subalpine fir, which has a very limited range in Alaska.

Wood Borers
Neospondylis upiformis (Mannerheim)
Tetropium sp. Kirby

Several areas with recently-killed, large diameter western hemlocks were noted at Spuhn Island, Lemon Creek and Smugglers Cove area of Juneau, Starrigavan in Sitka, and the northern end of Prince of Wales Island (Figure 65). The causal agent has not been confirmed, however the galleries of a wood boring beetle were noted in most places (Figure 66). Longhorned beetle larvae were collected from dying trees and adult beetles were captured in traps in the Juneau and Sitka sites. Two species were collected in abundance in this area: *Neospondylis upiformis* and *Tetropium* sp. Typically these species attack trees that are already dead or dying so it is unclear if they are the cause of the hemlock mortality or if these beetles are merely opportunistic on the recently killed hosts.

Map 11. Spruce beetle and northern spruce engraver damage 2015.

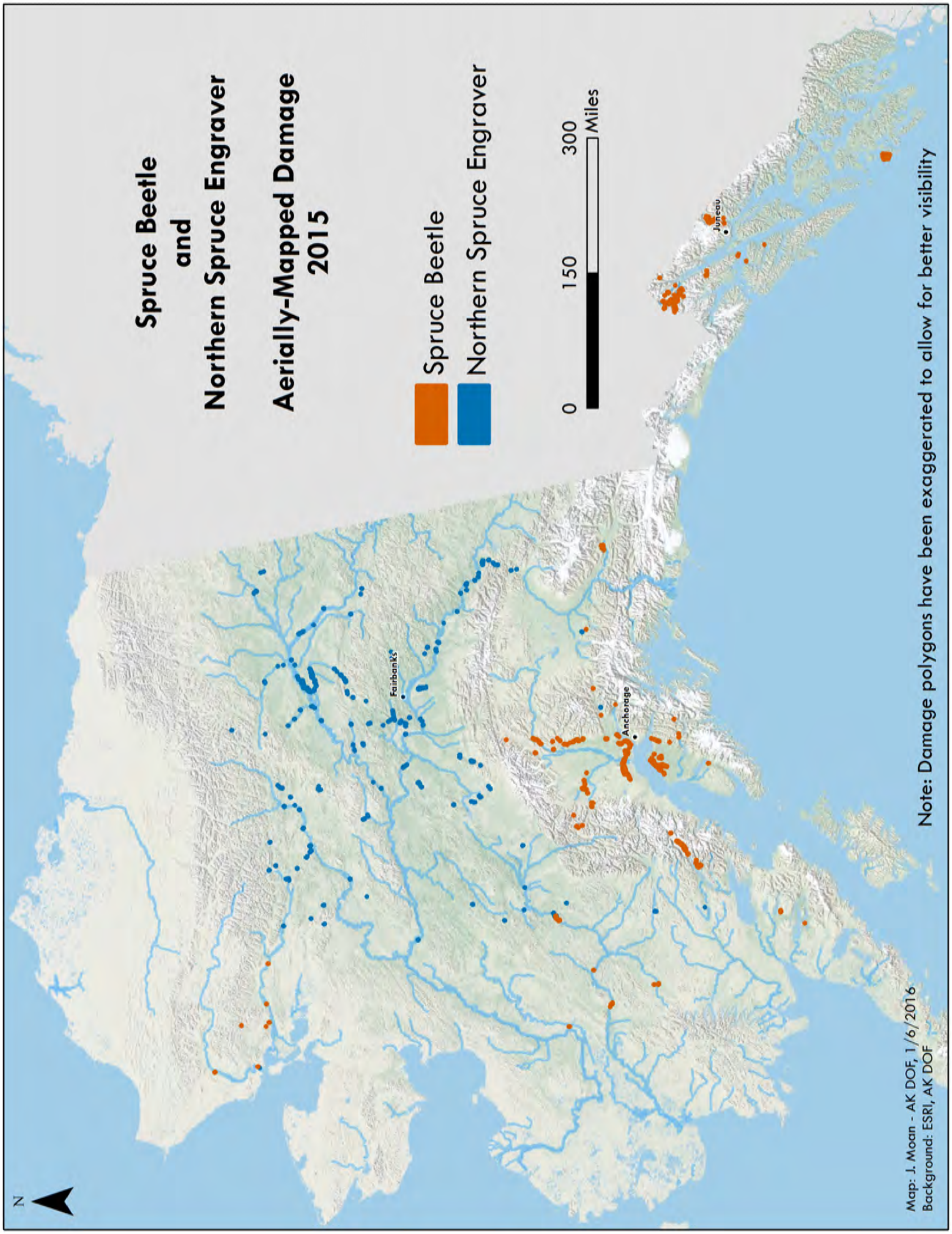


Figure 65. Recently killed western hemlocks found on Spuhn Island in Juneau. Trees exhibited signs of beetle attack however the causal agent has not been confirmed.

Figure 66. Larval feeding damage found under the bark of a recently killed western hemlock. The gallery was caused by a longhorned beetle, likely *Neospondylis upiformis* or *Tetropium velutinum*.

Other Pest Activity

Miscellaneous Hardwood Defoliation

Operophtera bruceata (Hulst)
Epirrita undulata (Harrison)
Hydriomena furcata (Thunb.)
Eulithis spp. Hübner
Orgyia antigua (L.)
Rheumaptera hastata (L.)
Sunira verberata (Smith)

During aerial pest survey flights, severe defoliation was observed on a number of hardwood species scattered around western Alaska (Figure 67), including various areas around Lake Clark National Park, the east side of the Alaska Range (Yentna River and Chakachamna Lake areas), in the Wood-Tikchik State Park, and where the Innoko River flows into the Yukon. Although the causal agent could not be confirmed, the damage and descriptions and photographs of the larvae reported to FHP are consistent with *Sunira verberata* (Family Noctuidae), a species that has caused substantial damage in the past (Figure 68). If positively identified as *S. verberata* this will be the first time damage from this generalist defoliator has been observed during aerial survey in almost ten years. Elsewhere, defoliation of the different hardwoods was quite variable. Of especial note in surveyed areas, inchworms (Family Geometridae) appeared to cause less damage in 2015 than in prior years.

Figure 67. Defoliation on a willow at Chakachamna Lake. There was also damage to alder and birch in the area. Similar damage was also found in other areas in western Alaska. This generalist hardwood defoliation, which was observed scattered around western Alaska, is thought to be caused by *Sunira verberata*.

Figure 68. Feeding on alder leaf at Lake Nerka in the Wood-Tikchik State Park. Identical looking larvae were found scattered around western Alaska and is believed to be the generalist hardwood defoliator *Sunira verberata*.

Urban Tree Pests

Epinotia solandriana (L.)
Caloptilia spp. Hübner
Dendroctonus rufipennis (Kirby)
Euceraphis betulae (Koch.)
Pikonema alaskensis (Rohwer)
Pristiphora erichsonii (Hartig)
Caliroa cerasi Linnaeus
Oligonychus ununguis (Jacobi)
Tetranychus urticae Koch
Pissodes strobi (Peck)

In 2015, the primary insect pests in urban trees included spruce beetle and birch leaf rollers. Birch leaf rollers (*Epinotia solandriana* and *Caloptilia* spp.) have been reported for several years and it appears as though their populations are subsiding. Several more spruce beetle (*Dendroctonus rufipennis*) calls and site visits were addressed in Anchorage in 2015 than in 2014. It is unclear if this relates to an increase in spruce beetle activity in the urban environment, an increase in awareness of spruce beetle, or an increase in awareness of resources to contact. Additional arthropod pests affecting urban trees in 2015 include birch aphids (*Euceraphis betulae*) (Figure 69), yellow-headed spruce sawfly (*Pikonema alaskensis*), larch sawfly (*Pristiphora erichsonii*), pear slug sawfly (*Caliroa cerasi*), and spruce spider mites (*Oligonychus ununguis)*. A notable detection in 2015 was the identification of the non-native Sitka spruce weevil (*Pissodes strobi*) in newly planted Colorado blue spruce imported from the Pacific Northwest. More generally, the primary threat to urban trees remains poor planting and growing conditions, human activities such as construction, and environmental factors such as drought and above-normal temperatures.

Figure 69. Birch aphid adults and nymphs on the underside of a birch leaf.

APPENDICES

Appendix I:
Aerial Detection Survey

Introduction

Aerial surveys are an effective and economical means of monitoring and mapping insect, disease and other forest disturbances at a coarse scale. In Alaska, Forest Health Protection (FHP) and the Alaska Department of Natural Resources Division of Forestry monitor about 30 million acres of forest annually at a cost of less than a penny per acre. Much of the acreage referenced in this report is from aerial detection surveys, so it is important to understand how this data is collected and its inherent strengths and weaknesses. While there are limitations, no other method is currently available to detect subtle differences in vegetation damage signatures within a narrow temporal window at such low costs.

Aerial detection survey employs a method known as aerial sketch-mapping to observe and document forest change events from an aircraft. When an observer identifies an area of forest damage, a polygon or point is drawn on a computer touch screen. Trained observers have learned to recognize and associate damage patterns, discoloration, tree species, and other clues to distinguish particular types of forest damage from surrounding undamaged forest. Damage attributable to a known agent is a "damage signature", and is often pest-specific.

Knowledge of these signatures allows trained surveyors to not only identify damage caused by known pests, but also to be alerted to new or unusual signatures. Detection of novel signatures caused by newly invasive species is an important component of Early Detection Rapid Response monitoring.

Aerial sketch-mapping offers the added benefit of allowing the observer to adjust their perspective to study a signature from multiple angles and altitudes, but is challenged by time limitations, fuel availability and other factors. Survey aircraft typically fly at 100 knots and 1000 feet above ground level, and atmospheric conditions are variable. Low clouds, high winds, precipitation, smoke, and poor light conditions can inhibit the detection of damage signatures. Terrain, distance, and weather conditions prevent some areas from being surveyed altogether.

Prior to 1999, sketch-mapping was done on 1:250,000 (1 in = 4 miles) USGS quadrangle maps. Today, forest damage information is sketched on 1:63,000 scale (1 inch = 1 mile) USGS quadrangle maps or aerial and satellite imagery at a similar scale on a digital sketch-mapping system. This system displays the plane's location via GPS and has many advantages over paper maps including greater accuracy and resolution in polygon placement and shorter turnaround time for processing and reporting data. The sketch-map information is then put into a computerized Geographic Information System (GIS) for more permanent storage and retrieval by users. Over 35 years of aerial survey data has been collected in Alaska, giving a unique perspective of Alaska's dynamic and changing forests.

Many of the maps in this document are presented at a very small scale, up to 1:6,000,000. Depicting small damaged areas on a coarse scale map is a challenge. Damaged areas are often depicted with thick borders so that they are visible, but this has the effect of exaggerating their size. This results in maps depicting location and patterns of damage better than they do the size of damaged areas.

No two observers will interpret and record an outbreak or pest signature in exactly the same way, but the essence of the event should be captured. While some data is ground checked, much of it is not. Many times, the single opportunity to verify the data on the ground by examining affected trees and shrubs is during the survey mission, and this can only be done when the terrain will allow the plane to land and take-off safely. Due to the nature of aerial surveys, the data provides estimates of the location and intensity of damage, but only for damage agents with signatures that can be detected from the air during the survey period. Many root diseases, dwarf mistletoes, stem decays and other destructive pathogens are not represented in aerial survey data because these agents are not detectable from an aerial view. Signs and symptoms of some pathogens (e.g. spruce needle rust) generally do not coincide with the timing of the survey.

Each year approximately 15 percent of Alaska's 126 million forested acres are surveyed, which equates to approximately 3 percent of the forested land in the United States. Unlike some regions in the United States, we do not survey 100 percent of the states's forested lands. Availability of trained personnel, short summers, vast land area, airplane rental costs, and limited time all require a strategy to efficiently cover the highest priority areas. Map 12 contrasts survey flight line coverage in Alaska with the "wall to wall" coverage achieved in Oregon. Alaska and Oregon are first and second among US states by forested acres. Alaska has 126 million acres of forest land and Oregon has only 28 million.

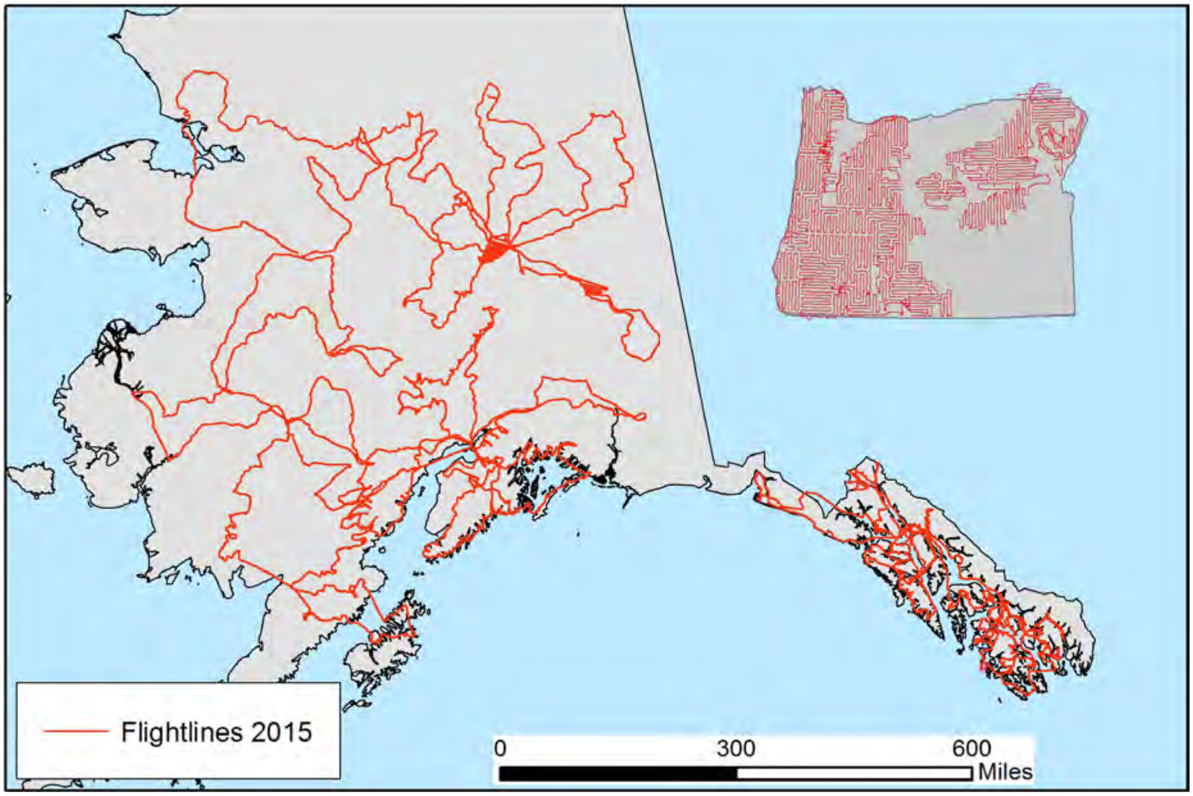
The surveys provide a sampling of the forests via flight transects. Due to survey priorities, various client requests, known outbreaks, and a number of logistical considerations, some areas are rarely or never surveyed, while other areas are surveyed annually. The reported data should only be used as a partial indicator of insect and disease activity for a given year. When viewing the maps in this document, keep in mind Map 2 on page 8, which displays the aerial survey flight lines. Although general trends in non-surveyed areas could be similar to those in surveyed areas, this is not always the case and no attempt is made to extrapolate infestation acres to non-surveyed areas. Establishing trends from aerial survey data is possible, but care must be taken to ensure that multi-year projections compare the same areas, and that sources of variability are considered.

Analysis of surveyed area by forest type

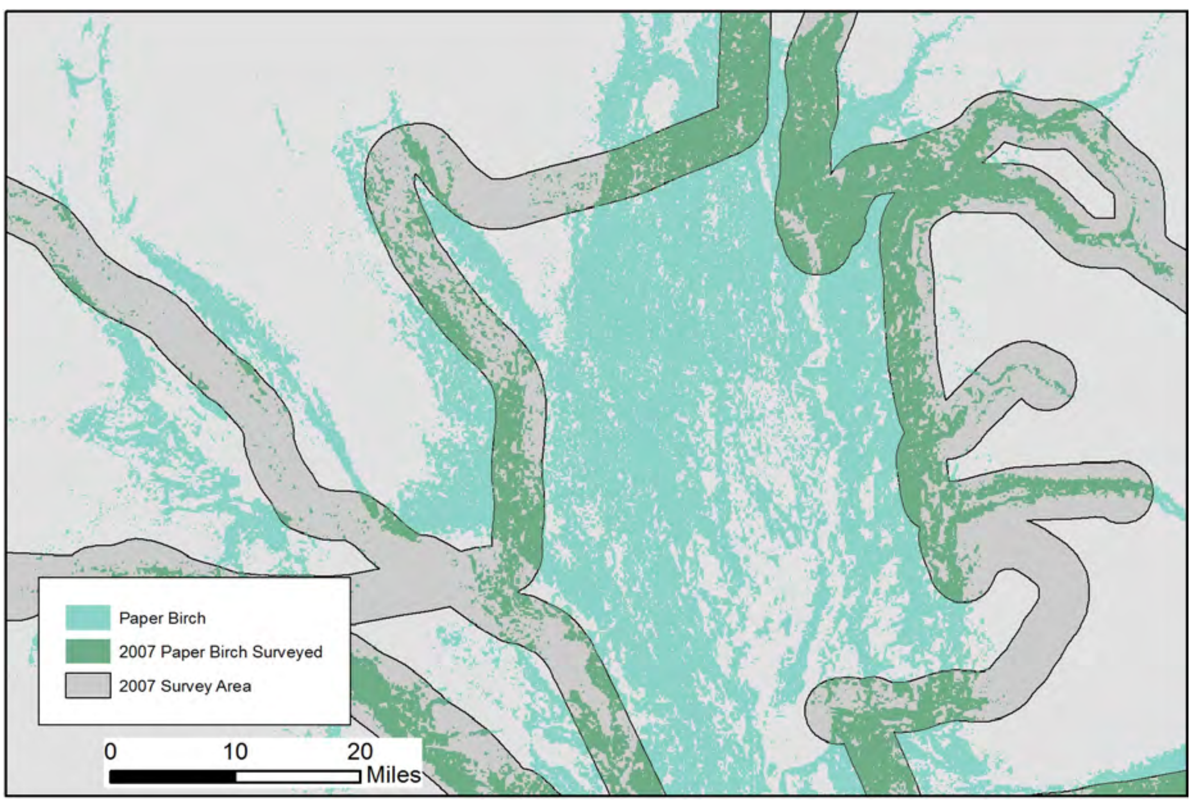
In 2015 we conducted an analysis of the number of acres and percent surveyed of seven representative forest types in order to better understand how our surveys sample various forest types. This was made possible by the improved 2014 Forest Health Technology Enterprise Team host model. This map (more accurately, raster layer) is a grid of 240 meter (14.2 acre) cells covering the entire state that depicts dominant tree species (forest type) in each cell. The result is a picture designed to be visualized at a scale of 1:250,000 showing forest type. From this map we can easily calculate the acres of each forest type surveyed in a given year. Note that areas are classified by dominant tree species, and do not take into account the mix of species that occur in many forest stands.

Once we acquired this host data, the next step was to overlay the surveyed areas with the forest type map layer. It is then easy to calculate the total area and percentage of each forest type surveyed in a given year using ArcGIS software (Map 13).

Map 12. Comparison of survey coverage in Alaska and Oregon.



Map 13. Surveyed area overlaid on birch forest type in the Susitna Valley.



Looking at the graph of acres surveyed by forest type below, you see that we survey quite a lot of white spruce. White spruce is the most widespread forest type in the state, with black spruce, birch, western hemlock, Sitka spruce and aspen in decreasing amounts. The surveyed acreage of each species is roughly correlated to each forest type's dominance on the landscape (Figure 70).

However; if we look at the next graph, showing *percentage* of each forest type surveyed, a different picture emerges. Our flight lines are more spread-out in the vast forests of the Interior, and are more concentrated on the coastal regions. This can result in yearly coverage where surveys may cover less than twenty percent of forests dominated by white spruce but more than forty percent of yellow-cedar forests (Figure 71).

This analysis suggests that percentages of all forest types surveyed are high enough to infer trends statewide. The minimum sampling is ten percent and some types are surveyed up to 40%.

On the other hand, insect outbreaks can be highly random in their distribution, making extrapolation to un-surveyed areas problematic. In 2015 for instance, we saw several outbreaks of extremely heavy defoliation that were separated by hundreds of miles, with no visible damage at all on millions of acres of host species in between these outbreak areas.

This data might also help us normalize acreages reported year to year when we make statements like "spruce beetle damage was observed on 8,300 acres in 2012 representing an 83% decline from 2011 acreage". We could further explain that while in 2011 we surveyed 40% of the primary host tree and in 2012 we surveyed 35% so the decline in acres was likely part of a downward trend.

Finally, to better meet information needs, we can use this data in our project planning to shift some of our survey time from one forest type to another.

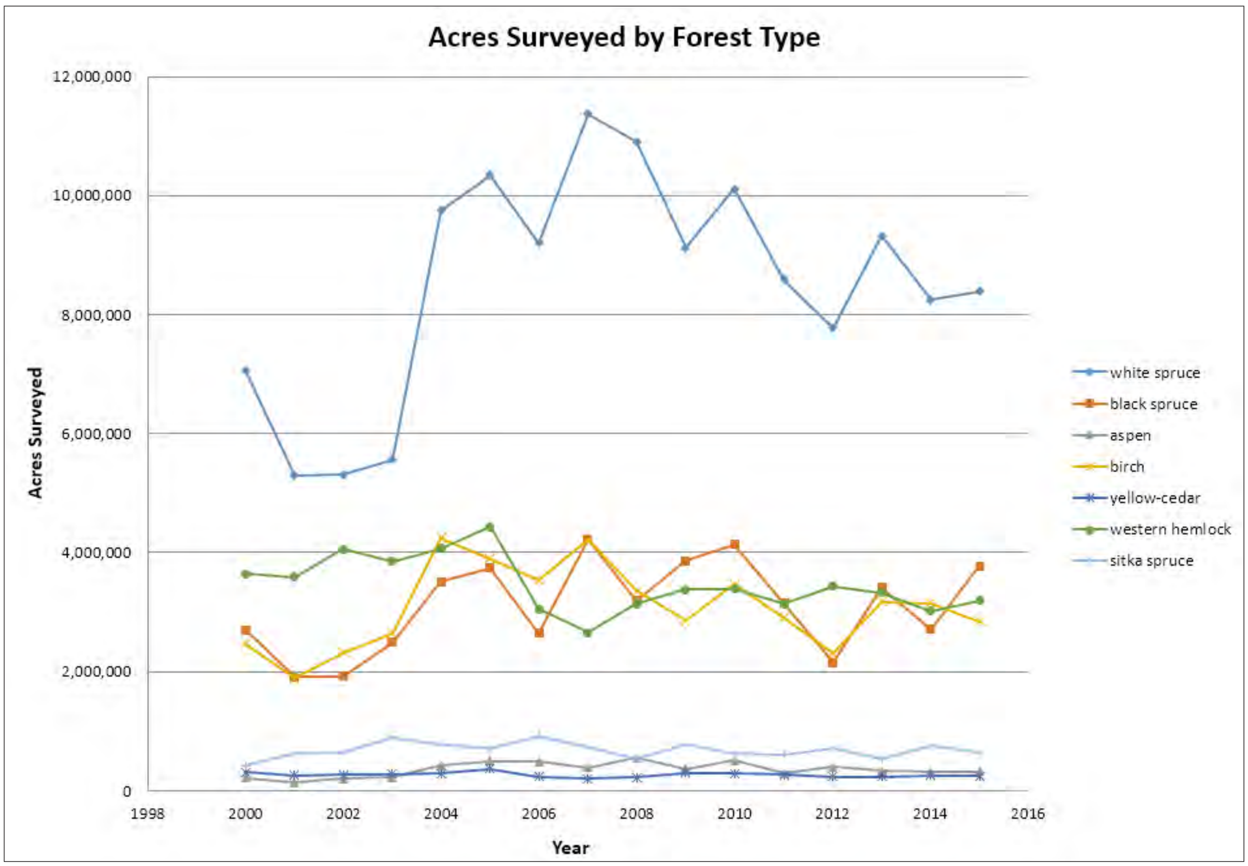


Figure 70. Acres surveyed by forest type, 2000-2015.

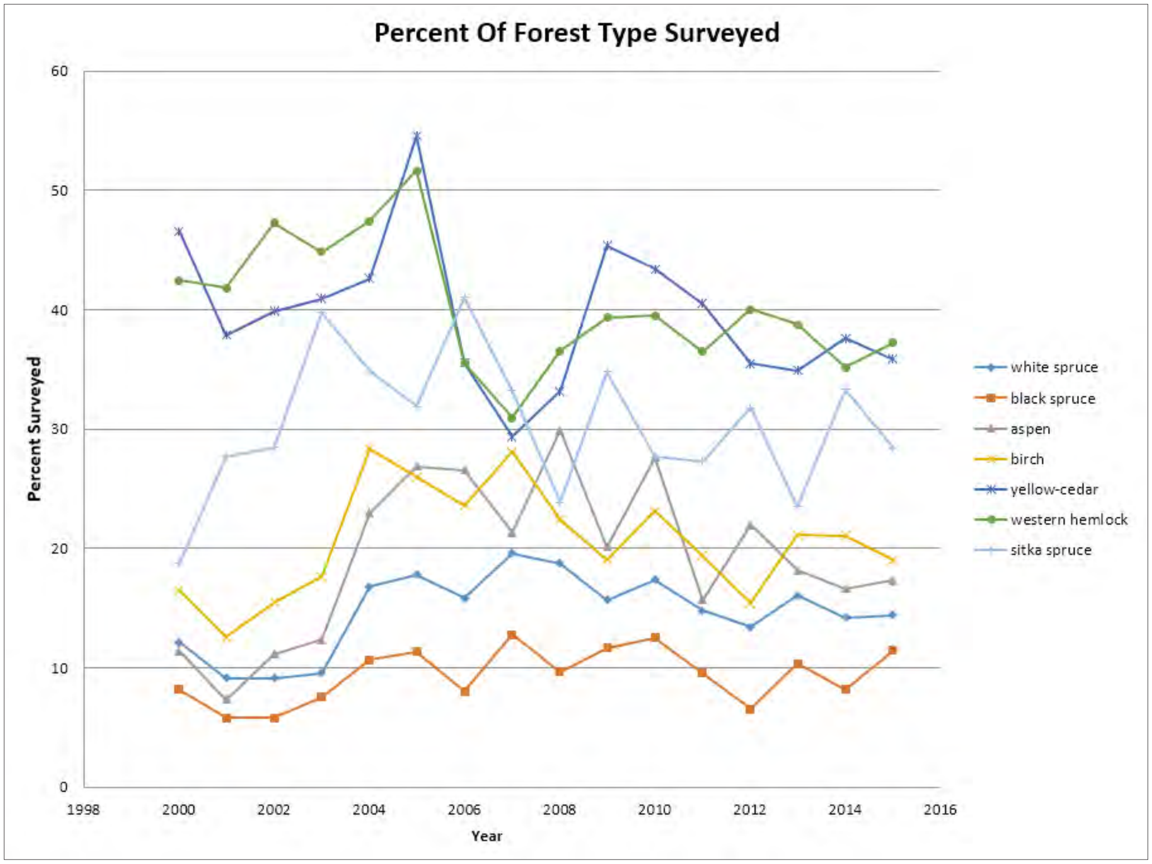


Figure 71. Percent of forest type surveyed, 2000-2015.

Ground-truthing work in 2015

Ground based verification is necessary to improve the quality of aerial survey data (Map 14). The plane's speed and elevation lead to uncertainty in our ability to accurately identify damage and to place the damage in a geographically precise way. Surveyors also need regular feedback on their aerial observations to give them insight on the causal agents behind the damage signature.

However, there are several impediments to ground truthing including limited time, personnel, and access. While some damage types, such as bark beetles, canker diseases, or cedar decline leave damage signatures that are more persistent on the landscape, many other types of damage are short lived. For example, most defoliating insects only cause damage as larvae; by the time the damage is noted from the air the larvae may have pupated and dispersed as adults. Trees defoliated early in the growing season may produce a second flush of leaves, hiding the damage. This means that for many types of damage, especially defoliation, verification must be made in a timely manner. Personnel are limited - our program has only ten people to assess damage on the ground throughout the entire state. Access is perhaps the biggest challenge. Alaska has very few roads, vast acreages of forest, and some of the most remote country in the US. Even forests that are close to roads can be difficult to access due to rugged terrain.

Just getting to a site takes time, planning and money. In most cases we take a trip by vehicle lasting up to several hours to a road head. A closer view can sometimes be gotten from a roadside overlook, often aided by binoculars; but usually we hike to the damage site. All too often cliffs, canyons, marshes, or no trespassing signs are in the way. Our field trips for other purposes take us far and wide, and we are always keeping aerial survey verification in mind when in the field. New tablet-based data technology will soon allow us to quickly access aerial survey data from the ground in near-real time. In Southeast Alaska, ground-truthing trips often include a commercial jet flight or multi-hour ferry ride. Remote areas off the road system, accounting for the majority of mapped acreage, are never visited unless an on-the-spot visit can be made by halting the survey, landing the survey float plane and seeing the site close-up. In most years we manage a handful of these spot visits, but the decision must be made quickly and carefully - the damage site has to be near a water body suitable for takeoffs; and the flight crew has to balance the need for the information against the increased time, fuel, and risk.

Boats have been used to verify aerial surveys in Southeast, and the Interior has extensive river systems that could be accessed by boat as well. Helicopters provide a convenient platform to verify damage. Given good weather conditions, they can access almost any location and hover near trees giving an excellent view of the damage, but the high expense of hiring a helicopter rules this option out except for the most critical information needs. A promising new technology is small unmanned aerial vehicles (UAV) carrying cameras or other sensors. FHP is planning test flights with the University of Alaska Center for Unmanned Aerial Systems Integration to prove this concept in the summer of 2016. A number of technical and regulatory issues need to be addressed before this tool could be used; but we may eventually use UAVs to capture close-up imagery to verify observations from manned fixed-wing aircraft.

Ground-Truthing Summary: Interior and Southcentral

In 2015 FHP recorded ground-truth data on 37 aerially surveyed damage polygons: 16 from the Fairbanks office (Chena River, Murphy Dome, Big Delta, and Fairbanks) and 21 in Southcentral from the Anchorage Office (Matanuska, Susitna, and Knik Rivers).

Accessibility

Twenty-seven of the 37 polygons were listed as fully accessible. This does not mean the entire polygon was surveyed on the ground, but enough of the polygon was seen to confirm or refute the aerial surveyor's determination. Seven out of the 37 polygons were listed as limited access. Limited access means the surveyors were not able to directly access the forest marked in the polygon but were able to view it at a distance and confirm or refute the aerial survey data for agent, intensity and polygon placement. Three polygons were listed as inaccessible. Original data was retained.

Accuracy of Damage Type

In 25 polygons the agent was confirmed. In seven polygons the agent was adjusted (changed to a more specific agent, such as replacing a generic call of willow defoliation with more specific willow leaf miner). In two polygons the agent was found to be incorrect, one damage agent was changed and the other polygon was deleted.

Accuracy of Polygon Placement

Twenty-nine polygons were determined to be correctly placed. Two polygons the placement was found to be incorrect or there was no evidence of the agent, leading to the polygon to be deleted. Three polygons were adjusted by moving or reshaping the polygon.

Ground-Truthing Summary: Southeast

In August 2015 FHP staff visited Haines and verified aerial survey polygons mapped as Dothistroma needle blight. Ground observations suggest that low intensity Dothistroma damage was occurring outside aerially mapped areas.

Several damage areas from previous years were revisited in Southeast Alaska. In June 2015 four sites on northern Kupreanof Island recorded as spruce beetle in 2012 were revisited by helicopter where it was determined the damage was not spruce beetle but rather yellow-cedar decline.

A site visit in June 2015 determined that a polygon mapped in 2012 as spruce beetle in the Maybeso Creek area of Prince of Wales Island was actually a girdling treatment. In July 2015, FHP staff confirmed alder canker that was mapped in 2015 in the Stikine River. For more information consult the species update on alder canker in the pathology section on page 17.

How to request surveys and survey data

We encourage interested parties to request aerial surveys (see request form page iii), and our surveyors use these requests and other information to determine which areas should be prioritized. Areas that have several years' worth of data collected are surveyed annually to facilitate analysis of multi-year trends. In this way, general damage trend information for the most significant, visible pests is assembled and compiled in this annual report. It is important to note that for much of Alaska's forested land, the aerial detection surveys provide the only information collected on an annual basis.

Forest insect and disease data can be obtained through the FHP Mapping and Reporting Portal (http://foresthealth.fs.usda.gov/portal/).

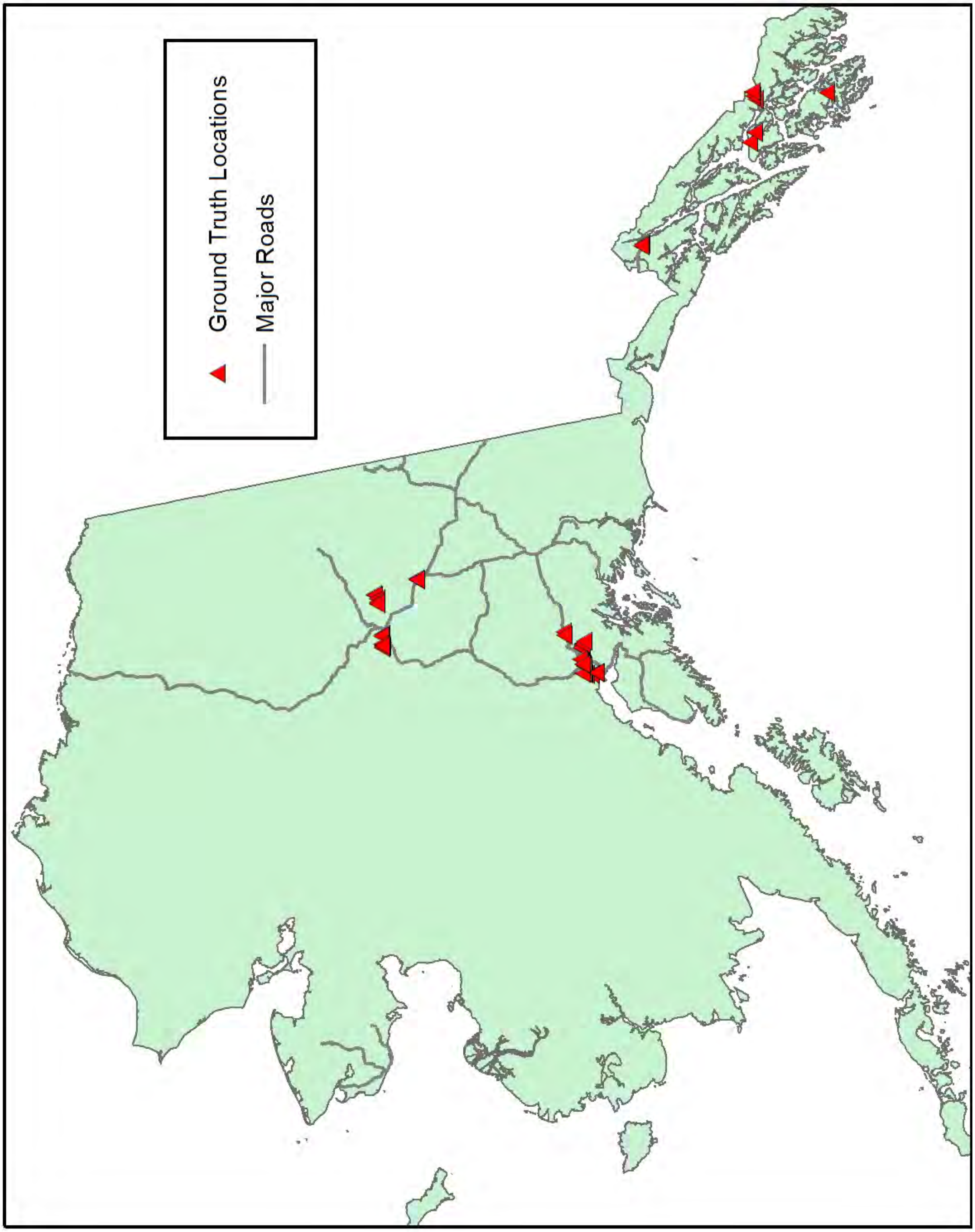
A number of applications are available, offering access to forest health data from Alaska and nationwide. The IDS Explorer (http://foresthealth.fs.usda.gov/IDS) allows the user to interactively visualize forest damage by agent and geographical area and print an area of interest. High quality full size 1:250,000 scale USGS quad maps may be generated with forest damage on them and downloaded as PDFs. GIS data from 1997 (by selecting all years when downloading) to the present can be downloaded from the site for all agents by state or region.

Other applications available on the Portal include forest pest conditions, data summaries, alien forest pest database, forest disturbance monitor, risk maps, tree species distribution data, forest health advisories, hazard rating information, and soil drainage and productivity. All available information within the FHP Mapping and Reporting Portal is on a national scale. Some products may not be complete for Alaska.

For data prior to 2009, contact Tom Heutte at theutte@fs.fed.us. Alaska Region Forest Health Protection also has the ability, as time allows, to produce customized pest maps and analysis tailored to projects conducted by partners.

Aerial Detection Survey Data Disclaimer:

Forest Health Protection and its partners strive to maintain an accurate Aerial Detection Survey (ADS) dataset, but due to the conditions under which the data are collected, FHP and its partners shall not be held responsible for missing or inaccurate data. ADS are not intended to replace more specific information. An accuracy assessment has not been done for this dataset; however, ground checks are completed in accordance with local and national guidelines (http://www.fs.fed.us/foresthealth/aviation/qualityassurance.shtml). Maps and data may be updated without notice. Please cite "USDA Forest Service, Forest Health Protection and its partners" as the source of this data in maps and publications.



Map 14. 2015 ground-truthing locations.

Appendix II:

Damage type by host species

Abiotic
Drought
Flooding
Landslide/avalanche
Windthrow
Winter damage

Alder Defoliation
Alder defoliation
Alder leaf roller
Alder sawfly

Alder Dieback
Alder dieback

Animal Damage
Porcupine damage

Aspen Defoliation
Aspen defoliation
Aspen leaf blight
Aspen leaf miner
Large aspen tortrix

Birch Defoliation
Birch aphid
Birch defoliation
Birch leaf miner
Birch leaf roller
Dwarf birch defoliation
Spear-marked black moth

Cottonwood Defoliation
Cottonwood defoliation
Cottonwood leaf beetle
Cottonwood leaf miner
Cottonwood leaf roller

Hardwood Defoliation
Hardwood defoliation

Hemlock Defoliation
Hemlock looper
Hemlock sawfly

Hemlock Mortality
Hemlock canker
Hemlock mortality

Larch Defoliation
Larch budmoth
Larch sawfly

Larch Mortality
Larch beetle

Shore Pine Damage
Dothistroma needle blight
Shore pine dieback

Spruce Damage
Spruce aphid
Spruce broom rust
Spruce budworm
Spruce defoliation
Spruce needle cast
Spruce needle rust

Spruce Mortality
Northern spruce engraver beetle
Spruce beetle

Spruce/Hemlock Defoliation
Black-headed budworm
Conifer defoliation

Subalpine Fir Mortality
Western balsam bark beetle

Willow Defoliation
Willow defoliation
Willow leaf blotch miner
Willow rust

Willow Dieback
Willow dieback

Yellow-cedar Mortality
Yellow-cedar decline

Appendix III:

Information Delivery

Publications:

Blodgett, J. T., J. W. Hanna, E. W. I. Pitman, S. M. Ashiglar, J. E. Lundquist, M.-S. Kim, A. L. Ross-Davis, N. B. Klopfenstein. 2015. Bioclimatic models estimate areas of suitable habitat for *Armillaria* spp. in Wyoming. pp. 29 - 33 in: Murray, M. and P. Palacios, compilers. Proceedings of the 62nd Western International Forest Disease Work Conference. 8-12 September 2014, Cedar City, UT.

Caouette, J. P., E. A. Steel, P. E. Hennon, P. G. Cunningham, C. A. Pohl and B. A. Schrader. 2016. Influence of elevation and site productivity on conifer distributions across Alaskan temperate rainforests. Canadian Journal of Forest Research. 46(2): 249-261.

D'Amore, D. V., K. Oiken, A. Steel, P. A. Herendeen and P. E. Hennon. 2015. Carbon accretion in unthinned and thinned young-growth forest stands of the Alaskan perhumid coastal temperate rainforest. Carbon Balance and Management. DOI 10.1186/s13021-015-0035-4.

Ha, A. Q. 2015. Sampling strategies for forest aerial detection surveys in Colorado. Ph.D Dissertation, Colorado State University, Fort Collins, CO. 192p.

Hanna, J. W., M. V. Warwell, H. Maffei, M. L. Fairweather, J. T. Blodgett, P. J. Zambino, J. Worrall, K. S. Burns, J. J. Jacobs, S. M. Ashiglar, J. E. Lundquist, M.-S. Kim, A. L. Ross-Davis, C. Hoffman, R. Mathiasen , R. Hofstetter , J. D. Shaw, E. W. I. Pitman, E. V. Nelson, G. I. McDonald, M. R. Cleary, S. Brar, B. A. Richardson, Klopfenstein, N. B. 2015. Bioclimatic modeling predicts potential distribution of *Armillaria solidipes* and *Pseudotsuga menziesii* (Douglas-fir) under contemporary and changing climates in the interior western U.S.A. In: Murray, M., P. Palacios, compilers. Proceedings of the 62nd Western International Forest Disease Work Conference. 8-12 September 2014, Cedar City, UT.

Hennon, P. E., C. M. McKenzie, D. V. D'Amore, D. T. Wittwer, R. L. Mulvey, M. S. Lamb, F. E. Biles, and R. C. Cronn. 2016. A climate adaptation strategy for conservation and management of yellow-cedar in Alaska. PNW-GTR-917. Portland, OR: U.S. Dep. Agric., For. Serv., Pacific Northwest Research Station. 382p.

Hennon, P. E. and D. V. D'Amore. 2014. Climate adaptation for the conservation and management of yellow-cedar. pp. 10-11. In: Shaw, K. and A. Hird, Eds. Global survey of ex situ conifer collections. Botanical Gardens Conservation International. Richmond, United Kingdom.

Hollingsworth, T., T. Barrett, E. Bella, M. Berman, M. Carlson, R. L. DeVelice, G. Hayward, J. E. Lundquist, D. Magness, T. Schworer. 2016. Chapter 6: Historic, current, and future vegetation distribution in the Chugach National Forest and Kenai Peninsula. In: G. Hayward et al. Climate Change Vulnerability Assessment-- Chugach National Forest. Pacific Northwest Research Station, Corvallis, OR. General Technical Report (in press).

Kepley, J. B., F. B. Reeves, W. R. Jacobi, and G. C. Adams. 2015. Species associated with cytospora canker on *Populus tremuloides*. Mycotaxon 130:783-805.

Kruse, J. J., L. Winton, N. Lisuzzo, G. Adams, K. Zogas and S. Swenson. 2015. Chapter 14. Alder (*Alnus incana tenuifolia*) mortality agent complex effects on riparian zone habitat, pp 187-195. *In*: Potter, K. M. and B. L. Conkling, Forest health monitoring: National status, trends, and analysis 2013. USDA Forest Service Research & Development, Southern Research Station, General Technical Report SRS-207.

Mulvey, R. L. and S. Bisbing. 2015. Complex interactions among multiple agents affect shore pine health in Southeast Alaska. Northwest Sci. (submitted).

Oakes, L., P. E. Hennon, K. O'Hara and R. Dirzo. 2014. Long-term changes in a temperate forest impacted by climate change. Ecosphere. 5(135): 1-28.

Oakes, L. E., P. E. Hennon, N. M. Ardoin, D. V. D'Amore, E. Ferguson, A. Steel, D. T. Wittwer and E. F. Lambin. 2015. Conservation in a social-ecological system experiencing climate-induced tree mortality. Biological Conservation. 192: 276-285.

Progar, R. A., J. J. Kruse, J. E. Lundquist, K. P. Zogas, and M. J. Rinella. 2015. An entomopathogenic fungus and nematode prove ineffective for biocontrol of an invasive leaf miner *Profenusa thomsoni* in Alaska. Biocontrol Science and Technology 25 (4): 373-382. DOI 10.1080/09583157.2014.977224.

Reich, R. M., J. E. Lundquist, and K. Hughes. 2016. Host-environment mismatches associated with subalpine fir decline in Colorado. Journal of Forestry Research (in press).

Sullivan, P. F., R. L Mulvey, A. Brownlee, T. M. Barrett, and R. P. Pattison. Warm summer nights and the growth decline of shore pine in Southeast Alaska. Environmental Research Letters. 10: 1-11. DOI 10.1088/1748-9326/10/12/124007.

Winton, L. M., R. Mulvey, E. E. Graham, N. Lisuzzo, and G. Dubois. 2015. Pocket guide for the identification of common forest diseases and insects in Alaska. R10-TP-161.

Presentations:

Burr, S. J. and N. J. Lisuzzo. 2015. Bark beetle dynamics in the forests of the Tanana River Valley. The Society of American Foresters, Yukon River Chapter. December 16. Oral presentation.

Fettig, C. J., R. E. Burnside, C. J. Hayes, J. J. Kruse, N. J. Lisuzzo, S. R. Mori, S. K. Nickel and M. E. Schultz. Factors influencing northern spruce engraver performance in white spruce slash in interior Alaska. 2015 Society of American Foresters National Convention, Baton Rouge, Louisiana, November 5. Oral presentation.

Graham, E. E. and T. Heutte. 2015. Forest Pests of Alaska: How Forest Health Protection and the LEO Network can work together to monitor our forests. LEO Network Monthly Webinar. June 23. Oral presentation.

Graham, E. E. and A. M. Ray. 2015. Evaluation of lure and trap design to survey for longhorned beetles in Southeast Alaska. Alaska Entomological Society Meeting January 2015. Oral presentation.

Graham, E. E. 2015. Forest Pests of the Region Update. USFS Region 10 Silviculture Meeting. Juneau, Alaska. April 28. Oral presentation.

Graham, E. E. 2015. Invasive Insects: How do they get in and what can we do to keep them out? Alaska Regional Leadership Team meeting. June 2015. Oral presentation.

Hennon, P. E. 2015. Range-wide yellow-cedar climate vulnerability assessment. International Association of Landscape Ecology. Portland, OR. July 5-8. Abstract, oral presentation, and session co-lead.

Hennon, P. E. 2014. The yellow-cedar conservation and management strategy. Alaska Region, Regional leadership meeting, Juneau, AK. Oct 10. Oral presentation.

Heutte, T. M. 2015. A GIS-based approach for prioritization of water bodies for aquatic invasive species surveys. Alaska Invasive Species Workshop. Juneau, AK. October 28. Oral presentation.

Lisuzzo, N. J. 2014. Forest Insects and Diseases: Considerations for successful tree regeneration in South-Central and Northern Alaska. Science and Technical Committee, State of Alaska Forest Practices Act Revision. November 25. Oral presentation.

Lisuzzo, N. J. 2015. Insects and diseases associated with the trees of Interior Alaska. Alaska Community Forestry -Alaska Tree Stewards. May 6. Oral presentation.

Lisuzzo, N. J. 2015. Invasive insects and diseases: a threat to Alaska's forests. Osher Life Long Learning Program. October 8. Oral presentation.

Moan, J. E., E. E. Graham, and J. E. Lundquist. 2015. Invasive Forest Insects in Alaska: Where are they now? Alaska invasive Species Workshop. Juneau, AK. October 27-29. Oral presentation.

Mulvey, R. 2015. Young-growth yellow-cedar decline: prioritizing stands for monitoring. USFS Region 10 Silviculture Meeting. Juneau, Alaska. April 28. Oral presentation.

Mulvey, R. 2015. Hazard tree management for developed recreation sites for sawyers. Juneau Ranger District Sawyer Safety Training. Juneau, Alaska. May 26. Oral presentation.

Mulvey, R. 2015. Hazard tree management for developed recreation sites. May 26. Sitka, Alaska. Oral presentation.

Mulvey, R. 2015. Invasive forest pathogens of North America: lessons for Alaska. Alaska Invasive Species Council Workshop, Juneau, Alaska. October 27. Oral presentation.

Winton, L. M. Plant disease and disease diagnosis. Cooperative Extension Integrated Pest Management Training. Palmer, AK. April 28-29. Oral presentation.

Wurtz, T. L. 2015. The current status of Elodea in Alaska, and what Harding Lake property owners can do. Annual meeting of Harding Lake Homeowners Association. May 30. Oral presentation.

Wurtz, T. L. 2015. Early detection, rapid response: the status of invasive plants in Alaska. Regional Leadership Team meeting, Petersburg, Alaska. June 30. Oral presentation.

Wurtz, T. L. 2015. The silent invasion. Osher Life-long Learning Program. September 17. Oral presentation.

Wurtz, T. L. 2015. The current status of the invasive aquatic plant, Elodea, in Alaska. Osher Life-long Learning Program. September 24. Oral presentation.

Wurtz, T. L. 2015. Alaska's statewide spotted knapweed response effort: an ongoing success story. Alaska Invasive Species Meeting, Juneau, Alaska. October 27. Oral presentation.

Posters

Dubois, G., J. Moan, E. E. Graham, S. Swenson and J. E. Lundquist. Spruce aphid reaches the Western Kenai Peninsula. 2015 Alaska invasive Species Workshop. Juneau, AK. October 27-29. Poster and abstract.

Lundquist, J. E., S. Swenson, G. Dubois and B. Box. Return of amber-marked birch leaf miner to Southcentral Alaska. 2015 Alaska invasive Species Workshop. Juneau, AK. October 27-29. Poster and abstract.

Winton, L. M. Utilizing Cooperative Alaska Forest Inventory permanent plots for boreal forest disease detection and quantification. Forest Health Evaluation Monitoring Project WC-EM-B-14-1. Forest Health Monitoring Workgroup Meeting. April 21, 2015. Poster.

Trip Reports

Box, B., G. Dubois, J. E. Lundquist and B. Davidson. Sterling Highway, Cooper Landing to Nikiski *Profenusa thomsoni* survey. R10 FHP Trip Report. August 24, 2015.

Dubois, G. and J. E. Lundquist. Richardson Highway from Valdez to Tok forest health survey. R10 FHP Trip Report. June 25, 2015.

Dubois, G., J. E. Lundquist and B. Box. Deformed spruce foliage in Soldotna and Homer. R10 FHP Trip Report. October 2015.

Graham, E. E. and J. E. Moan. Evaluation of subalpine fir mortality in Klondike Gold Rush National Historical Park and shore pine dieback in Skagway. R10 FHP Trip Report. August 2015.

Graham, E. E. Assessment of leaf roller damage along the Perseverance Trail in Juneau. R10 FHP Trip Report. August 2015.

Lundquist, J. E. and G. Dubois. Forest health observations along Lake Klutina Trail. R10 FHP Trip Report. June 25, 2015.

Lundquist, J. E. Leaf rollers on the Central Kenai Peninsula. R10 FHP Trip Report. June 3, 2015.

Lundquist, J. E., J. Moan, M. Bowser, G. Dubois and J. Archis. Spruce aphid on the Kenai Peninsula. R10 FHP Trip Report. July 2015.

Lundquist, J. E., J. Moan, G. Dubois and S. Swenson. Capitol Christmas tree inspection. R10 FHP Trip Report. October 14, 2015.

Mulvey, R. L. and M. S. Lamb. Forest health assessment of a foliage disease outbreak on shore pine in Haines, AK. R10 FHP Trip Report. August 25-26, 2015.

Swenson, S. and G. Dubois. Palmer Creek Road Trip Report. R10 FHP Trip Report. September 21, 2015.

Swenson, S. Mid-June Kenai Trip Report. R10 FHP Trip Report. September 24, 2015.

Biological Evaluations

Mulvey, R. L., G. Roberts, S. Spores and T. Roland. 2015 Update: Forest health assessment of yellow-cedar young-growth on Zarembo Island. Biological Evaluation. Original 2013 report by R. L. Mulvey, E. E. Graham, P. E. Hennon and C. Cleaver. July 13-14, 2015.

Mulvey, R. L., P. Hennon, L. Winton, D. Martin, G. Dubois and R. D. Parks. Yellow-cedar decline in young-growth on Kupreanof Island. Biological Evaluation. June 7, 2015.

Lisuzzo, N. J., and J. Moan. Tok River Forest ips beetle prevention. R10 FHP Biological Evaluation. May 1, 2015.