USDA
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Forest Health Conditions in Alaska - 2013

A Forest Health Protection Report

Forest Service
Alaska Region

State of Alaska
Department of
Natural Resources
Division of Forestry

R10-PR-035
February 2014

Cover: Clockwise starting from top left: yellow-cedar bark beetle, the invasive aquatic plant Elodea, the birch conk (*Piptoporus betulinus*), the Brooks Range during aerial detection survey, and gallery of the aspen leaf miner (*photo credit: Derek Sikes*)

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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 (hosts species affected, damage type, disease or insects observed).

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.

Do you need additional forest pest information (GIS data, extra copies of the 2011 Forest Health Conditions in Alaska Report, etc.)? Please be as specific as possible. If hardcopies are desired, provide a mailing address.

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.

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

How do you and/or your organization use the information in this report and/or maps on our website?

SEND

Forest Health Conditions in Alaska - 2013

FHP Protection Report R10-PR-035

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Table of Contents

Maps

Tables

Introduction

By Steve Patterson
State and Private Forestry Assistant Director, Alaska

On behalf of the Forest Service's Forest Health Protection work group and its primary partners, I am happy to present to you the Forest Health Conditions in Alaska—2013 report.

One of the primary goals of this report is to summarize monitoring data collected annually by our Forest Health Protection team. The report helps to fulfill a mandate (The Cooperative Forestry Assistance Act of 1978, as amended) that requires surveying, monitoring, and reporting of the health of the forests annually. This report also provides information for the annual Forest Insect and Disease Conditions in the United States report. In addition, the Forest Health Conditions in Alaska—2013 report facilitates accomplishment of an integral part of our core mission: technical assistance for you, our stakeholders. Our goal for this report is to help resource professionals, land managers, and other decision-makers identify and monitor forest health risks and hazards. This report integrates information from multiple sources summarized and synthesized by our forest health team. It's as much about your forests as it is reflective of our collective abilities to monitor and describe their conditions.

I invite you to read this report at whatever pace or in whatever mode you might choose: find a pest or condition of concern, look for what's changed since last year, examine the essays, or study it cover-to-cover. Some of the noteworthy changes this year are the continued impact and abundance of defoliating insects and canker diseases, especially on broadleaf tree and shrub hosts; and the aggressive spread of the invasive plants European bird cherry and Elodea.

Within the report you can also find more in-depth essays about current topic and issues of interest. We describe new work in uncovering the role of a variety of disease agents contributing to alder dieback, which was previously thought to be caused by a single fungus. We report on an investigation of yellow-cedar decline found for the first time in young-growth stands. We tell the story of efforts to control an explosion of spruce engraver beetles following the Manley Hot Springs Airport expansion and our monitoring of the response of engravers to a recent windstorm in Interior Alaska. We follow up on our early detection and rapid response (EDRR) monitoring for exotic forest insect pests and our collaboration with private property owners to limit the spread of invasive bird vetch in Fairbanks.

Cooperators made several notable contributions to this publication. Matt Bowser with the US Fish and Wildlife Service relates the story of his work on pre-survey mapping of hardwood defoliation using satellite data. Partners from Oregon State University and the Pacific Northwest Research Station bring us up to date on new measurement protocols for growth of mosses and lichens that are a key component in the global carbon cycle. Gino Graziano with University of Alaska Cooperative Extension tells us about his work with Anchorage-area youth to determine if invasive cherry trees are causing increased moose damage to native trees in Anchorage.

You are welcome to contact me or this report's contributors to let us know how we can improve future versions to make it more useful for you. I am happy to announce that the updated version of the National Insect and Disease Risk map has been published and distributed. More information can be found at www.fs.fed.us/foresthealth/technology/nidrm.shtml. If you need information or briefings about NIDRM or any other report we have produced, please let us know. I hope you can interact with our forest health team, especially the new members, to provide data and/or observations to make this report and others relevant and reflective of the true scope and magnitude of impacts from insects, disease, abiotic conditions and invasive plants to our forests of Alaska.

I want to take this opportunity to introduce some new members of our Alaska forest health team and new offices in Anchorage and Juneau.

Jason Moan – Entomologist, DOF, Anchorage

Prior to joining the Alaska Division of Forestry, Jason Moan spent close to eight years with the North Carolina Forest Service, most recently as the forest health monitoring coordinator. While in North Carolina, he was involved in aerial and ground surveys, forest health diagnostics, mapping and spatial analysis, database development, and outreach. He has a B.S. in Forest Resources from the University of Idaho and a M.S. in Forestry from Virginia Tech. His graduate work focused on remote sensing of southern pine beetle hazard variables. He looks forward to tackling the challenges of forest health in Alaska and having the opportunity to see the state from the air.

Garret Dubois – Biological, Technician, FHP, Anchorage

Garret grew up in New Hampshire where his family has been in the wood and forestry industry for many years. Before going to school for forestry he worked for nearly ten years in the family sawmill and planer mill. After leaving the mill he earned an A.A.S in Forest Technology, a B.S. in forest science with a plant biology concentration, and a M.S. in natural resources from the University of New Hampshire. He has worked for the State of New Hampshire

Division of Forests and Lands Forest Health Section and most recently worked as a biological technician for the Northeastern Area, State and Private Forestry, Forest Health Protection (FHP). While working for FHP he was able to do some method development work on northeastern woodborer trapping, forest health assessments for national wildlife refuges, and aerial survey of federal and state lands throughout Maine, New Hampshire, New York and Vermont. Additionally, he had the opportunity to work on a number of invasive insect projects helping to detect and manage Asian longhorn beetle, emerald ash borer and sirex wood wasp. He is really excited about having the opportunity to work in Alaska and is looking forward to seeing some new ground and learning some new flora and fauna.

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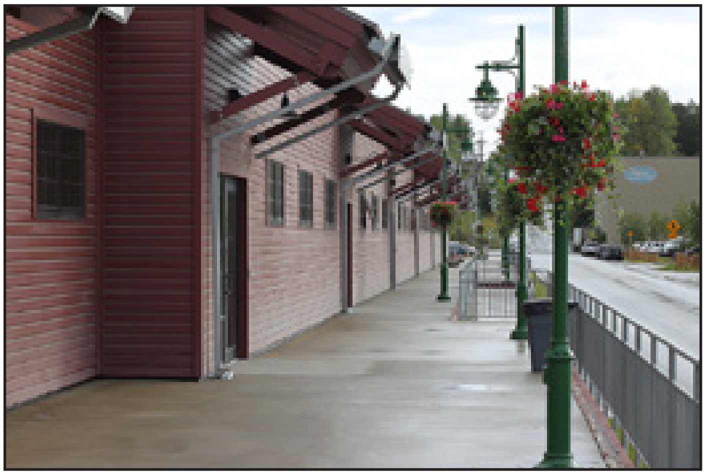


Highlights from 2013

Figure 1: Office of the Aerial Detection Survey staff in July.

The Forest Health Protection (FHP) Program (State and Private Forestry, USDA Forest Service), together with the Alaska Department of Natural Resources Division of Forestry, conducts an annual, statewide Aerial Detection Survey across all land ownerships. In 2013, staff and cooperators identified over 879,000 acres (*Figure 1*) of forest damage from insects, diseases, declines and abiotic agents on the 31.5 million acres surveyed (Maps 1 and 2, Table 1). The total damaged acreage observed is up by 42% from 2012. Much of the change since last year is due to substantial increases in spruce, alder and birch defoliation, with a combined increase of over 367,000 acres mapped in 2013 (Table 2). The warm and dry conditions experienced throughout most of the state contributed to this increase in defoliator activity.

The acreage of aerially detected damage reported here serves only as a sample of statewide conditions in a state with 127 million acres of forested land. Generally, the acreage affected by pathogens is not accurately represented by the aerial survey, since many of the most destructive disease agents (e.g. wood decay fungi, root diseases, and dwarf mistletoe) are not readily visible from the air. The Aerial Detection Survey appendix of this report provides a detailed description of survey methods and data limitations (Appendix I). Additional forest health information is acquired through ground surveys, monitoring plots, site visits, qualitative observations, and reports from forestry professionals and the general public. This information is included in the report, where possible, to complement the aerial survey findings. Forest Health Protection staff work alongside many agency partners on invasive plant issues, conducting roadside and urban surveys, public awareness campaigns, and general outreach and education efforts.

Insects

The amount of insect damage detected by aerial survey in 2013 increased from 2012 for alder and birch. Over 536,000 acres of external feeding damage were observed on Alaskan hardwood trees and shrubs in 2013, particularly birch and alders, an increase from the 280,000 acres observed last year. A variety of insects contributed to this defoliation, including several geometrid moth species, the rusty tussock moth, leaf rollers, and leaf beetles.

Figure 2: The green alder sawfly was found feeding on red alder in Sitka, AK.

One major contributor to this damage was the birch leaf roller, which was mapped on 331,000 acres across the state. The green alder sawfly (*Figure 2*), a non-native defoliator of alder, was found feeding on red alder in Sitka, Ketchikan, and Juneau. Defoliation of aspen, cottonwood, and willow detected by aerial survey was down in 2013 compared to 2012. The aspen leaf miner, which was previously ranked as the number one pest in terms of acreage damaged, increased in activity from last year but is still not at the level seen in 2010. More information about defoliators can be found on page 18.

Spruce defoliation from insects and disease decreased by half in 2013. However, there was a dramatic outbreak of western black-headed budworm damage, with nearly 122,000 acres mapped in and around the Wood-Tikchik State Park in Southwestern Alaska. The acreage affected by spruce aphid continues to decrease; another cold winter may push this pest to undetectable levels next year. Spruce beetle was observed on 27,000 acres during aerial surveys this year representing a 227% increase over 2012. While this increase seems significant, in 2012 forest health specialists recorded the lowest annual figure for spruce beetle-caused mortality since the systematic surveys began in the early 1970s.

Hemlock defoliation continues to increase in Southeast Alaska. Over 13,300 acres of hemlock sawfly defoliation were mapped during the aerial detection survey in 2013. The acreage is more than double that of 2012, however, hemlock sawfly damage did not become apparent in many locations until after completion of the aerial survey last year. The only areas with hemlock sawfly damage detected in both 2012 and 2013 were Etolin and Revillagigedo Islands.

Diseases

A two-year Evaluation and Monitoring project on shore pine health funded by the USFS Forest Health Monitoring Grant Program was completed in 2013. The goal of this project was to investigate the insect and disease agents of shore pine, a subspecies of lodgepole pine typically found on peatland sites in Southeast Alaska. Forest Inventory Analysis data had detected a significant decline in shore pine biomass, highlighting critical knowledge gaps for this non-timber species. FHP installed a network of 46 permanent plots across five locations in Southeast Alaska. Western gall rust, foliage disease and bole wounding were important damage agents of shore pine. Work is needed to determine the key causes of bole wounding, which probably include a variety of animals (porcupines, beavers, bears and deer), mechanical breakage from snow loading, and a possible bole canker pathogen (samples have been collected for molecular diagnosis). Secondary insects and fungi caused extensive localized mortality of western gall rust infected boles and branches. Final results of the project will be reported in 2014 and permanent plots will be revisited at regular intervals to track change over time.

Dothistroma foliage disease of pine was confirmed as the cause of severe but localized damage to shore pine in Gustavus and Glacier Bay National Park. Three consecutive years of this outbreak has been sufficiently damaging to cause mortality of affected pines, since shore pine frequently retains three or fewer needle cohorts in Alaska. Most damage occurred in dense pine-cottonwood-spruce stands, where pine regeneration is limited. Survival of affected tagged trees will be assessed in 2014. Aerial and ground surveys will help to determine whether the outbreak continues or expands in coming years. Approximately 5,000 acres were sufficiently damaged to have a signature detectable by aerial surveyors.

A hemlock canker outbreak occurred along roadsides and riparian areas of Prince of Wales Island in 2012 and 2013. Hemlock canker causes periodic mortality and branch dieback of western hemlock in Southeast Alaska, but the causal fungus is unconfirmed. Samples were sent to Gerry Adams (Associate Professor of Practice, University of Nebraska) for culturing and genetic sequencing, which yielded several potential fungal pathogens. Inoculation trials with these fungal isolates were initiated near Thorne Bay and Staney Creek on Prince of Wales in May 2013, and additional diseased tissue samples were collected for culturing and sequencing. Inoculated trees will be evaluated in spring 2014. If inoculations have resulted in symptom development and the inoculation fungi can be re-isolated from infected tissue, we will have identified the causal fungus and gained valuable insight into hemlock canker epidemiology.

Rhizosphaera needle cast on Sitka, white, and Lutz spruce was severe throughout many areas of the state in 2013. Older needles became symptomatic in late summer, leaving trees with thin crowns. The disease was particularly evident in late August on Sitka spruce in the Juneau area. The outbreak on white and Lutz spruce was moderate with severe pockets extending from the Kenai Peninsula to the Interior near Fairbanks and Tok.

Hemlock dwarf mistletoe and stem decays (heart rots) are important diseases of coastal forests that do not vary year-to-year. They cause tree growth loss and mortality, but also have important ecological functions such as initiating disturbance, altering carbon and nutrient cycles, and providing wildlife habitat. Stem decays cause unseen damage that increases the risk of tree failure. These hazard trees are an important consideration in urban and recreational settings.

Figure 3: Aspen canker debarked

A project was initiated with the Cooperative Alaska Forest Inventory (CAFI), an existing network of boreal forest permanent plots.

This project will investigate tree disease and mortality in Southcentral and Interior Alaska by utilizing CAFI plots to: monitor disease agents of forest trees and evaluate the extent of mortality and damage; assess correlation between disease agents and tree damage and mortality to determine the primary causal agent/s; evaluate geographic, plant community, or age-class trends associated with disease damage and mortality through assessment of ground-based plots: evaluate correlations of individual diseases with tree growth and volume loss, and facilitate ground-truthing of the Aerial Detection Survey. A severe, but localized outbreak of aspen canker was discovered during the course of this project (*Figure 3*).

Noninfectious Disorders

Yellow-cedar decline has been mapped on more than 400,000 acres over the years across an extensive portion of Southeast Alaska, and the 2013 aerial survey mapped almost 14,000 acres of active yellow-cedar decline (reddish dying trees). This climate-driven decline is associated with freezing injury to fine cedar roots that occurs where snowpack in early spring is insufficient to protect fine roots close to the soil surface from late-season cold events. In 2013, decline injury was documented for the first time in portions of two adjacent young-growth stands on Zarembo Island (see essay on page 50). Wet-site indicator plants in the understory of these stands suggest that shallow rooting due to poor soil drainage predisposed yellow-cedar to decline at this location.

A comprehensive yellow-cedar strategy is being developed in collaboration with the Regional Office, the National Forest System and other cooperators (expected 2014). This document will provide information on yellow-cedar biology and decline, and guidance on yellow-cedar management for specific regions and Ranger Districts in Alaska.

There was a large amount of snow damage reported during December 2013. Heavy snow loads caused small hardwood trees and conifer trees with a high height to diameter ratio to snap at the bole or break limbs. The abundance of host material could aid in building populations of woodboring insects. Alternatively snow falling from branches can strip overwintering eggs off the foliage, as is the case with the hemlock sawfly.

Invasive Plants

University of Alaska Cooperative Extension Service (CES) staff have developed an outreach program for middle school and high school students in Anchorage. The program focuses on the spread of European bird cherry in Anchorage parks and examines how it affects the availability of browse to Anchorage's urban moose population.

Members of the Fairbanks Cooperative Weed Management Area (CWMA) are working with local residents to combat the spread of bird vetch into residential subdivisions.

A three-day invasive plant workshop held in Bethel, Alaska, brought together the CES, the UAF Biology and Wildlife Department and the Kuskokwim River Watershed Council. The workshop jump-started invasive plant interest and activity in the Yukon-Kuskokwim delta.

In an important development, the Alaska Department of Transportation and Public Facilities (ADOT&PF) released a new Integrated Vegetation Management plan in June. The plan will assist ADOT&PF in "its responsibility to manage the vegetation upon its lands to improve safety and control invasive plant species."

FHP staff working on aerial survey found a dense infestation of the invasive aquatic plant Elodea when they landed on Martin Lake in the Copper River Delta. Though they carefully removed strands of Elodea from the floatplane's rudders before taking off, once in flight a staff member glanced back and saw Elodea still clinging to the rudder assembly. He quickly snapped a photo. As the plane approached Hinchinbrook Island, the staff member looked back again and found the Elodea was gone. The photo has proven to be influential in the Elodea discussion, countering the arguments of skeptics who claimed that the spread of aquatic plants by floatplane was unlikely.

In cooperation with the Alaska Association of Conservation Districts (AACD), work on developing invasive plant management plans and forming new cooperative weed management areas continues in Southeast Alaska. AACD continues to address the garlic mustard infestation in downtown Juneau, and the Juneau CWMA has had success in reducing a major perennial sowthistle infestation at Outer Point.

CES continued its series of live webinars in 2013. The theme of the webinar series is Integrated Pest Management, and one of the goals is to help certified pesticide applicators across the state earn continuing education units that will help them maintain their certifications. More than 100 people participated in the webinar series.

Table 1. Forest insect and disease activity detected during aerial surveys in Alaska in 2013 by land ownership[1] and agent. All values are in acres[2].

Agent	National Forest	Native	Other Federal	State & Private	Total
Abiotic causes[3]	864	1,925	2,190	3,894	**8,872**
Alder defoliation[4]	4,542	32,853	16,275	79,414	**133,083**
Alder dieback[5]	2,473	6,130	4,547	13,339	**26,489**
Aspen leaf miner		27,893	41,794	29,904	**99,592**
Birch aphid			67	230	**297**
Birch defoliation[6]	392	125,200	156,397	72,604	**354,593**
Black-headed budworm	44	41,865	807	79,173	**121,889**
Cedar decline[7]	12,692	99	72	491	**13,353**
Conifer defoliation	1,866	19	2,115	750	**4,750**
Cottonwood defoliation[4]		7,315	7,098	5,169	**19,582**
Cottonwood leaf beetle	10		92	15	**117**
Dwarf birch defoliation[6]				601	**601**
Hardwood defoliation	183	75	686	1,867	**2,811**
Hemlock sawfly	10,146	295	827	2,062	**13,329**
Large aspen tortrix		682	1,547	1,054	**3,283**
Porcupine damage	339		49	99	**488**
Dothistoma needle blight	97	128	1,868	2,739	**4,831**
Spruce beetle	2,137	23	19,752	5,119	**27,031**
Spruce broom rust		0	662	242	**904**
Spruce budworm		5,122	787	525	**6,434**
Spruce engraver and spruce beetle[8]		13		299	**312**
Spruce engraver beetle		2,527	2,640	2,574	**7,741**
Spruce needle aphid				158	**158**
Spruce needle cast	35			12	**47**
Willow defoliation[4]	364	4,392	6,113	11,482	**22,351**
Willow leafblotch miner		1,839	1,950	2,091	**5,880**

1. Ownership derived from the 2008 version of Land Status GIS coverage, State of Alaska, DNR/Land records Information Section. State & private lands include: state patented, tentatively approved, or other state-acquired lands, and patented disposed federal lands, municipal lands, or other private parcels.
2. Acre values are only relative to survey transects and do not represent the total possible area affected. Table entries do not include many of the most destructive diseases (e.g., wood decays and dwarf mistletoe), which are not readily detectable in aerial surveys.
3. Damage acres from some types of animals and abiotic agents are also shown in this table. Mapped abiotic damage can include windthrow, snow loading, freezing injury, flooding, snow slides, and landslides.
4. Significant contributors include alder sawflies, internal leaf miners, and leaf rollers for the respective host.
5. Alder dieback is description used since 2012 to label alder stem mortality mapped during the survey. Past reports have referred to it as alder canker, but verification of alder canker requires ground-checks and dieback symptoms are the damage signature observed from the air.
6. 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 Labrador tea, small willows, Spiraea and other woody shrubs, and is attributable to several external leaf-feeding insects. In contrast, birch tree defoliation is caused by a combination of internal and external leaf-feeding insects.
7. 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.
8. Acres on which northern spruce engraver and spruce bark beetle activity occurred in the same stands.

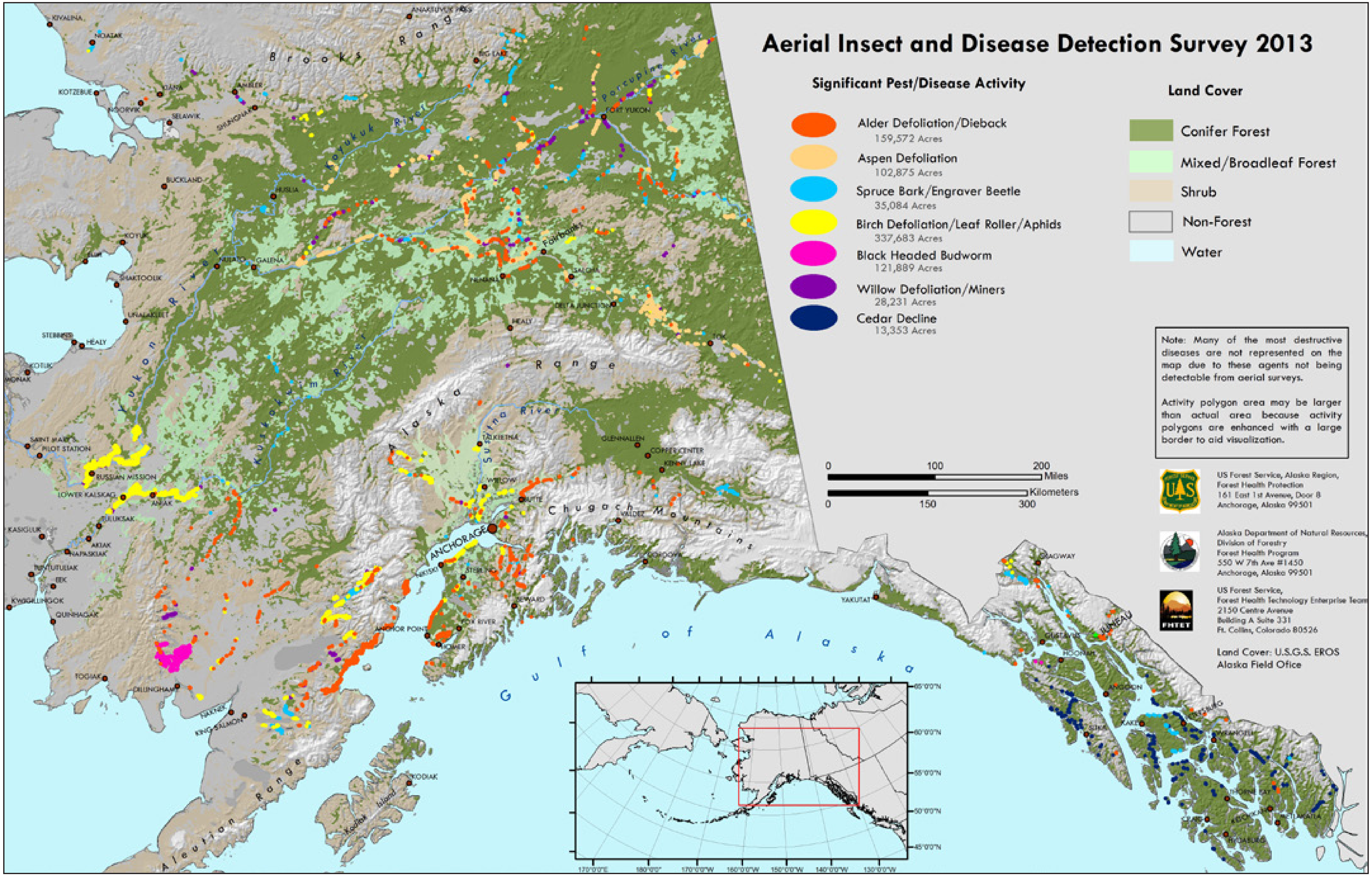
Table 2. **Affected area (in thousands of acres) for each host group and damage type from 2009 to 2013 and a 10-year cumulative sum. For detailed list of species and damage types that compose the following categories, see Appendix II on page 78.**

Host Group / Damage Type[1]	2009	2010	2011	2012	2013	10-year Cumulative[2]
Abiotic damage	1.8	12	16.3	15.8	8.8	**62**
Alder defoliation	3.4	7	123	58.5	133.1	**373.3**
Alder dieback	1.3	44.2	142	16.4	26.4	**244.9**
Aspen defoliation	310.8	464	145.6	82.7	102.4	**2789.9**
Birch defoliation	14.3	33.3	76.7	177.8	349	**1219.7**
Cottonwood defoliation	11.2	14.1	23.4	27.1	19.5	**149.7**
Hemlock defoliation	3.6	9.1	11.1	5.5	13.3	**38.2**
Hemlock mortality	2.1	0.4	6.2	0	0	**10.6**
Larch defoliation[3]	0.1	0	0.1	0	0	**17.7**
Larch mortality	0.1	0	0	0	0	**34.6**
Shore pine damage	0	0	0	2.9	4.8	**6.7**
Spruce damage	0.8	40.9	5.5	14.2	7.5	**302.1**
Spruce mortality	138.9	101.8	55.5	19.8	35.1	**794.3**
Spruce/hemlock defoliation	1.1	0.3	0	0	121.2	**126.1**
Spruce/larch defoliation	13.2	0	0	0	0	**16.5**
Subalpine fir mortality	0	0	0	0	0	**0.8**
Willow defoliation[3]	139.7	562.7	63.9	47.7	28.2	**1136.9**
Total damage acres - thousands	**656.9**	**1336.8**	**707.0**	**491.1**	**849.3**	**7324**
Total acres surveyed - thousands	**33,571**	**36,878**	**31,392**	**28,498**	**31,497**	
Percent of acres surveyed showing damage	**2%**	**3.6%**	**2.2%**	**1.7%**	**2.7%**	

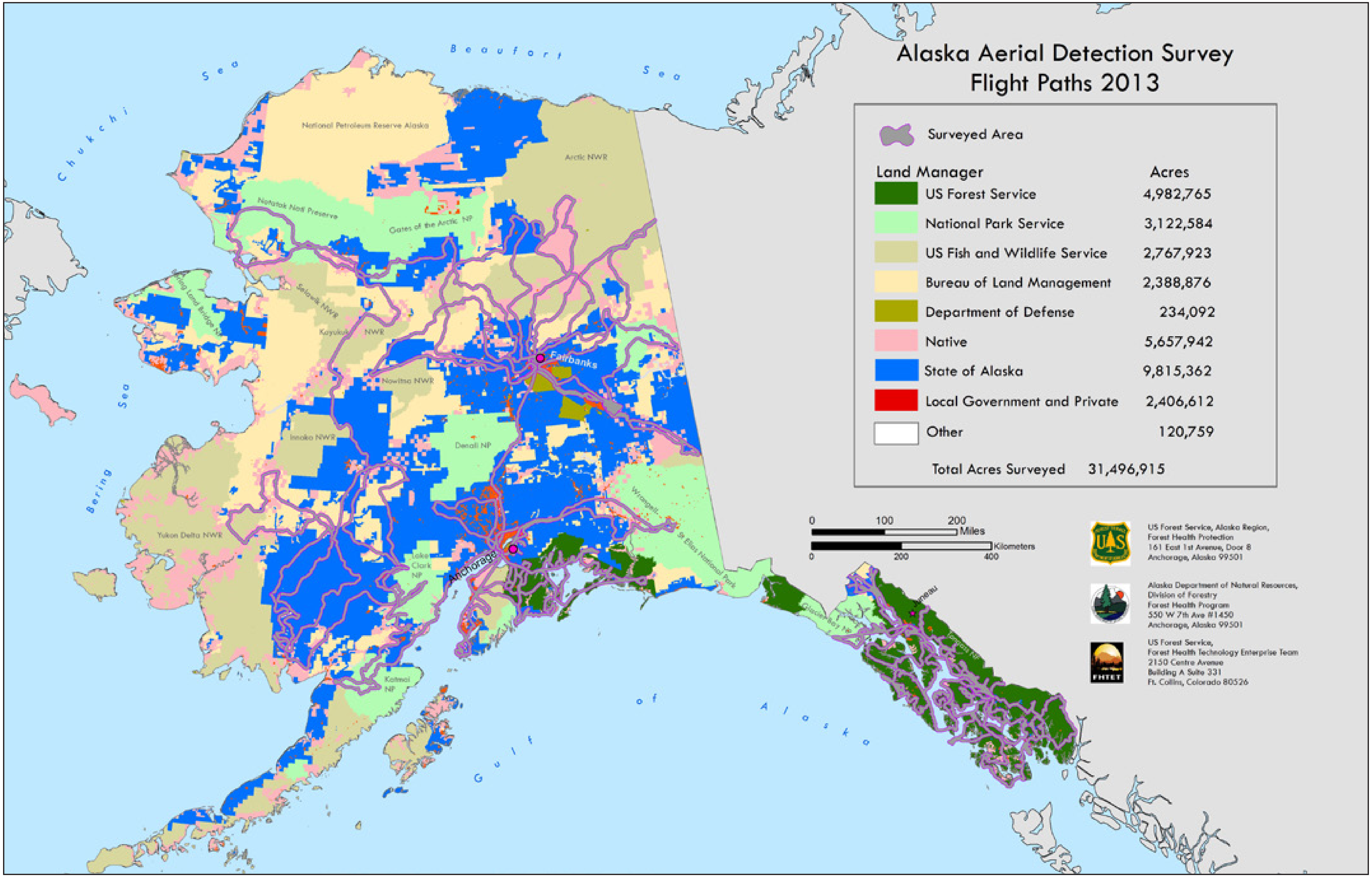
[1] Values summarize similar types of damage, mostly from insect agents, by host group. Disease agents contribute to the totals for spruce defoliation, hemlock mortality and alder dieback. Damage agents such as fire, wind, flooding, slides and animal damage are not included.

[2] The same stand can have an active infestation for several years. The cumulative total combines all impacted areas from 2003 through 2013 and does not count the same acres twice.

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



Map 1: Significant pest activity for the 2013 Aerial Detection Survey.



Map 2: Survey flight paths from 2013 aerial survey and general ownership.

Status of Insects

Figure 4: Larvae of the striped alder sawfly which feed gregariously on alder leaves.

Early Detection Rapid Response (EDRR) Monitoring of Non-Native Bark Beetles and Wood Boring Insects

Roger Burnside and Jason Moan, Entomologists
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Exotic, or non-native, insects can be a serious threat to our nation's urban and rural forests (www.fs.fed.us/foresthealth/publications/EWS_final_draft.pdf). Case histories of non-native beetles and other wood boring insects already established in North America (e.g. Asian longhorn beetle, emerald ash borer, and Sirex woodwasp) have demonstrated the importance of early detections of non-native forest pests to more effectively conduct quarantine, control, and eradication efforts where feasible.

The early detection and rapid response (EDRR) pest monitoring system is critical to forest health management efforts in Alaska given the extensive area of Alaska's remote forest habitats, expansive coastline, and ever-changing patterns of commerce in a changing climate. It's also imperative that EDRR monitoring efforts be conducted via an ongoing program to more effectively manage the risk of unintended non-native species introductions.

The goals of the Alaska Early Detection and Rapid Response (EDRR) non-native bark beetle and wood borer monitoring project are to (1) detect, delimit and monitor newly introduced non-native bark beetles, ambrosia beetles, and wood borers at selected high-risk forest areas, (2) identify additional pathways and areas for expanding annual monitoring, and (3) quickly assess and respond to newly detected non-native forest insect infestations. Providing systems for early detection of non-native forest insects entering Alaska has necessitated the establishment of a cooperator monitoring network. This network assists the Alaska Division of Forestry (DOF) and the USDA Forest Service Forest Health Protection - Region 10 (R10 FHP) with identifying and assessing the risk of non-native insect introduction and establishment in Alaska's forests.

The cooperative DOF/FHP non-native bark beetle and wood borer EDRR monitoring partnership in Alaska began in 2002, with traps (*Figure 5*) concentrated near potentially high-risk sites in Anchorage, Fairbanks and Juneau. In 2008, DOF received significant funding from the USDA Forest Service FHP National Program to enable expansion of this EDRR monitoring into areas that had been identified by state and federal agency cooperators as potential pathways for new beetle introductions. Since 2008, key partners have included the Animal & Plant Health Inspection Service/Plant Protection & Quarantine (APHIS/PPQ), U. S. Customs & Border Protection, U.S. Fish & Wildlife Service, AK DNR Division of Agriculture, AK DNR Division of Forestry Haines and Ketchikan Area Offices, Alaska Native corporations, the Natural Resources Conservation Service, and others, including citizen volunteers. A primary goal of this more recent effort has been to solidify agency and cooperator partnerships and put additional geographic locations "on the map" for ongoing non-native beetle EDRR monitoring.

Figure 5: Lindgren funnel traps are commonly used to capture bark beetles. The design is meant to mimic the silhouette of a tree and is baited with attractive compounds.

Since 2010, monitoring sites outside the main population centers have been established with a number of EDRR cooperators, primarily through DOF and R10 FHP involvement with the Alaska Pest Risk Assessment Committee (AKPRAC; *Map 3*). AKPRAC is an ad hoc State group, chartered nationally through a compact between the U.S. Dept. of Agriculture (APHIS/PPQ) and U.S. Customs and Border Protection . AKPRAC's primary focus is to provide a local forum for more effective communication among state and federal agencies working in the area of invasive forest insect pest regulation and management.

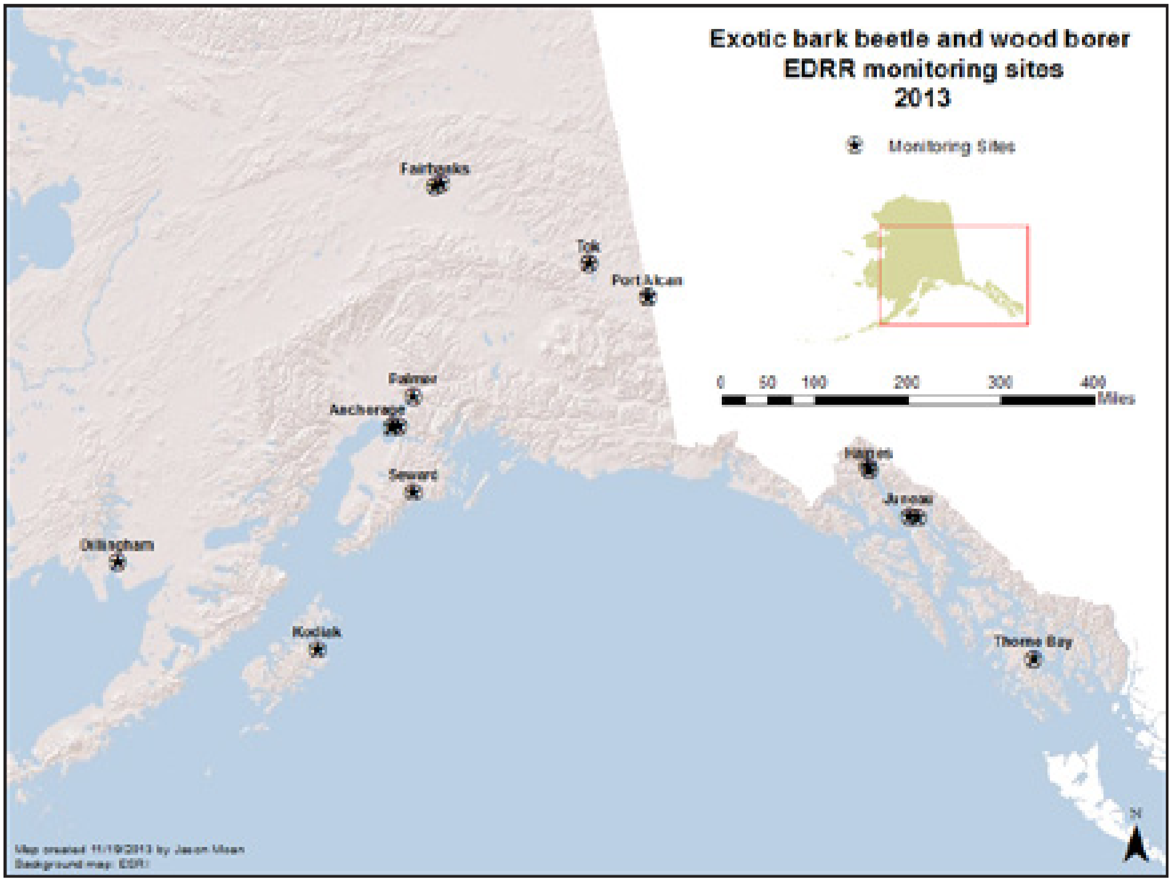
Pre-screening of samples for potential non-native bark beetles and wood borers is done at the state level, with confirmation by EDRR lead taxonomists under contractual agreement with FHP. Over 100,000 bark beetles and woodborers have been trapped and identified to the species level from Alaska's non-native bark beetle and wood borer EDRR monitoring efforts since 2002. As of 2013, no tree-killing non-native bark beetles or woodborers have been detected from this base level EDRR monitoring in Alaska. This is in contrast to introductions and expansions of a few non-native insect defoliators which have been detected over the past decade (e.g., amber-marked birch leaf miner, green alder sawfly, European yellow underwing).

EDRR trapping results from all participating states are assembled in a national database maintained by FHP in Washington, D.C. The following insects in *Table 3* (primarily bark beetle and wood boring species) are considered targets based on risk assessments of economic damage in the country of origin (lures chosen for the surveys are attractive to these species).

Firm establishment of ongoing monitoring sites for Alaska's base exotic bark beetle and wood borer EDRR monitoring program will hinge on solidifying willing partners, maintaining adequate staffing capacity and funding levels to support the EDRR network, and resolving the inevitable logistical challenges to effectively monitor the more remote Alaska sites. Efforts are ongoing to better define potential risk pathways for entry of non-native forest insects and other damaging invasive species, and to refine strategies for conducting ongoing EDRR monitoring with the various agency and private cooperator networks in Alaska.

Table 3. Insects targeted for the Early Detection Rapid Response program.

Common Name	Species	Approx. Native Distribution
Golden haired bark beetle	*Hylurgops palliatus*	Europe and N. Asia
Mediterranean pine engraver beetle	*Orthotomicus erosus*	Asia, Mediterranean
Six-spined engraver beetle	*Ips sexdentatus*	Across Europe
European spruce beetle	*Ips typographus*	Central Europe
Lesser pine shoot beetle	*Tomicus minor*	Europe
Common pine shoot beetle	*Tomicus piniperda*	Europe
European hardwood ambrosia beetle	*Trypodendron domesticum*	Asia
Redbay ambrosia beetle	*Xyleborus glabratus*	China
Camphor shot borer	*Xylosandrus spp.*	Asia
Sirex woodwasp	*Sirex noctilio*	Europe, Asia, N. Africa
Asian longhorn borer	*Anoplophora glabripennis*	China
Brown spruce longhorn borer	*Tetropium fuscum*	Europe and Russia
Pine-tree lappet	*Dendrolimus pini*	Europe



Map 3: Map of 2013 early detection rapid response monitoring sites. Three baited funnel traps were placed at each monitoring site.

Pre-Flight Mapping of Defoliation Using eMODIS Data

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U.S. Fish and Wildlife Service

Mapping the occurrence and extent of insect-caused defoliation events over Alaskan forests has been a daunting task due to the vast extent of forested areas. Traditionally, as in many other places, this mapping has been done using aerial detection surveys (ADS). These surveys provide maps covering a large area made by experienced, local specialists who can identify host plants, attribute damage to the mostly likely agents, and judge the extent and severity of infestations from the air. The main deficiencies of these methods are that only a small portion of the total forested area can be surveyed; the same areas are not visited every year; each area is surveyed only once per year, the dates are not fixed; and mapping is subject to considerable observer bias and error. See Appendix I on page 76 for a discussion of ADS methods.

Satellite-derived reflectance data can be used to complement ADS to generate maps of potential defoliation over the full extent of Alaska's forested area. The Alaska eMODIS product (Jenkerson et al. 2010) delivers the Normalized Difference Vegetation Index (NDVI) obtained by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellites. NDVI is a widely-used, reflectance-based measure of the density of active chlorophyll. Values of NDVI range from -1 to 1, with values near 1 representing dense vegetation and values near 0 indicating barren ground, water, or ice. Although reflectance-based maps of potential defoliation provide little information as to the causes of damage, strengths of the eMODIS dataset are that the images cover the full extent of the area of interest; the processing is timely, with images available weekly; the parameters are consistent, the annual time periods and pixel locations held constant; there is no observer bias; and the data are freely available on the internet.

In the summer of 2013, I used Alaska eMODIS data to produce a map of early season defoliation on the Kenai Peninsula before the ADS was flown so that the map could help guide the flight.

As in some comparable studies, my analysis used a simple concept: plants are less green in years when they are heavily defoliated than in normal years. To measure annual productivity for each year from 2003-2012, I generated annual index rasters (composite satellite images), picking the third-highest value over the course of the growing season to represent near-peak productivity. From this set of annual rasters, I selected the third highest value for each pixel to make a decadal index raster that represented near-maximum productivity of each pixel over the longer term, even when the pixel had been affected by defoliation in some years. For the 2013 annual index raster, for which only partial data were available, I picked the highest value for each pixel. A defoliation score was generated by subtracting the 2013 annual index values from the 2003-2012 decadal index values. I removed pixels that were not thickly vegetated (decadal index value < 0.9) and pixels that showed only small decreases in productivity (defoliation score < 0.05). I had selected these cutoff thresholds by iteratively adjusting them and comparing the resulting defoliation maps with a defoliation event I had previously georeferenced in the Mystery Hills, Kenai Peninsula on July 10. I produced a map of potential defoliation on July 23 from data posted to the eMODIS website on July 18 with data acquired by the satellite through July 15.

Figure 6: Heavy leaf roller damage to Sitka alder and paper birch in the Nikiski area, Frost Street, (60.7184°N, 151.3654°W), July 16, 2013.

On July 30, I joined Forest Health Protection specialists on the ADS over the Kenai Peninsula. Areas of apparent defoliation that I had mapped in spruce forest were erroneous, while mapped defoliation of Sitka alder in the Homer area and of alders and mixed deciduous trees in the Nikiski area aligned well with what we saw (*Figure 6*). My methods appeared to map early-season defoliation of broadleaf woody plants well, but yielded false positives in conifer forest.

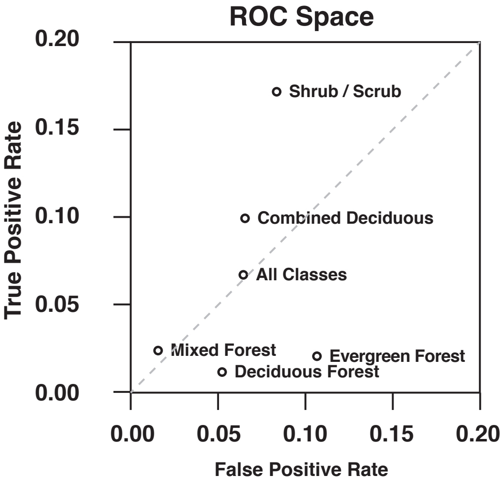
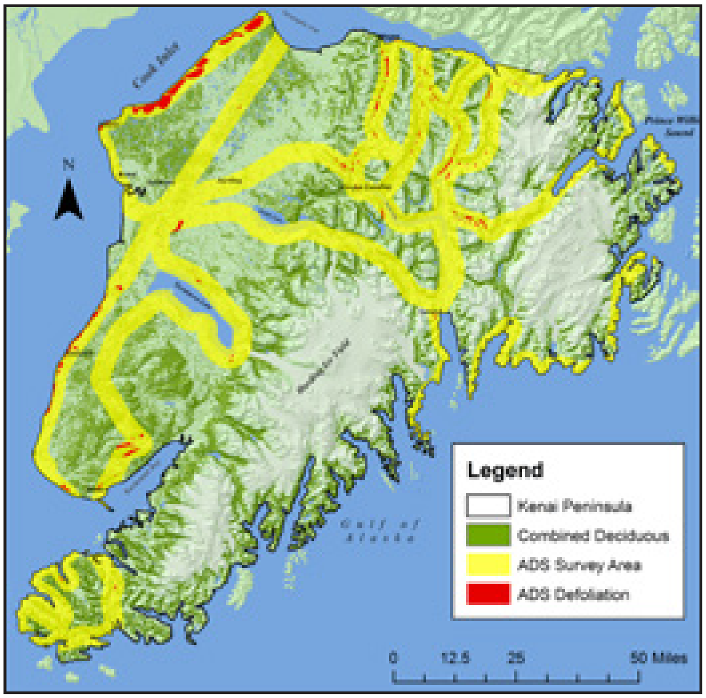


Figure 7: Receiver Operating Characteristic (ROC) comparison of defoliation mapped from eMODIS data compared to ADS data. The dotted line represents a random guess. Points closer to (0,1) indicate better classifiers than points closer to (1,0). Combined Deciduous: Deciduous Forest + Mixed Forest + Shrub / Scrub. All Classes: all cover classes including water, non-forest, etc.

A quantitative comparison with the 2013 ADS data corroborated our impression. I rasterized the ADS damage polygons with a damage intensity of high, severe, or very severe. The rasterized ADS swath and damage were considered to be the true values of undamaged versus damaged pixels for the purpose of evaluating the eMODIS-derived defoliation classifier because no other sample data were available. The 2001 Alaska National Land Cover Database data were used to classify pixels as combined deciduous (deciduous forest + mixed forest + shrub) or evergreen.

In evergreen forest, the omission error rate was 0.4%, the commission error rate was 11%, and the accuracy was 89%, with a Receiver Operating Characteristic (ROC) score of 0.20; in the combined deciduous class, the omission error rate was 1.4%, the commission error rate was 6.5%, and the accuracy was 93%, with an ROC score of 1.5 (*Figure 7*).

The 4-mile wide ADS (*Map 4*) swath covered 1.7 million acres (28%) of the Kenai Peninsula, of which 43,000 acres (2.5% of the area surveyed) were marked as damaged by ADS.



Map 4: Defoliation on the Kenai Peninsula mapped by the 2013 ADS. ADS Survey Area: stated survey area of 2 miles to either side of flight lines. ADS defoliation: ADS sketch-mapped defoliation clipped to the survey area.

By comparison, eMODIS (*Map 5*) predictions in the combined deciduous class mapped 110,000 acres of damage within the flight lines (6.5% of the area surveyed) and 126,000 acres over the Kenai Peninsula (2.1% of the Kenai Peninsula). The reason that so much of the eMODIS-mapped damage fell within the ADS swath (88%) was that the ADS intentionally overflew the largest areas of damage mapped by the eMODIS methods.

Based on this season's experience, it appears that maps of potential defoliation generated from early-season eMODIS productivity data can be useful for guiding ADS, even using my simple, somewhat arbitrary methods. These worked tolerably well for detecting damage in deciduous trees and shrubs, but not in conifer-dominated forests. The high rate of false positives in conifer forests may have been partially due to a masting event we observed in Sitka spruce on the southern and eastern Kenai Peninsula. Heavy cone crops made the spruce forest perceptibly less green than usual, possibly reducing NDVI values measured by MODIS.

Map 5: Potential defoliation on the Kenai Peninsula mapped from early-season eMODIS data. Combined Deciduous: combined Deciduous Forest, Mixed Forest, and Shrub / Scrub classes from Alaska National Land Cover Database dataset. Defoliation: potential defoliation derived from eMODIS data.

The methods I used certainly could be improved upon by optimizing the cutoff thresholds, evaluating additional information (e.g. additional cover classifications, elevation, etc.), considering more complicated models, or using computer learning methods. For example, ForWarn (Norman et al. 2013) provides timely maps of forest damage over the contiguous 48 states by comparing phenology of MODIS-derived NDVI measurements over multiple years. An essential constraint on pre-flight mapping methods is that they must be performed quickly so that maps can be delivered before ADS flights.

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Manley Hot Springs Airport Expansion: A Bark Beetle Suppression Story

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In 2012, the Alaska Department of Transportation (AKDOT) began construction on the Manley Hot Springs Airport expansion project located just south of the community of Manley, Alaska, along the Tanana river floodplain 160 miles west of Fairbanks. This area represents a portion of the property now controlled by the Federal Aviation Administration that adjoins Native Corporation and private land holdings along the edge of Manley. Approximately 143 acres were cleared during January and February 2012. Small (less than 3 inch) diameter trees were processed on site leaving a large amount of shredded and chipped woody debris spread throughout the area. Two to three thousand cords of mature white spruce (*Picea glauca*) and Alaska birch (*Betula neoalaskana*) were cut and decked.

Figure 8: Dead spruce trees adjacent to the Manley Hot Springs Airport as a result of an outbreak of NSE.

During the following summer, residents and AKDOT began to notice standing dead spruce trees along the edges of the airfield project area (*Figure 8*). Spruce trees along the forest edge to the north and west of the airfield in close proximity to Manley had been killed by bark beetles, mainly the northern spruce engraver (NSE *Ips perturbatus, Figure 9 Figure 10*).

Figure 9: Emergence holes of the northern spruce engraver.

The AKDOT contacted professionals with the Alaska Division of Forestry and the USDA Forest Service's Forest Health Protection Program to conduct a bioevaluation. In August of 2012, forest health professionals visited the project area and participated in a community meeting hosted by the AKDOT. Over the course of the next few weeks, a Western Bark Beetle Initiative grant proposal was awarded and a plan to mitigate the outbreak was developed.

In the past, and in warmer regions of the country, engraver beetle populations have been controlled by tarping over emergence sites (*Figure 11*). NSE adults emerge from their host trees in the fall and overwinter in the duff, then disperse the following summer. For this project, the log deck was moved and made available for fuel wood access, and the ground beneath the deck that contained overwintering beetles was covered in October.

Figure 10: An adult northern spruce engraver.

Figure 11: Tarps were placed on top of overwintering NSE beetles to create an unsuitable habitat for the beetles and to hinder emergence.

The purpose of the covering was not to "cook" the beetles, as is done in other regions, since high ambient temperatures can't be guaranteed during the beetle flight period, but rather to create environmental conditions under the tarps to encourage high moisture and fungal growth levels and to disrupt the timing of spring beetle emergence. Additionally, the covered conditions serve to physically block a large percentage of beetles from successfully emerging and dispersing from the duff into adjacent spruce stands. The tarps consisted of two layers of 6 mil polyethylene sheeting. All tarp edges were secured with logs from non-host species to ensure the tarps did not dislodge during wind events. Tarps were extended 15-20 feet beyond the former edges of the log decks to ensure that any beetles that may have moved past the deck edges were captured.

In order to monitor beetle populations, Lindgren funnel traps baited with the three-component NSE lures were placed in the open on the edge of the stand in April, while sub-freezing temperatures and snow cover were still present (*Figure 12*). Traps were maintained throughout the beetle flight season (approximately May 1 to July 31). Insecticidal strips were placed in each trap to kill any captured beetles.

Figure 12: Lindgren funnel traps were baited with NSE pheromone and used to monitor beetle populations.

A late-summer inspection of the site indicated that the tarping of the beetle-infested decked areas was highly effective at eliminating the NSE brood. Cursory inspection under one edge of the tarp revealed dead engraver beetles, verifying the emergence and subsequent mortality of overwintered beetles. Exit holes through the tarps were infrequent; approximately 1 hole per 100 square feet. There were spruce on the fringes of the cleared airport site that were attacked by engraver beetles in 2013, but the number of attacks were low considering the beetle populations and environmental stresses on the residual trees from the previous year. Trap catches, with an average of 85 beetles/trap for the summer, were an order of magnitude lower than previously seen in areas with active tree mortality resulting from bark beetle attacks, which often capture 1000-5000 beetles/trap in a single summer. Overall, a total of 2,000 beetles were captured, including 1,275 NSE, 360 metallic woodborers (Buprestidae), and 100 longhorn beetles (Cerambycidae).

The success of this effort may have been aided in some aspects by unusual weather conditions during the beetle flight period in 2013. A late spring resulted in snow persisting into the end of May and was followed by a rapid warm-up resulting in an extended period of hot and dry conditions. A record was set in June for the number of days with temperatures above 80 degrees, and it was the 10th driest June in the last 100 years. Overall, the methods used and the conditions at the site allowed for a successful bark beetle suppression treatment. The site will be inspected in 2014 to confirm bark beetle populations have returned to endemic levels.

Northern Spruce Engraver Beetle Response to a Recent Windstorm in Interior Alaska

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In Interior Alaska, wildfire, seasonal flooding, and riverbank erosion are common forms of disturbance. Weakened trees on the perimeter of wildfires and along eroded and flooded stream beds provide a ready source of breeding material for the northern spruce engraver (*Ips perturbatus*, NSE). Although large-scale NSE outbreaks have occurred in response to these disturbances, disturbance-related activity is generally confined to small pockets. However, under the right circumstances it can extend for many miles and persist for a number of years.

While wind has not been considered a major disturbance factor in Interior Alaska, this trend may be changing with climate. As reported in last year's USDA Forest Service - Forest Health Protection (FHP) Conditions Report, a series of severe wind events that occurred in mid-September 2012 along the upper Tanana Valley resulted in a 70-mile-long swath of stem breakage, blowdown and tipped spruce and hardwoods over the region (*Figure 13, Map 6*).

Figure 13: An example of damage characteristic in many stands resulting from the September 2012 windstorm.

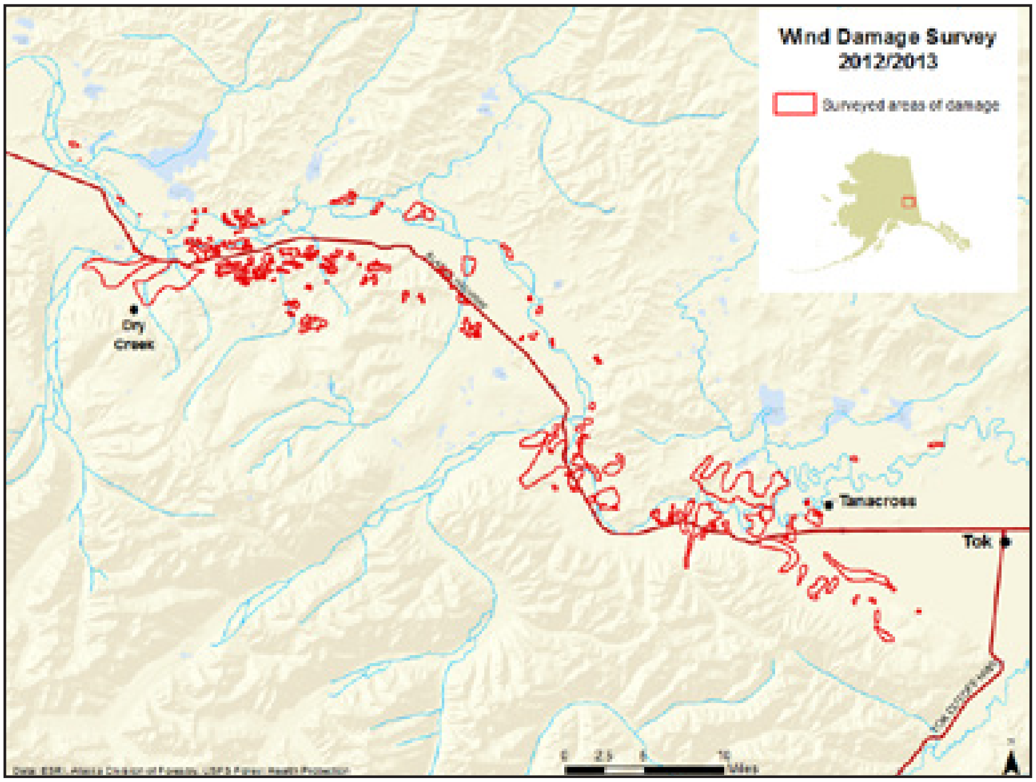
It is estimated that 1.2 to 1.4 million forested acres were damaged across the wind-impacted area. A preliminary helicopter assessment conducted by Alaska Division of Forestry (DOF) foresters in late September 2012, with a subsequent fixed-wing mapping effort in July 2013 and DOF satellite imagery interpretation, estimated ~33,000 acres of lightly to severely damaged spruce/hardwood forest was accessible and near communities along the road system (*Map 7*). This presents an opportunity to implement spruce salvage, hazardous fire/fuels reduction, as well as bark beetle mitigation management activities. These storms are expected to cause an increase in NSE brood material during the next few years, thereby increasing the chance of a future outbreak.

A small network of sites was established to provide background information and to establish a baseline for future monitoring of potential tree damage and mortality from NSE following the unusually severe September 2012 windstorm. On June 3rd, 2013, Lindgren funnel traps were deployed between the villages of Tanacross and Dry Creek, along the Alaska Highway. Traps were set in five locations, with three traps at each location. Monitor trapping began a couple of miles west of Tanacross, and locations were spaced 8 – 10 miles apart. Each trap was baited with 3-component NSE lures (Alpha Scents, Oregon, USA) and a piece of solid state insecticide to prevent predators from eating trapped beetles (Revenge™ , DOW Chemical, Michigan, USA). Traps were checked on June 18th, July 2nd, and July 25th, 2013. Results from the 2013 NSE monitoring effort indicate that current NSE population levels are mostly typical of beetle populations found in areas with light anthropogenic (human-caused) and natural spruce forest disturbance (*Map 6*). A portion of the wind-damaged area near Tok, however, may contain NSE populations slightly elevated above what is typically found in the spruce forest.

In addition to aerial survey mapping and monitoring trapping, spot ground checks were made in a few of the heaviest wind-impacted sites along the road system between Delta Junction and Tok during the peak NSE beetle flight (June and July), and again in mid-October after the main beetle flights had occurred. This additional ground survey work was done specifically to assess if the NSE had yet utilized any spruce trees downed or damaged by the September 2012 storms. It was determined that most of the downed or damaged spruce were not attacked or were lightly attacked by the NSE during the 2013 flight season. Much of the downed or damaged (partially down or tipped) spruce still retained adequate bark moisture as evidenced by portions of limbs with green foliage and healthy cambium (inner bark). NSE exit holes were light and often absent in spruce that still retained live branches. This initial assessment suggests that NSE utilization of the wind-damaged spruce material is currently at or slightly above levels of natural, endemic populations in the affected forests. Future assessments and monitoring of NSE populations within the blowdown areas will include sampling through semiochemical attractant monitoring and observation of NSE utilization of spruce habitat in the wind-damaged forest.

The recent wind events in Interior Alaska have presented a unique and challenging opportunity to document success or failure of beetle attacks in residual damaged trees; and to assess the efficacy of mitigation activities. Weather plays an important role in beetle population dynamics following a disturbance. Both the NSE and the spruce beetle respond favorably to warm, dry weather, particularly in the spring, when their mass dispersal and attack flights occur. Cool, wet weather can either prevent this flight altogether, or allow it to proceed at such a slow pace that mass attacks are not possible.

Continued monitoring of Interior Alaska wind-damaged areas can provide good baseline information to assist with future bark beetle population assessments and mitigation efforts during timber harvest and beetle suppression activities. Only time will tell if the September 2012 storms will precipitate future large NSE beetle outbreaks, but it's important that ongoing monitoring and assessments occur to facilitate better decision-making to mitigate beetle populations when local climatic conditions favor a shift above endemic levels.



Map 6: Areas of wind-damaged forest identified near the Alaska highway via aerial surveys and satellite imagery interpretation.

Map 7: Sites with an average capture of less than 150 NSE beetles/trap are shown above in green. This level of activity corresponds to typical trap catches from the Bonanza Creek Experimental Forest, during time periods of light anthropogenic and natural disturbances. Sites with an average of 150-300 NSE beetles/traps are shown in yellow above. This degree of activity is elevated above normal.

2013 Entomology Species Updates

Defoliating Insects

Defoliating insects eat the leaves or needles of trees and are found throughout Alaska on all tree species. When defoliator populations are epidemic, vast acreages of trees are affected. During an outbreak, nearly every tree in a stand can be damaged to varying degrees. In addition to the effects on individual tree physiology, defoliators can also have ecological and socioeconomic impacts on wildlife habitat and forage, aquatic ecosystems, timber and property values, forest aesthetics, and recreation. Extensive hillsides of brown or red defoliated trees in the midst of an outbreak can be quite alarming. Fortunately, the effect is typically ephemeral, and the plants often leaf out again later in the season or during the following spring. Defoliation also provides a number of ecological benefits; larvae represent an abundant food source for many species of birds and other wildlife, increased light penetration to the understory can increase herbaceous browse for wildlife, and leaf litter and larval frass inputs create a pulse in soil nutrients.

Defoliator outbreaks tend to be cyclic and are often dramatic. Outbreaks of some species tend to be closely tied to weather conditions that affect insect development, reproduction and dispersal, as well as host phenology. Other species appear to be genetically predisposed to outbreak in regular cycles of 10 to 30+ years.

Figure 14: Internal leaf feeding damage, note the larvae (circled) feeding actively inside the leaf. Holding a leaf with a blemish to the light will often reveal the tiny larvae within the leaf.

The last few summers marked a shift from internal leaf feeders (*e.g. leaf miners, Figure 14*) to external leaf feeders (*e.g. skeletonizers, Figure 15*) as the most common sources of insect damage on Alaska's hardwoods.

Figure 15: External leaf feeding damage - Defoliators can completely consume all the soft plant tissue, leaving nothing but a withered skeleton of leaf veins.

Over 536,000 acres of external feeding damage were observed on Alaskan hardwood trees and shrubs in 2013, particularly birch and alder, an increase from the 280,000 acres observed last year. Unlike many of the leaf miners, which tend to attack only a single host species or genus, external leaf feeding insects are often polyphagus, feeding on a variety of hosts. Defoliators belong to multiple insect orders and families including beetles (Coleoptera: Chrysomelidae), sawflies (Hymenoptera: Tenthredinadae), and moths (Lepidoptera: Geometridae, Tortricidae), which contribute the greatest amount of activity.

Figure 16: The birch leaf roller is a delicate creature, with little but a thin shield of silk tied leaf to protect it from the harsh environment.

Hardwood Defoliators – External Leaf Feeding

Birch Defoliation

***Epinotia solandriana* (L.), *Rheumaptera hastata* (L.)**

Birch leaf rollers (*Figure 16*) are a recurrent problem in Southcentral and Interior Alaska, and were responsible for about one-third of the insect and disease related observations and almost all of the birch defoliation in 2013. In the 1980s, and again in the early 2000s, a considerable amount of defoliation caused by birch leaf roller was observed in Southcentral Alaska. For example, the last known large scale outbreak was recorded in 2003, when approximately 185,000 acres were affected. In 2013, 331,000 acres of birch leaf roller on birch were mapped. The most intense birch leaf roller activity was found near Holy Cross, Russian Mission, and Lake Clark. Moderate populations were also noted throughout the Anchorage Bowl and into the Matanuska-Susitna Valley. Birch leaf rollers were also extremely active throughout the interior of Alaska. This species is also commonly found feeding on alder, and contributed to alder defoliation in 2013. In ground observations, aspen and cottonwood also experienced birch leaf roller feeding.

The spear-marked black moth (*Rheumaptera hastata*), a black and white banded geometrid moth, defoliated over 17,000 acres in 2013. Most of the damage occurred within the McGrath and Medfra quadrangles. This species is also capable of large scale outbreak events. Therefore, populations bear monitoring for the next few years to detect significant increases. FHP will continue to monitor, conduct ground checks, and coordinate with landowners to characterize defoliation events and identify the insects involved.

Alder Defoliation

***Epinotia solandriana* (L.)**
***Eriocampa ovata* (L.)**
***Hemichroa crocea* (Geoffroy)**
***Monsoma pulveratum* (Retzius)**
***Orgyia antigua* (L.)**
Geometrid moths (*see willow and miscellaneous hardwood defoliation*)

A large amount of alder defoliation was reported across the state in 2013. Over 133,000 acres were mapped during aerial detection survey; this is more than twice the defoliation mapped in 2012, but only 8% higher than in 2011. In Southeast Alaska, alder defoliation was sparsely mapped except near Juneau along the Gastineau channel.

The invasive green alder sawfly (*Monsoma pulveratum, Figure 17*) was positively identified in Sitka, Ketchikan, and Juneau, the first confirmed records in this region. It was found feeding on red alder along with two other species of sawflies, the striped alder sawfly (*Hemichroa crocea*) and the wooly alder sawfly (*Eriocampa ovata, Figure 18*).

Table 4. The most common defoliators found on hardwood trees throughout Alaska. Internal leaf feeders (i.e. leaf miners) live inside leaves, feeding on the plant tissue. External leaf feeders (i.e. skeletonizers) can consume all or part of the leaves.

Insect Order	Insect Family	Species	Host	Type of Defoliator
Beetles (Coleoptera)	Chrysomelidae	*Chrysomela* spp. *Phratora* spp. *Macrohaltica* spp.	Various hardwood species	External Leaf Feeder
Moths (Lepidoptera)	Geometridae	*Epirrita undulata* (Harrison) *Eulithis* spp. *Hydriomena furcata* (Thunb.) *Operophtera bruceata* (Hulst) *Rheumaptera hastata* (L.)	Various hardwood species	External Leaf Feeder
Moths (Lepidoptera)	Gracillariidae	*Phyllocnistis populiella* Chambers	Various hardwood species	Internal Leaf Feeder
Moths (Lepidoptera)	Gracillariidae	*Micrurapteryx salicifoliella* (Chambers)	Willow	Internal Leaf Feeder
Moths (Lepidoptera)	Gracillariidae	*Phyllonorycter nipigon* (Chambers)	Aspen/cottonwood	Internal Leaf Feeder
Moths (Lepidoptera)	Lymantriidae	*Orgyia antigua* (L.)	Willow, birch, spruce, and blueberry	External Leaf Feeder
Moths (Lepidoptera)	Tortricidae	*Epinotia solandriana* (L)	Various hardwood species	External Leaf Feeder
Moths (Lepidoptera)	Tortricidae	*Choristoneura conflictana* (Walker)	Aspen	External Leaf Feeder
Wasps (Hymenoptera)	Tenthredinidae	*Eriocampa ovata* (L.) *Hemichroa crocea* (Geoffroy) *Monsoma pulveratum* (Retzius)	Alder	External Leaf Feeder
Wasps (Hymenoptera)	Tenthredinidae	*Profensusa thomsoni* (Konow) *Heterarthrus nemoratus* (Fallén) *Fenusa pumila* Leach	Birch	Internal Leaf Feeder

Figure 17: Green alder sawfly larvae found feeding on red alder in Sitka. Far from it ancestral homeland in Eastern Europe, no one is sure exactly how or when this sawfly made its journey to Alaska.

Figure 18: The woolly alder sawfly can be found feeding in combination with the striped alder sawfly and the green alder sawfly.

However there were multiple reports of heavy defoliation throughout the state. The heaviest alder defoliation in the state was mapped along the west coast of the Cook Inlet with > 21,000 acres of alder defoliation mapped in the McNeil River State Game Sanctuary and Refuge alone. External leaf feeders such as birch leaf rollers, rusty tussock moth, and alder sawflies can skeletonize and kill leaves causing alder to look thin and brown

It should be noted, there can be confusion with the symptoms of insect defoliation and dieback caused by a canker fungi as they look very similar at 100 knots and 1000 feet. Compounding the confusion, many sites have a combination of multiple damage agents.

Cottonwood Defoliation

***Epinotia solandriana* (L.)**
***Chrysomela* spp.**
***Phratora* sp.**
***Macrohaltica* sp.**

Widely scattered areas of cottonwood defoliation were mapped throughout the state. The 19,500 acres of defoliation this year was a slight increase in acreage from 2012, but a decrease compared to 2011. A variety of agents are associated with cottonwood defoliation, including sawflies, leaf miners, leaf rollers, leaf beetles, and foliar diseases. In addition, old, large cottonwoods growing in riparian areas commonly exhibit dieback in the form of spiked tops. This dead woody material often supports woodborers. Leaf beetle feeding is caused by a variety of different species from the family Chrysomelidae. They are found across Alaska, and the adults are small round beetles with a variety of color patterns on their elytra. Their larvae can be aggressive feeders on birch, poplar, willow and alder, eating all of the soft plant tissue found in between the leaf veins (*Figure 19*). This feeding pattern leaves only a "skeleton" of a leaf by late summer. Leaf beetles were found in lesser numbers throughout Alaska in 2013 compared to 2011 and 2012, especially on birch and alder trees.

Figure 19: Leaf beetle larvae feeding on cottonwood leaves. Note the "windows" created by larval feeding.

Willow and Miscellaneous Hardwood Defoliation

***Operophtera bruceata* (Hulst)**
***Epirrita undulata* (Harrison)**
***Hydriomena furcata* (Thunb.)**
***Eulithis* spp.**
***Orgyia antigua* (L.)**

Willow defoliation was mapped on 22,000 acres and 600 acres of dwarf birch (i.e. shrub) defoliation were also mapped during 2013. The species responsible for the damage vary regionally. The most destructive geometrids were the Bruce spanworm (*Operophtera bruceata, Figure 20*) in Southcentral and Southeast Alaska; undulated autumnal moth (*Epirrita undulata*) and at least two species of Eulithis in Southcentral Alaska; spear-marked black moth (*Rheumaptera hastata*) and furcate hydriomena (*Hydriomena furcata*) in Interior Alaska.

Figure 20: Bruce spanworm moth found on the Forestry Sciences Lab in Juneau, the moths were prevalent on the sides of buildings in October.

Throughout Southcentral and Interior Alaska, the rusty tussock moth was a common sight in 2013, and populations appear to be on the increase. The dark brown caterpillars are about 3 cm in length, with two dark tufts of hair near their head and a third at their rear. They also bear four "tussocks" of yellow hair on their backs for which they are named and are covered with small tufts of very thin spines. The larvae are voracious herbivores and they will eat entire leaves off of a wide variety of trees and shrubs. Although they can severely defoliate large areas of forest, Alaska populations have not built to that size yet. If food, weather and other variables remain favorable we may see continued growth in rusty tussock moth populations over the next few years.

Large Aspen Tortrix

***Choristoneura conflictana* (Walker)**

During the 2013 aerial survey, 3,000 acres of tortrix activity were identified, and all of those acres occurred in the interior region of the state. The amount of damage from tortrix observed in recent years has fluctuated between about 1,000 to 6,000 acres/year. As is typical of many insect defoliators, aspen tortrix populations can increase to epidemic levels, then collapse to nearly undetectable levels, all within the span of just a few years. Aspen stands can be completely defoliated for up to two seasons. Complete defoliation of an aspen stand before the larvae have reached their final stage of development can result in mass starvation, which usually signals the end of an outbreak. Tortrix are also susceptible to adverse weather conditions and parasitism.

Hardwood Defoliators – Internal Leaf Feeding

Birch Leaf Miners

***Profenusa thomsoni* (Konow)**
***Heterarthrus nemoratus* (Fallén)**
***Fenusa pumila* Leach**

Leaf mining injury to birch trees caused by the amber-marked birch leaf miner (AMBLM) *(Profenusa thomsoni)*, the late birch edge leaf miner (*Heterarthrus nemoratus, Figure 21*) and the birch leaf miner (*Fenusa pumila, Figure 22*) has been reported in various locations of Alaska since 1997. Infested trees have been reported primarily in major urban areas including Anchorage, Fairbanks, Haines and Skagway, and at various locations on the Kenai Peninsula. Native paper birch is the most common host, but both native and horticultural varieties of birch are susceptible. Impact is primarily aesthetic and this insect seldom, if ever directly causes mortality. However, thousands of dollars have been spent by homeowners on control efforts.

Figure 21: An adult late birch edge leaf miner wasp.

Figure 22: Damage caused by birch leaf miners is primarily aesthetic.

The Alaska location with the longest history of birch leaf miners is Anchorage, where an outbreak reached its most intense level in the mid-2000s. Birch leaf miners are still present now after a decade, but their severity and distribution is much reduced. Based on surveys conducted within the Anchorage Bowl during late August 2013, incidence of both the amber-marked birch leaf miner and the late birch leaf edge miner were much lower than last year, and both now show roughly equal levels of infestation. The birch leaf miner has also been reported from this area, but its role in the recent outbreak is unknown.

Surveys for birch leaf miners along major roadways on the Kenai Peninsula were conducted this year for the first time since 2008. Trees infested with *P. thomsoni* were observed at the Russian River Campground, but in contrast to moderate to high severity levels in 2008, severity this year was low. Elsewhere, infestations were lacking or too low to observe. One exception is the Fred Meyer grocery store in Soldotna where trees planted in and around the parking lot are still heavily infested. Nearer to Anchorage, another heavy infestation caused by *P. thomsoni* was found along the Seward Highway starting about six miles south of the municipality. Unfortunately, we were unable to conduct the aerial survey of this area until after the birch leaves started turning autumn colors this fall. Consequently, it was not possible to estimate the extent of this infestation.

Fairbanks area AMBLM populations were the highest observed to date, with high populations evident in Fairbanks, North Pole, Salcha, and the military bases Fort Wainwright and Eielson AFB. Densities of AMBLM rivaled those seen in Anchorage during the mid-2000s. In 2011, several hundred parasitoid wasps (*Lathrolestes thomsoni*) were introduced from the Anchorage Bowl, and an effort to determine establishment will be conducted in 2014.

Aspen Leaf Miner
***Phyllocnistis populiella* Chambers**

Aspen leaf miner continues to be widespread and common, although the incidence has been steadily decreasing since a high of around 750,000 infested acres in 2007. During 2013, damage was mapped on 99,500 acres. This is slightly greater than that mapped in 2012. The primary host of this leaf miner is aspen (*Figure 23*), but it commonly occurs on other poplar species. Aspen leaf miner can be found throughout the range of its host, but the area most heavily infested has been generally bounded by the Alaska Range to the south, the Brooks Range to the north, the Tanana drainage and Yukon-Charley Rivers Preserve to the east, and Ruby to the west. Areas of damage around Fairbanks, Delta Junction, and Tok have been especially severe. During 2013, affected trees were especially abundant along the Tazlina River.

Figure 23: An aspen leaf miner larva, note the serpentine gallery it creates. As the summer progresses the larva will escape from the leaf and its gallery will take on a silvery sheen.

In stands with continuous high severities, many dead individual and scattered trees with branch dieback and otherwise misshapen crowns have been observed. Outbreaks typically crash after two to three years in areas where defoliation has been heavy. Disease or predator build-up has been commonly attributed to these collapses. In 2006, FHP professionals noticed that the intensity varied within aspen patches, and intensity was highest on the edges and lightest in the center of each patch. This would indicate a disease outbreak in the leaf miner population, as opposed to an increase of parasitoid or predator populations in response to the high leaf miner populations.

Willow Leaf Blotch Miner
***Micrurapteryx salicifoliella* (Chambers)**

In 2013 only 5,800 acres of damage from willow leaf blotch miner were observed. This continues an annual trend of decreasing populations of this insect throughout much of Interior Alaska. Pockets of activity continue to exist along the Yukon River, the Yukon Flats, the Tanana Flats, and in places around the Fairbanks North Star Borough. Although it is still common to find infested willows, there is relatively little damage compared to the peak of the outbreak three years ago, when nearly 500,000 acres of damaged was observed during aerial surveys.

Cottonwood Leaf Blotch Miners
***Phyllonorycter nipigon* (Chambers)**

Cottonwood leaf blotch miners are virtually undetectable during aerial surveys. However, blotch mines were a common ground observation in some parts of Interior Alaska. Unlike the serpentine leaf mines often found in aspen leaves, these small moths create a single gallery that is shaped like an elongated oval. In the middle of summer the larva can easily be seen when a leaf is silhouetted against the sky.

Spruce Budworm

Choristoneura fumiferana **(Clemens)**

There was a decrease in activity of spruce budworm from ~13,000 acres of observed damage in 2012, to 6,000 acres of damage in 2013. Most of the damage was located along the Kobuk and Koyukuk Rivers. Spruce budworms are one of the most widespread and damaging forest pests found in the North American boreal forest. They can cause a loss in productivity, utility, and at times mortality in our native spruce forests across Alaska, Canada and parts of the lower 48 States. Historic outbreaks have occurred in Alaska in the late 1970s near Anchorage, the 1980s in the Copper River Valley, as well as in the early 1990s and the early 2000s throughout Interior Alaska. By 2007, budworm populations fell to background levels across Alaska, and new damage was not detected from aerial detection surveys in 2010 or 2011.

Western Black-Headed Budworm

Acleris gloverana **(Walsingham)**

The western black-headed budworm (*Figure 24*) is native to the coastal forests of Southeast Alaska, Prince William Sound, and Southwestern Alaska. Although it has historically occurred primarily in Southeast Alaska, populations have been recorded from Turnagain Arm near Anchorage and west to Dillingham. The 2013 aerial survey recorded 122,000 acres of black-headed budworm damage. All but 44 of these acres were found in Southwestern Alaska, in and around the Wood-Tikchik State Park, just north of Dillingham. Due to bad weather last year, we were not able to survey the Wood-Tikchik State Park, so it is not known if 2013 is the first year of the current budworm outbreak. This was one of the largest outbreaks of western black-headed budworm seen during aerial detection survey.

Figure 24: Western black-headed budworm damage on white spruce.

Black-headed budworms are wasteful feeders, not usually consuming entire needles. The partially consumed needles turn reddish-brown and when in white spruce, the damage from the air looks very similar to a heavy cone crop (*Figure 25*). Since there are also other insects that cause similar-looking damage, the cause of the reddish-brown needles in the Wood-Tikchiks was ground verified.

Figure 25: The damage caused by western black-headed budworm looks very similar to a heavy cone crop when seen from the air.

Western black-headed budworm populations in Alaska have generally been cyclic. They appear rapidly, affecting extensive areas, and then decrease just as dramatically in a few years. Consecutive years of budworm defoliation may cause growth loss as trees become weakened, predisposing them to secondary mortality agents. In severe outbreaks, top-kill and substantial lateral branch dieback can lead to the death of large numbers of trees. Tree death and crown thinning can significantly influence both stand composition and structure.

Yellow-Headed Spruce Sawfly

Pikonema alaskensis **(Rohwer)**

The yellow-headed spruce sawfly, although widespread and native, tends to be an urban pest in Alaska. It feeds on the new needles of small to medium sized spruce trees, and was first reported as a problem near the Alaska Native Hospital in 2003. The most commonly damaged species is ornamental blue spruce, *Picea pungens*, but other spruce species are also susceptible. Trees growing in busy parking lots and along roadside corridors, and those that are newly planted, seem to be most affected. The major impacts are aesthetic associated with thinned scrappy crowns, but consecutive heavy defoliation over multiple years can cause mortality. Most new reports received by the

UAF Cooperative Extension Service during 2013 were from homeowners in the southern parts of Anchorage.

Hemlock Sawfly

***Neodiprion tsugae* Middleton**

Hemlock sawfly (*Figure 26*) is a native pest of western hemlock and is found throughout Southeast Alaska. A total of 13,300 acres of defoliation were mapped during the aerial detection survey in 2013. The acreage is more than double that of 2012; however, hemlock sawfly damage did not become apparent in many locations until after the ADS last year. Young larvae feed gregariously on older foliage at first but then feed singly as they mature. They then drop to the duff and understory to pupate. Feeding damage rarely kills trees outright, but it does reduce radial growth. Outbreaks that occur in the same location year after year or in conjunction with the black-headed budworm can prove to be fatal to hemlock. The only areas with hemlock sawfly damage detected in both 2012 and 2013 were Etolin and Revillagigedo Islands. These areas will be monitored closely in the coming years. Populations of hemlock sawfly are typically controlled by natural elements such as parasitoids, predators, fungal pathogens, and weather.

Figure 26: Hemlock sawfly larvae were active in areas throughout Southeast Alaska.

Spruce Aphid

***Elatobium abietinum* (Walker)**

Little defoliation was attributed to spruce aphid during the 2013 aerial detection survey. A small amount of damage, totaling 158 acres, was found near the Petersburg Airport on Mitkof Island, across from the airport on Kupreanof Island, and near Tee Harbor in Juneau. Weather plays a major role in controlling aphid populations, which cannot survive long exposures to temperatures <15F. Southeast Alaska experienced a moderate winter in 2013, with temperatures rarely falling below 15F in some areas, yet little damage was recorded. Spruce aphids reproduce asexually, which contributes to sudden increases in activity when conditions are ideal. Large scale outbreaks of spruce aphid have occurred in Southeast Alaska following mild winters in 1992, 1998, and 2010. Spruce needle aphids feed on older needles of Sitka spruce; often causing significant needle drop (*Figure 27*). After a few years of defoliation, some trees retain only the most recent year or two of foliage. Spruce aphids usually favor the same trees year after year and outbreak after outbreak.

Figure 27: Spruce aphid damage as seen from the air during aerial detection survey. Outbreaks of spruce aphid typically occur near the coastline in Southeast Alaska, following a mild winter.

Bark Beetles and Woodborers

Spruce Beetle

***Dendroctonus rufipennis* (Kirby)**

Spruce beetle (*Figure 28*) activity was observed on 27,000 acres during aerial surveys this year, representing a 227% increase over 2012. While this increase seems significant, in 2012 forest health specialists recorded the lowest annual figure for spruce beetle-caused mortality since the systematic surveys began in the early 1970s. Although spruce beetle activity mapped in 2013 still remains low compared to historical numbers, spruce beetle remains the leading cause of spruce mortality in Southcentral, Southwest, and Southeast Alaska.

Figure 28: Adult spruce beetles found feeding under the bark. Spruce beetles are one of the most devastating tree-killing insect in Alaska; in the 1990s they killed spruce trees on an estimated 1.3 million acres.

Alaska experienced a cold spring and a summer with above average temperature and below average precipitation. There was little significant rainfall recorded from mid- May through most of July. The very cool and late spring conditions provided an extended snow melt into late May to replenish groundwater slowly without significant runoff, in spite of the lack of rainfall during the remainder of Alaska's summer. These climatic conditions should have been quite favorable to bark beetles in terms of increasing the number of flight days for dispersal and brood survival. However, in many areas it may have been just as favorable to spruce stands that received replenishing soil moisture to better withstand successful beetle attacks. It will be interesting to see if the apparent increase in spruce beetle activity mapped this year continues in 2014 and a new trend of increasing statewide spruce beetle activity is established over the next several years.

Several areas of Southcentral and Southwestern Alaska still appear to be declining in intensity of spruce beetle activity as was reported in 2011 and 2012, but the ongoing outbreaks continue to exhibit signs of persistent, residual activity based on the 2013 aerial detection survey (*Map 8*). These areas include Katmai and Lake Clark National Parks in Southwest Alaska, and Chickaloon Bay and Skwentna/Puntilla Lake in Southcentral Alaska. Interestingly, the outbreaks in Katmai National Park and Lake Clark National Park appear to have increased slightly in terms of total acres mapped although the intensity remains light to moderate. A significant decrease in activity was mapped on the west side of Cook Inlet (45 acres in 2013 vs. 2,200 acres in 2012), as well as in the small outbreak in Bird Valley within the Chugach State Park along Turnagain Arm near Anchorage (13 acres in 2013 vs. 1,230 acres in 2012).

Similar to 2012, Southeast Alaska accounted for about 25% of the total statewide spruce beetle-caused mortality in 2013, but the total number of acres mapped increased significantly compared to 2012. The Kupreanof Island outbreak remained static in 2013 with approximately 1,750 acres and an area of significant spruce beetle activity was mapped northwest of Haines along the lower Klehini River and around Chilkat Lake. These two areas near Haines comprise 4,700 acres of new and ongoing infestations in an area that was impacted heavily during the 1990s Alaska spruce beetle outbreak. Also, the Haines area outbreak appears to be a significant expansion of the spruce beetle activity observed in 2012. Given the warm summer conditions in 2013, we can probably expect this Haines area outbreak to expand significantly in 2014. The balance of the observed 2013 spruce beetle activity in Southeast Alaska is scattered from Juneau to Ketchikan, and generally observed in patches of less than 50-100 acres.

Northern Spruce Engraver

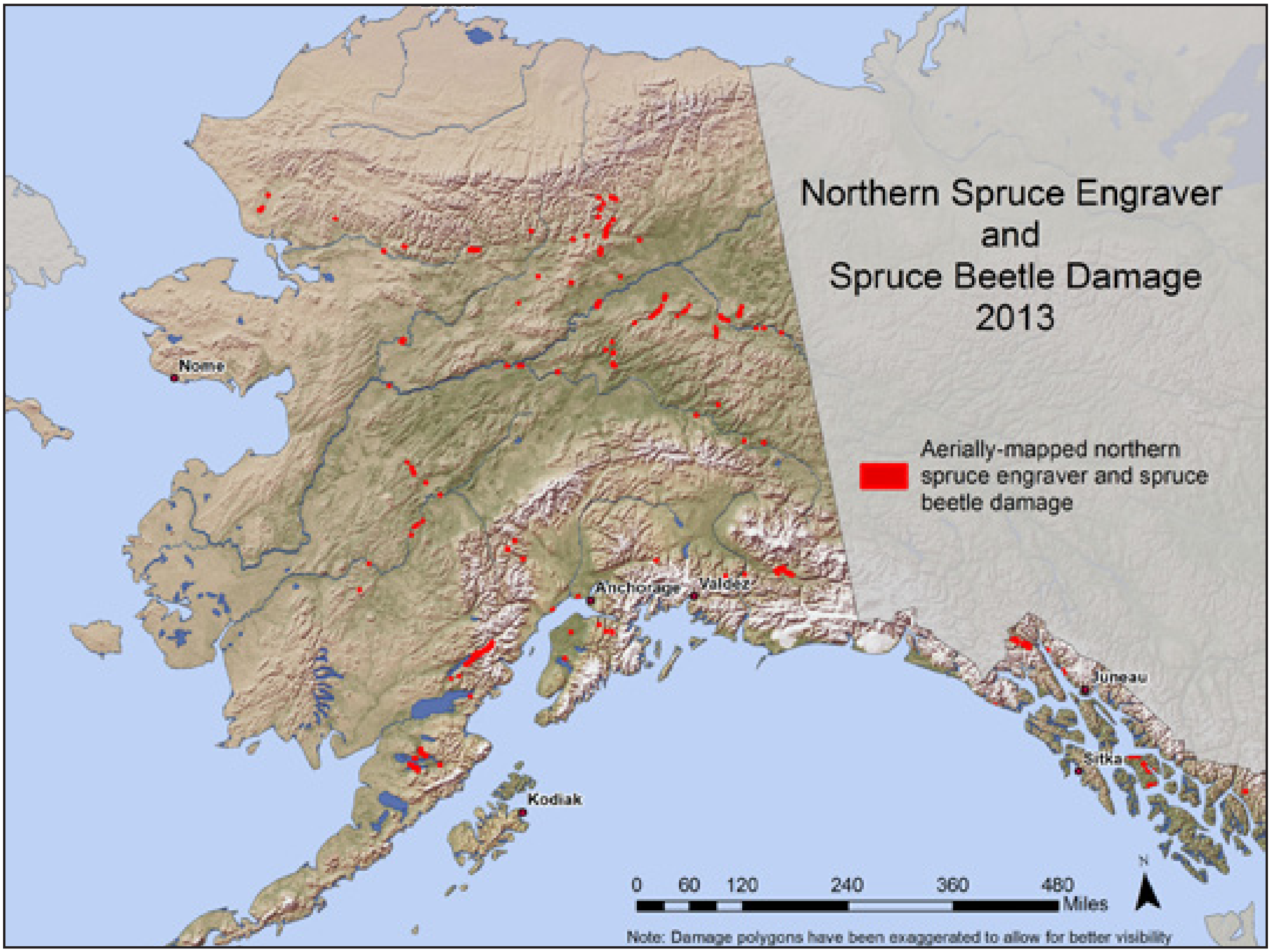
***Ips perturbatus* (Eichhoff)**

Northern spruce engraver (NSE) activity was observed on 8,050 acres in 2013, which represents only a modest increase over 2012 mapped NSE (*Map 8*) activity of 7,200 acres. A portion of the current NSE activity represents stands also containing recent spruce beetle infestation (310 acres). This is important to understand when trying to project past trends over short periods of time to future activity of spruce-feeding bark beetles. Observed tree damage from NSE can easily be confused with spruce beetle activity, and vice versa. NSE activity is generally more localized, and can usually be distinguished from new and ongoing spruce beetle activity by characteristic reddening in the upper crowns of mature trees during the current season of engraver attack. Conversely, spruce beetle injury is usually first detectable in the mid- to lower-crown in the year following initial attack. NSE are more sensitive to host stresses and nutrient changes brought on by sudden disturbances, and typically attack trees sooner after a disturbance than spruce beetles.

Reviewing the historical mapped NSE activity tallied from the annual aerial detection surveys back over the past 30 years, it appears that NSE activity has declined significantly since a recent 10-year peak ending in 2008. In 2013, most of the reported NSE activity occurred along the major river systems and their tributaries in the northeastern and central portions of Interior Alaska, which follows a similar, long-term pattern.

In 2013, the two largest NSE outbreaks occurred along the Koyukuk River near Roundabout Mountain SW of Huslia (2,250 acres) and along the Chandalar River (1,900 acres) and Beaver Creek (1,210 acres) near Fort Yukon. Smaller scale outbreaks were also concentrated along these and other major river systems of Interior Alaska, including the Tanana and Yukon, and also extending to rivers in the western and northwestern part of Interior Alaska, such as the Noatak and John Rivers. New and ongoing NSE activity continues to be spotty in several areas of the Interior still recovering from the recent significant wildfire activity over the past decade.

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 that are 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. A summary of NSE activity in response to a recent wind event along the Tanana River in late 2012 is included in a separate essay on page 16.



Map 8: Northern spruce engraver and spruce beetle damage detected during the 2013 aerial detection survey. Areas in red indicate damage areas.

Status of Diseases

Figure 29: Steve Swenson, biological technician with Forest Health Protection, using the Arborsonic Acoustic Tomograph. This device provides a minimally invasive and objective method to detect and measure stem decay.

Building an index of alder canker pathogens in Alaska

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Gerard Adams, Associate Professor
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Thin-leaf alder (*Alnus incana* ssp. *tenuifolia*), has experienced widespread branch dieback and whole stem mortality from Alaska to the southern Rocky Mountains. Alaska's aerial detection survey has mapped active alder dieback and older whole stem mortality since 2010 (see the following section on alder dieback for more survey information). Most disease occurs on thin-leaf alder; however both Sitka alder (*Alnus viridis* ssp. *sinuata*) and Siberian alder (*Alnus viridis* ssp. *fruticosa*) are affected to lesser extents. Alder dieback on thin-leaf is usually due to girdling cankers (*Figure 30*) caused by the fungus Valsa melanodiscus. But we have frequently noticed several additional fungal species associated with very similar cankers on all three alder species in Alaska. Therefore, we are attempting to identify the major causal pathogens in the North American alder dieback epidemic with a focus on Alaska. In related studies, we are also examining the wood decay fungi which decompose dead alder stems, and water molds in the associated rhizosphere.

We began by reviewing the literature; however, national and regional disease records reflect limited investigation of alder diseases in Alaska. Our objective has been to isolate and identify fungi from diseased tissues and determine their respective roles in alder canker disease. Identifications are based upon DNA sequence similarity and standard morphology. The majority of fungi present in woody plants are referred to as endophytes. They exist benignly between plant cells and grow and metabolize especially slowly, utilizing the carbohydrates that are present to "glue" the plant cells together. Many endophytes are adapted to take advantage of senescing leaves or branches; similarly to pathogens, they will grow rapidly and reproduce on dying tissues. Some are latent pathogens that infect and then persist as endophytes for years. When the host begins to senesce, or is under enough stress, they become virulent, invading and killing healthy tissues. True pathogens are able to incite disease given a suitable host and environment conducive to infection. To determine pathogenicity we isolated each fungal species, and then performed inoculation trials on thin-leaf, Sitka, and Siberian alder in replicated plots in Southcentral and Interior Alaska. Inoculated stems were then monitored for symptom development and the inoculation site was measured (length and width of wound or resultant canker) approximately a year after inoculation. Because the annual window of opportunity for successful inoculation is short and weather dependent, this work will continue for an additional two years.

We have thus far isolated and identified 19 fungal species that are associated with cankers on the 3 alder species. Reported here are summaries for each of these fungi from the USDA Fungus-Host Distribution Database (http://nt.ars-grin.gov/fungaldatabases/fungushost/fungushost.cfm). We also note pathogens that have demonstrated significant virulence in our inoculation trials. Although results are preliminary, it is evident that several fungi are involved in alder canker disease in Alaska, rather than the more typical single-disease/single-pathogen scenario. These include *Valsa melanodiscus*, *Melanconis alni*, and *M. stilbostoma*. Surprisingly, although the following fungi have not previously been reported as causing disease, *Diatrype disciformis* and *Massarina corticola* were also found to be pathogenic.

Our studies on alder pathogens and endophytes, instigated by the widespread outbreak of alder dieback in Alaska, are providing significant contributions to plant pathology, fungal ecology, and mycological taxonomy. We have found unnamed species new to science, known species with expanded ecological roles, and a rather large and diverse community of visually similar canker pathogens on alder.

Figure 30: Alder canker caused by *Valsa melanodiscus*. A canker is a necrotic, often sunken lesion on a stem, branch, or twig which grows slowly, often over several years. Note distinct margin between healthy and dead (brown) tissue.

Figure 31: *Annulohypoxylon multiforme*. (Ascomycetes, Xylariales) The Fungus-Host Distribution Database lists 12 records of this species; all of which were from Poland, Russia, and Turkey. These records are from a diverse set of hardwoods, but one was from an unstated species of Alnus. Index Fungorum lists the synonymous *Hypoxylon multiforme* var. *alaskense* on corticated wood of *Alnus sitchensis* Alaska as reported in Ju, Y.M. and Rogers, J.D. 1996. A revision of the genus *Hypoxylon*. Mycologia Mem. 20: 365 pp.

Figure 32: *Cryptosphaeria ligniota*. (Ascomycetes, Xylariales) The Fungus-Host Distribution Database lists 34 records from north temperate regions, all but one (from dead limbs of *Salix viminalis*) were found upon species of *Populus*, including a record of canker from *P. tremuloides* from Alaska. This record came from Hinds, T.E., and Laurent, T.H. 1978. Common Aspen Diseases Found in Alaska. Pl. Dis. Reporter 62: 972-975.

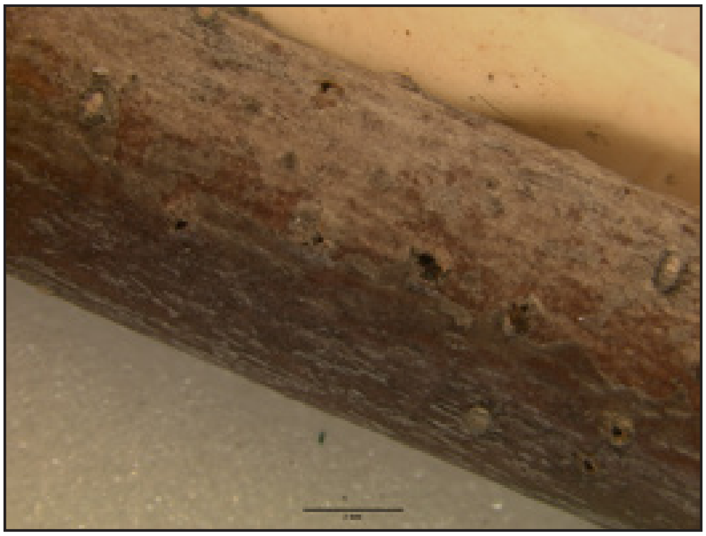


Figure 33: *Cryptosporella alni-sinuatae*. (Ascomycetes, Diaporthales) Only two records are found in the Fungus-Host Distribution Database, both are listed from *A. viridis* ssp. *sinuata*. One record is labeled as from USA and one from Washington state as reported in Mejia, L.C., Rossman, A.Y., Castlebury, L.A., and White Jr., J.F. 2011. New species, phylogeny, host-associations and geographic distribution of genus *Cryptosporella* (Gnomoniaceae, Diaporthales). Mycologia 103: 379-399.

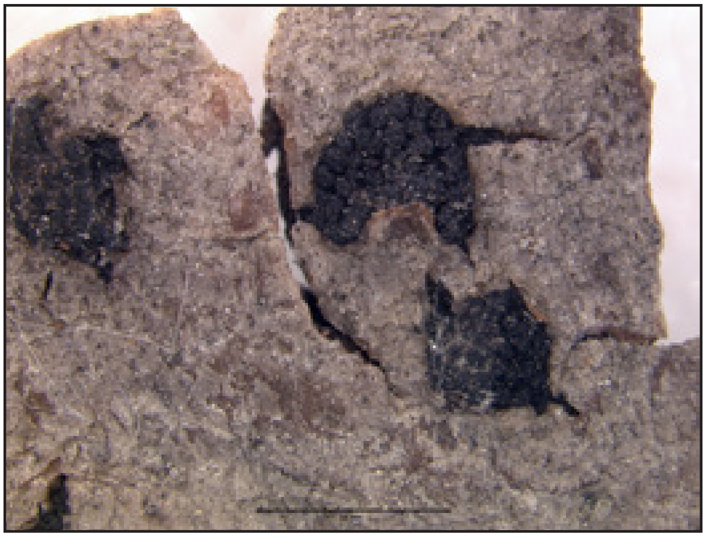


Figure 34: *Cryptosporella suffusa*. (Ascomycetes, Diaporthales) The Fungus-Host Distribution Database lists 59 records and cites this fungus as causing alder dieback in Europe. However, it also lists it from Canada (*A. incana* ssp. *rugosa*), Washington and Idaho (*A. viridis* ssp. *sinuata*, *A. incana* ssp. *tenuifolia*), and California (*A. rubra*). Although this fungus produced cankers with a larger mean size than the controls, statistically the canker size was not significantly different.

Figure 35: *Daldinia loculata*. (Ascomycetes, Xylariales) The Fungus-Host Distribution Database lists 8 records on hardwoods from North America, Asia, and southwestern Europe. The only *Alnus* species listed is from Germany.

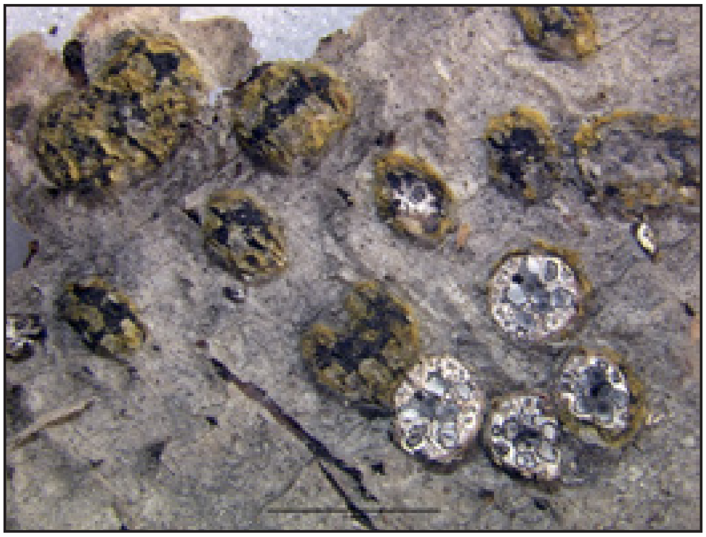


Figure 36: *Diatrype disciformis*. (Ascomycetes, Xylariales) The Fungus-Host Distribution Database lists 73 records mainly from hardwoods in temperate northern hemisphere, although India, Pakistan, and Turkey are also listed. The only reports from *Alnus* were from Alaska and Canada as recorded in Cash, E.K. 1953. A checklist of Alaskan fungi. Pl. Dis. Reporter Suppl. 219: 1-70. and Conners, I.L. 1967. An Annotated Index of Plant Diseases in Canada and Fungi Recorded on Plants in Alaska, Canada and Greenland. Res. Bra. Canada Dept. Agri. 1251: 1-381. Although not reported as pathogenic in the literature, this fungus was strongly pathogenic on all three alder species in the inoculation trials.

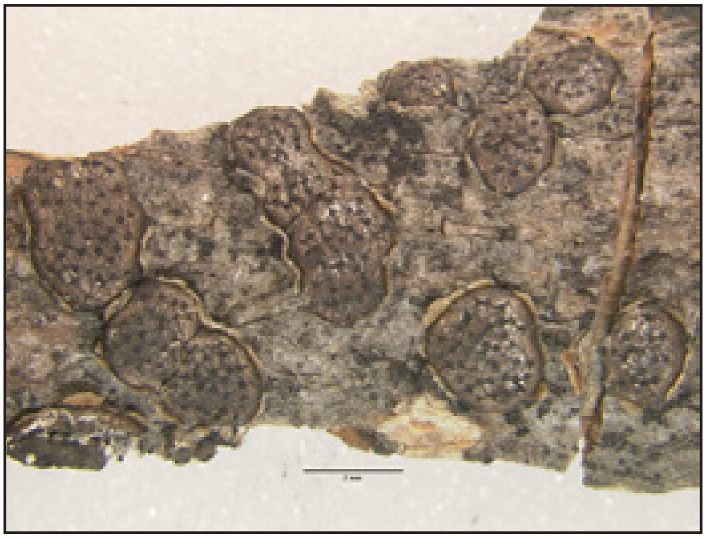


Figure 37: *Diatrype spilomea*. (Ascomycetes, Xylariales) The Fungus-Host Distribution Database only has three records of this fungus, all on Acer species from Europe.

Figure 38: *Diatrypella pulvinata*. (Ascomycetes, Xylariales) None of the 13 records in the Fungus-Host Distribution Database were found on Alnus, and all but one were from Europe.

Figure 39: *Hypoxylon fuscum*. (Ascomycetes, Xylariales) The Fungus-Host Distribution Database lists 175 records mainly on dead wood of the Betulaceae in the Northern hemisphere. Many were also found on various species of Alnus and one of these was listed as *Alnus* sp. in Cash, E.K. 1953. A checklist of Alaskan fungi. Pl. Dis. Reporter Suppl. 219: 1-70.

Figure 40: *Massarina corticola*. (Ascomycetes, Pleosporales) The Fungus-Host Distribution Database lists 18 records from temperate regions on numerous woody hosts. None of these 18 records are on *Alnus*. Although not reported as pathogenic in the literature, this fungus was strongly pathogenic on all three alder species in the inoculation trials.

Figure 41: *Melanconis stilbostoma*. (Ascomycetes, Diaporthales) The 98 host records are mainly from *Betula* species in temperate northern hemisphere. Only one from an *Alnus* species (*A. rhombfolia*). Kobayashi. 1970 Bull. Gov. Forest Exp. Sta. 226:13 associated it with branch dieback. This fungus is somewhat common on all three alder species and pathogenic in inoculation trials.

Figure 42: *Nectria dematiosa*. (Ascomycetes, Hypocreales) Only 12 records are recorded in the Fungus-Host Distribution Database that lists the fungus as widespread on deadwood of various hosts. Neither *Alnus* or Alaska were mentioned in the records, however Canada and Finland are prominent.

Figure 43: *Physalospora scirpi*. (Ascomycetes, Xylariales) *Physalospora scirpi* (current name in Index Fungorum) was previously known as *Anthrinium curvatum* a common inhabitant of leaves. The GenBank isolate that our Alaska fungus most closely matches was a CBS culture and phylogenetically it falls closest to *Anthrinium japonicum* and *Nigrospora* species. *Physalospora* spp. are common canker pathogens of apple and pear, but today many of those *Physalospora* have been transferred to *Botryosphaeria*. Apparently, *Physalospora scirpi* has not yet been transferred out of *Physalospora* into a suitable genus (it is not a *Botryosphaeria*).

Figure 44: *Plagiostoma samuelsii*. (Ascomycetes, Diaporthales) The Fungus-Host Distribution Database lists 6 records, all are on *Alnus* in California, Oregon, and Washington. Three of the records were on *A. incana* ssp. *tenuifolia*.

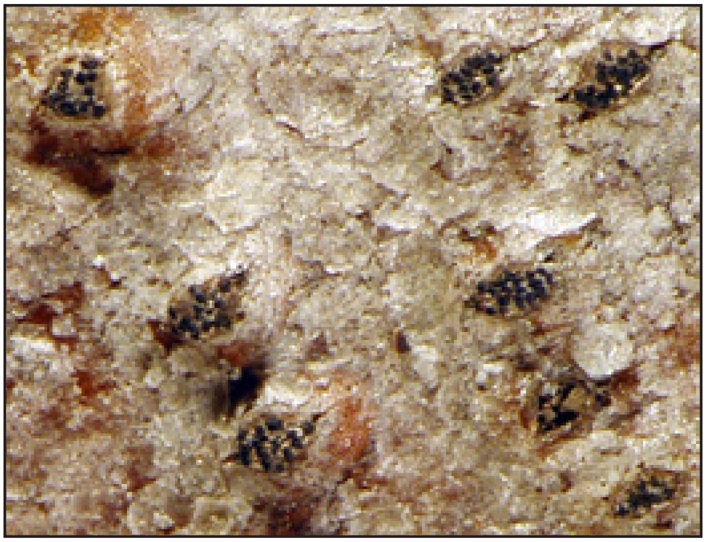


Figure 45: ***Valsa diatrypoides*****. (Ascomycetes, Diaporthales) The Fungus-Host Distribution Database lists only 3 records, all on *Alnus* from Canada and Poland. The Canadian records were reported in Conners, I.L. 1967. An Annotated Index of Plant Diseases in Canada and Fungi Recorded on Plants in Alaska, Canada and Greenland. Res. Bra. Canada Dept. Agri. 1251: 1-381.**

Figure 46: ***Valsa melanodiscus*****. (Ascomycetes, Diaporthales) The Fungus-Host Distribution Database lists 13 records on species of *Alnus* in Europe and North America, including Alaska. These are reported in Spielman, L.J. 1985. A monograph of *Valsa* on hardwoods in North America. Can. J. Bot. 63: 1355-1378, Cash, E.K. 1953. A checklist of Alaskan fungi. Pl. Dis. Reporter Suppl. 219: 1-70, and Conners, I.L. 1967. An Annotated Index of Plant Diseases in Canada and Fungi Recorded on Plants in Alaska, Canada and Greenland. Res. Bra. Canada Dept. Agri. 1251: 1-381. this fungus is extremely common on cankered *A. tenuifolia* throughout south-central and interior Alaska. Although it caused lesions on all three alder species in our inoculation trials, it is much less commonly found on Sitka and Siberian alder.**

Figure 47: ***Valsa*** **sp. (leucostomoid). (Ascomycetes, Diaporthales) *Valsa* sp. (leucostomoid) = *Leucostoma* sp. Our sample is morphologically a *Leucostoma* but phylogenetic work shows no support for the genus *Leucostoma* which instead falls within *Valsa*. This specimen has not yet been determined to species.**

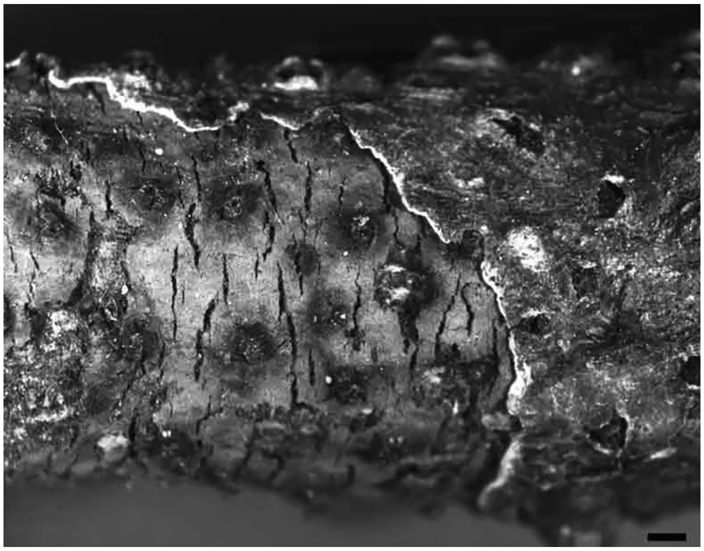


Figure 48: ***Valsalnicola oxystoma*****. (Ascomycetes, Diaporthales) The Fungus-Host Distribution Database lists 18 records, all on various species of *Alnus*. This fungus is described as causing alder dieback at high elevations in Europe and Alaska. The Alaskan record is from *A. incana* ssp. *tenuifolia* as recorded in Crous, P.W., Rossman, A.Y., Shivas, R.G., Summerell, B.A., Alves, J.L., Wingfield, M.J, Adams, G.C., Groenewald, J.Z., Bell, A., and Barreto, R.W. 2012. Fungal Planet description sheets: 128-153. Persoonia 29: 146-201. The record in Alaska and the new genus were a product of our study.**

2013 Pathology Species Updates

Cankers and Shoot Blights

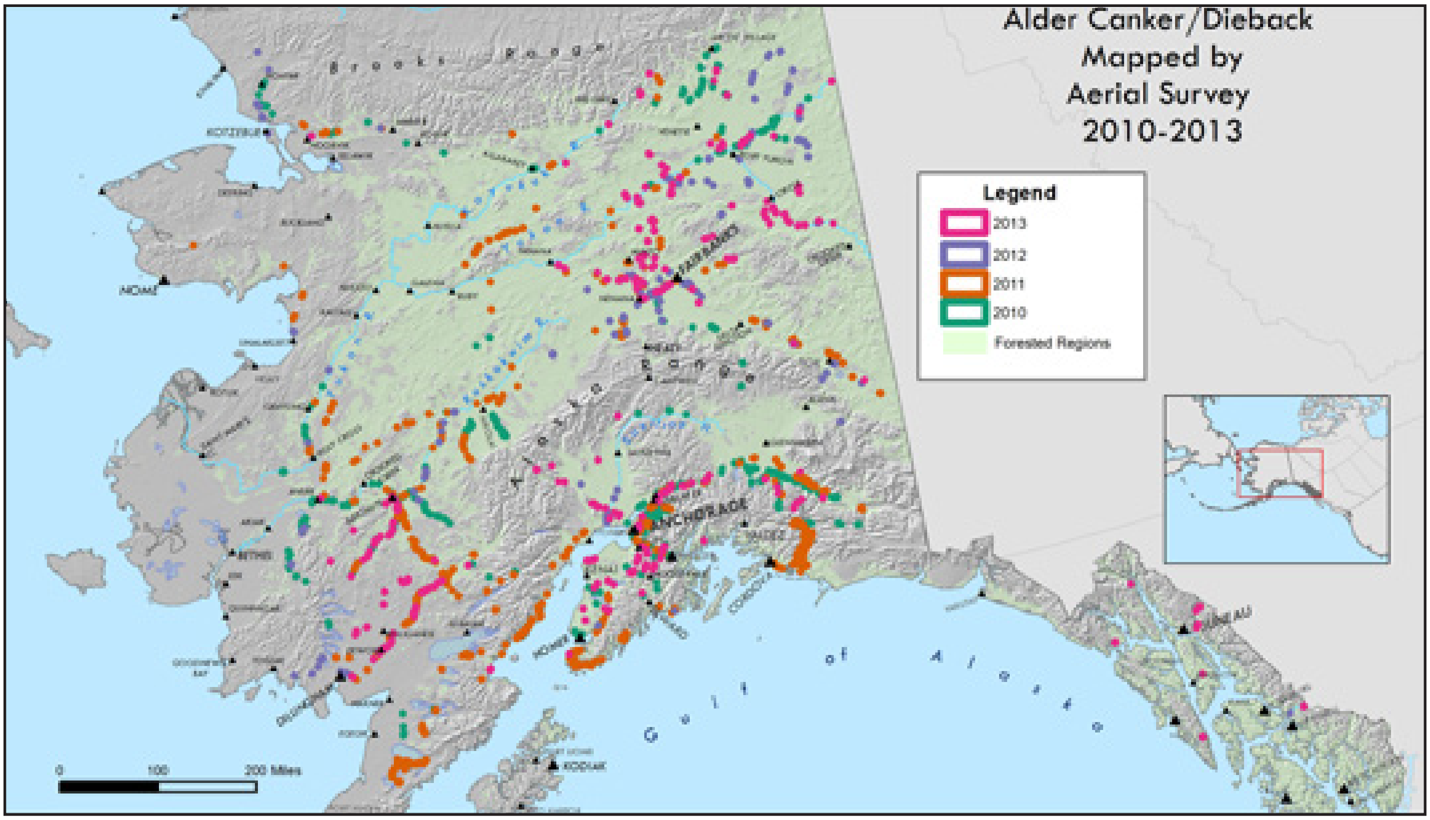
Alder Canker

***Valsa melanodiscus* Otth. and other fungi**

Alder dieback was mapped on approximately 26,000 acres in Alaska in 2013 and for the first time included locations in Southeast Alaska but this has yet to be ground verified (*Map 9*). Significant alder dieback was first observed in Alaska in 2003 and the fungus *Valsa melanodiscus* was determined to be the main pathogen involved, causing girdling cankers on branches and main stems. More recently, fungal pathogens other than *V. melanodiscus* have been found to also cause branch dieback of alder in Alaska (see alder canker essay on page 28), including a species in the newly recognized genus *Valsalnicola*. Damage from alder canker continues to be a significant concern. Most alder canker damage occurs within 1,600 feet of streams, but has been observed greater than 2 miles away and up to 1,500 feet in elevation. The distribution of alder canker is closely linked to the distribution of the most susceptible alder species, thin-leaf alder (*Alnus tenuifolia*, *Figure 49*), although Siberian/green alder (*A. fruticosa)* and Sitka alder (*A. sinuata*) are also susceptible.

Figure 49: Alder canker has killed many of the thin-leaf alder stems in the background. However, the Sitka alder in the foreground appears healthy.

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.



Map 9: Alder dieback mapped during aerial detection survey from 2010 to 2013. Alder dieback is caused by the fungus *Valsa melanodiscus*, as well as other species of canker fungi. In 2011, a focused survey effort mapped active alder dieback and older mortality. More than 200,000 acres of alder dieback have been mapped since 2010.

The aerial detection survey has attempted to consistently map alder dieback since 2010. Seen from the air, alder defoliation and dieback are challenging to differentiate. For this, and several other reasons (see alder defoliation update on page 19), the number of mapped acres varies markedly among years (Table 2). The aerial signature of defoliator damage can vary even within a season, as alder can grow new leaves and mask early season damage. However, dieback is much less ephemeral, since the development of new shoots is a multi-year effort. From the air, it is impossible to discern the cause of dieback and whole stem mortality, but extensive ground surveys have found that a large portion of alder dieback in Alaska is due to canker-causing fungi. Some dieback is due to persistent flooding or animal damage. Ground surveys have also found heavily impacted stands that appear completely dead from the air often have live basal shoots below the dead aerial stems.

Grovesiella Canker (Scleroderris Canker)

***Grovesiella abieticola* (Zeller and Goodd.) M. Morelet & Gremmen (= *Scleroderris abieticola*)**

Grovesiella is an annual canker that causes twig dieback, branch mortality, and occasional top-kill of true firs along the Pacific Coast. It is usually not a serious disease. Small, black, cup-shaped fruiting bodies (*Figure 50*) can be seen on dead bark tissue of recently killed branches, and live tissue adjacent to cankers may be resinous and swollen. Young trees are the preferred hosts, but lower branches of large trees may also be affected. In the past, Grovesiella has been reported on subalpine firs near Skagway. In 2011 and 2012, mortality of small subalpine firs with disease symptoms consistent with this canker was reported along the Taku River drainage. This year the disease was also observed causing branch mortality of ornamental firs in Juneau.

Figure 50: Black fruiting bodies of *Grovesiella abieticola* on a resinous, swollen fir stem.

Hardwood Cankers (other than alder)

Several fungal species

Table 5. Common canker fungi found on living hardwood trees in Alaska.

Canker fungus	Trembling aspen	Paper birch[1]	Balsam poplar	Cottonwood	Willow
Ceratocystis fimbriata	X				
Cryptosphaeria populina	X		X	X	
Cytospora chrysosperma	X		X	X	X
Encoelia pruinosa	X		X		
Nectria galligena		X			

1. Including Alaska paper birch, *Betula neoalaskana*, and Kenai birch, *B. kenaica.*

Several canker-causing fungi infect species of poplar, aspen, willow and birch in Alaska (*Table 5*). While the incidence of hardwood cankers changes little from year to year, the environmental conditions in some years are more favorable than others for the infection process. Infection primarily occurs through wounds on stressed trees, causing relatively localized death of the bark, cambium, and underlying wood on branches or the main tree bole. Annual cankers persist for only one season; whereas perennial cankers expand into adjacent healthy tissue over time. Canker appearance varies significantly, depending on the causal fungus. Cankers can have irregular or well-defined margins, and may be subtle and sunken, elongate, diffuse or target-shaped. Cankers may girdle or weaken branch or bole tissue, directly killing stems or making them susceptible to breakage.

Figure 51: *Encoelia pruinosa,* which causes an elongated, black canker on aspen, is more aggressive than many other hardwood cankers.

Although most hardwood canker fungi are considered weak pathogens, some are more aggressive. *Encoelia pruinosa* (=*Cenangium singulare*), which causes elongated, sooty black cankers that may be mistaken for fire scars (*Figure 51*), can girdle and kill aspen in three to ten years. Another canker on aspen, *Ceratocystis fimbriata*, creates a distinctive target-shaped canker with flaring bark (*Figure 52*). A small pocket (0.25 acres) of what we presume to be *C. fimbriata* was found on trembling aspen upslope from the Sterling Highway near Cooper Landing. The disease had been present in the area for many years and several trees were killed. Many trees had numerous large cankers along the entire length of the bole into the crown (*Figure 53*).

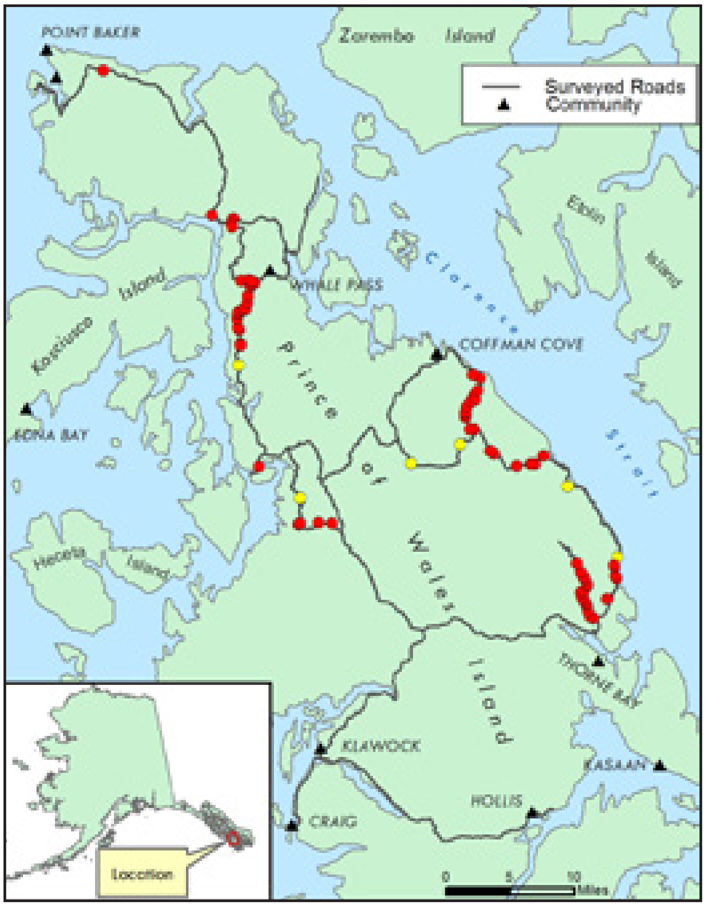
Figure 52: A target-shaped canker on aspen caused by *Ceratocystis fimbriata.*

Figure 53: An aspen stand severely impacted by a canker pathogen. There were no fruiting bodies available for diagnosis, therefore we are pursuing molecular identification.

Hemlock Canker

Unknown fungus

An outbreak of hemlock canker occurred along roadways on Prince of Wales Island in 2012 and 2013 between Thorne Bay and Coffman Cove and between Staney Creek and Whale Pass (*Map 10*). Cankered branches were collected in 2012 and sent to Gerry Adams at the University of Nebraska for fungal isolation and genetic sequencing. Several potential canker pathogens were identified. Inoculation trials with the isolated fungi were conducted in May 2013 (*Figure 54*) in an effort to determine which fungus causes this canker disease of western hemlock in Alaska. Outbreaks of this pathogen have been documented 1-2 times per decade on Prince of Wales, Kosciusko, Kuiu, and Chichagof Islands in Southeast Alaska, and western hemlock is thought to be the only species affected. Inoculated trees will be assessed in spring 2014, and additional inoculations may be conducted with fungi collected in 2013.



Map 10: Hemlock canker symptoms observed on Prince of Wales Island during a road survey in August 2013. Only roads that were surveyed are shown. Red circles represent locations where disease was observed in 2013, while yellow circles represent locations observed in 2012.

Symptoms of hemlock canker include bark lesions, bleeding or resinous cankers, and branch or small tree mortality (<14" dbh). The disease behavior suggests it is an aggressive, annual canker. This disease is most often seen along roads and natural openings (riparian zones and occasionally shorelines), where it causes widespread, synchronized mortality of small hemlocks and lower branches of larger trees (*Figure 55*). The microclimate in openings may contribute to the disease. Road dust was once thought to be a predisposing factor, but outbreaks continued to occur along gravel roads that were subsequently paved. Resistant tree species (spruce and cedars) may benefit from reduced competition in affected stands, and wildlife habitat may be enhanced where understory hemlock mortality promotes increased herbaceous vegetation.


Figure 54: Lori Winton inoculates western hemlock trees on Prince of Wales Island in May 2013. Seven inoculation treatments were applied to 350 western hemlocks, ranging 1.5-7 inches in diameter, across six sites to determine the cause of hemlock canker. The fungal isolates used in the inoculation were locally collected from diseased hemlock trees in 2012.


Figure 55: Symptoms of hemlock canker along the Prince of Wales road network.

Shoot Blight of Yellow-cedar
Possibly *Kabatina thujae* Schneider & Arx

Shoot blight of yellow-cedar regeneration in Southeast Alaska was noted again in 2013. Terminal and lateral shoots on seedlings and saplings become infected and die during late winter or early spring, and dieback may extend 4 to 10 inches from the tip of the shoot. Entire seedlings up to 1-2 feet tall are sometimes killed. Leader infections are periodically observed, but since yellow-cedar is capable of producing new terminal leaders, long-term tree structure is not thought to be compromised. This year we noticed that some infections appeared to originate on shoots damaged by deer browse. Symptoms of this disease are sometimes confused with spring frost damage. There has been confusion about the identity of the causal fungus. Jeff Stone at Oregon State University identified collections made this year as *Kabatina thujae*, a species known to damage young yellow-cedar trees in British Columbia, including those in ornamental settings. More collections, identifications, and an inoculation study are needed to determine if this fungus is the cause of the widespread damage to yellow-cedar postharvest regeneration in Southeast Alaska.

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

Damage from Sirococcus shoot blight was not severe or remarkable in 2013. Sirococcus shoot blight symptoms were observed on western hemlock along Montana Creek and Eagle River in Juneau in 2013. This disease of young lateral or terminal shoots occurs in Southeast Alaska on both western and mountain hemlock (rarely spruce), but mountain hemlock is more susceptible. Infection occurs through young needles and moves into developing shoots, causing canker formation, distorted shoot growth, and shoot mortality. Spores are dispersed from small, circular fruiting bodies by rain splash. For unknown reasons, ornamental mountain hemlocks experience heavier infections than forest trees; this may be due to the genetic source of landscape trees or differences in the infection environment. In natural stands, damage from this disease appears to be concentrated along rivers and creeks, possibly due to factors in the environment such as temperature and humidity.

Foliar Diseases

Dothistroma Needle Blight
***Dothistroma septosporum* (Dorog.)**

Dothistroma needle blight, also called red band needle blight, is a foliage disease that affects a wide range of pine hosts in North America. The causal fungus produces black, pimple-like fruiting bodies on discolored infected needles in spring and early summer (*Figure 56*). Diseased trees may have sparse crowns and reduced growth from premature needle shed. *D. septosporum* occurs throughout the range of pine in Southeast Alaska, where climate conditions are conducive to foliage disease. Under normal conditions, the disease causes premature needle shed but does not kill or significantly stress trees. However, a localized outbreak of this disease in shore pine-spruce-cottonwood stands and pure shore pine stands in Gustavus has been ongoing for the past three years (*Figure 57)*. Three consecutive years of disease have resulted in tree mortality, since shore pine frequently retains three or fewer needle cohorts in Alaska.

The combination of mortality and limited regeneration is likely to reduce the abundance of shore pine in the mixed species stands in Gustavus. Successful regeneration in open muskegs without competition from other tree species will allow shore pine to persist on those sites. Aerial survey and ground checks indicate that the extent of this outbreak is limited to the flatlands of Gustavus. Monitoring plots installed in June 2013 will be revisited in 2014 to evaluate survival of severely diseased trees.

Figure 56: Pimple-like orange-black fruiting bodies of *Dothistroma septosporum* on discolored shore pine needles.

Figure 57: Discolored shore pine tree crowns, most with less than 1 year of foliage retained. Needle discoloration and poor needle retention are typical during severe foliage disease outbreaks, such as the current outbreak in Gustavus.

Rhizosphaera Needle Cast

***Rhizosphaera pini* (Coda) Maubl.**

The fungus *Rhizosphaera pini* causes spruce needle cast (also called spruce needle blight). Rhizosphera needle cast on Sitka, white, and Lutz spruce was severe throughout many areas of the state in 2013; it was particularly evident on the Kenai Peninsula, in the Interior near Fairbanks and Tok, and in the Juneau area. The epidemic that occurred in 2009 remains the largest and most intense recorded outbreak in Southeast Alaska. Generally, symptoms become apparent in late summer, and include yellow-brown foliage discoloration and premature needle shed of heavily infected ≥1-year-old needles. Severely defoliated trees can lose nearly all of their older needles, causing substantial growth loss and physiological stress; however, trees are expected to recover unless there are repeated, successive outbreaks. Small, black fruiting bodies occupy pores for gas exchange on the undersides of needles (*Figure 58*). Spores are dispersed from fruiting bodies during shoot elongation in the spring, primarily infecting new needles. Fungal colonization and fruiting body development occur in the months and years following infection. Epidemics develop when temperature and moisture conditions are favorable for *R. pini* dispersal and infection for multiple consecutive years.

Figure 58: Fruiting bodies of *Rhizosphaera pini* on the undersides of Sitka spruce needles.

Lirula Needle Blight

***Lirula macrospora* (Hartig) Darker**

Lirula needle blight was observed but did not cause significant damage in 2013. Scattered red-brown to tan needle discoloration is a symptom of minor infection. More severe infection results in a distinctive pattern of foliage discoloration, with green current year needles, reddish-brown one-year-old needles, and yellow two-year-old needles. Elongated black fruiting bodies are present on the undersides of infected two-year-old needles, often along the midrib, and spores are disseminated by rain splash to infect new needles in spring and early summer. Needles greater than two years old turn grayish-brown and remain attached for several years. Spruce trees usually recover after an outbreak, as the upper tree crown is not significantly affected and optimal weather conditions for severe infection rarely occur in consecutive years. Observers have noted that the disease is more pronounced in spruce-alder forests, but this has not been quantified and the possible reasons for this are not understood. *Lophodermium piceae* is another fungus that causes discoloration and premature casting of spruce needles, but is considered a weak foliar pathogen in Alaskan forests.

Spruce Needle Rust

***Chrysomyxa ledicola* Lagerh.**

In contrast to 2011 and 2012, there were few reports of spruce needle rust in 2013. In 2012, outbreaks of spruce needle rust caused massive quantities of rust spores to wash up on shorelines in Lake Clark National Park, Katmai National Park, and the Kenai Peninsula, and notable needle rust also occurred in Southeast Alaska. In 2011, large quantities of rust spores washed onshore near the village of Kivalina in northwestern Alaska. Since spruce trees are not abundant in Kivalina, it is thought that heavily infected spruce trees upriver or upwind of Kivalina served as the source of the spores. Significant spruce needle rust outbreaks also occurred in 2007 (Southeast Alaska) and 2008 (Interior Alaska).

Heavily infected spruce trees have a distinctive orange tinge when the rust is fruiting on the needles in summer (*Figure 59*). However, sometimes trees are not obviously infected despite abundant orange spores on lake surfaces. Outbreaks are triggered by cool, wet weather in May, when fungal spores from Labrador tea (the alternate host) infect newly emerging spruce needles. Damage from spruce needle rust 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. Infected trees may be stressed or experience growth loss, but these impacts have not been quantified. In the future, it may be possible to develop methods to use satellite technology to detect needle rust outbreaks in Alaska.

Figure 59: Aeciospores of spruce needle rust, *Chrysomyxa ledicola*, on current-year needles of Sitka spruce in Southeast Alaska.

Stem Diseases

Hemlock Dwarf Mistletoe

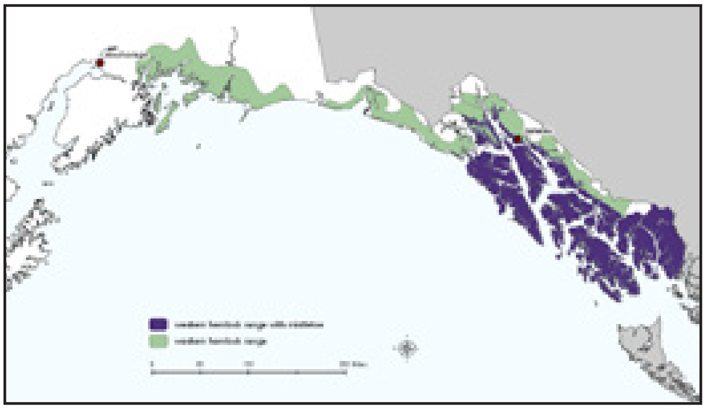
***Arceuthobium tsugense* (Rosendhal) G.N. Jones**

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 (*Figure 60*) provide important wildlife habitat. Suppression and mortality of mistletoe-infected trees play a significant role in gap creation and succession in coastal rainforest ecosystems. Although clear-cutting practices eliminate dwarf mistletoe from second-growth timber stands, reduced clear-cutting under current forestry practices may allow managers to retain some desirable quantity of mistletoe in their stands for wildlife benefits without incurring significant growth losses.

Figure 60: Prolific branching (brooms) caused by hemlock dwarf mistletoe, *Arceuthobium tsugense.*

Dwarf mistletoe incidence, severity and distribution changes little over time without active management. Forest Inventory and Analysis (FIA) plot data has been scaled up to estimate the occurrence 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. Dwarf mistletoe was present in a higher percentage of FIA plots classified as large sawtimber (13.5%) and small sawtimber (19.8%) compared to smaller size classes. Values estimated from FIA plot data are conservative, because dwarf mistletoe may not have been recorded when other damage agents were present. Also, it is important to note that scattered larger trees may have been present in the plots designated as smaller and younger classes. This helps to explain the higher than expected incidence of hemlock dwarf mistletoe in the young sawtimber class.

The occurrence of hemlock dwarf mistletoe is apparently limited by climate (elevation and latitude), becoming uncommon or absent above 500 ft in elevation and 59°N latitude (Haines, AK) despite the continued distribution of western hemlock (*Map 11*). Dwarf mistletoe is conspicuously absent from Cross Sound to Prince William Sound, although in 2013 we received an unconfirmed report that the disease might occur in the vicinity of Icy Bay. However, this observation might be confusing spruce broom rust with hemlock dwarf mistletoe. It is thought that short growing seasons or snow loads on trees may limit fruiting, seed dispersal, germination, infection, or survival of hemlock dwarf mistletoe at higher elevations and more northerly latitudes. Considering apparent climate constraints on dwarf mistletoe distribution, an effort has been conducted 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, forecasting significant increases (374% to 757%) in suitable mistletoe habitat over the next century. These results must be interpreted cautiously, as actual migration rates will be limited by the biology and natural spread rates of the host and pathogen.



Map 11: The distribution of western hemlock dwarf mistletoe, *Arceutobium tsugense*, and its host, western hemlock.

Spruce Broom Rust

***Chrysomyxa arctostaphyli* Diet.**

Broom rust is common on spruce branches and stems throughout Southcentral and Interior Alaska. The disease is only abundant where spruce grows in association with the alternate host, bearberry/kinnikinnik (*Arctostaphylos uva-ursi*), because the fungus requires both hosts to complete its lifecycle. Sitka spruce is not affected throughout most of Southeast Alaska, but spruce broom rust has been found on Sitka spruce in Glacier Bay and near Halleck Harbor on Kuiu Island. Infection by the rust fungus results in the formation of brooms; dense clusters of branches with dwarfed stems and foliage. The brooms appear yellow to orange in mid to late summer when spores are produced on infected foliage (*Figure 61*). Infection of bearberry causes a purple-brown leaf spot, and orange spores are produced on the undersides of leaves in late spring and early summer (*Figure 62*).

Figure 61: . Perennial broom of spruce broom rust (*Chrysomyxa arctostaphyli*).

Figure 62: . Purple leaf spots and spores of spruce broom rust (*Chrysomyxa arctostaphyli*) on bearberry.

The actual infection process may be favored during specific years, but the incidence of the perennial brooms changes little over time. In 2013, about 900 acres of broom rust were mapped by aerial survey. In 2012, less than 90 acres were mapped compared to nearly 900 acres in 2011; these changes represent differences in detection methodologies rather than differences in disease distribution over time.

For high value trees and stands, brooms can be pruned and infected trees can be removed, or the alternate host can be removed to manage the disease. Bearberry eradication is generally not recommended in forested systems, since this approach would be ineffective given the broad distribution of this native and ecologically valuable species. Spruce broom rust may cause spike tops, dead branches, or growth loss, but usually does not kill trees. Brooms may provide a path to infection for decay fungi and habitat for some wildlife species, similar to brooms caused by dwarf mistletoe.

Figure 63: Conks of several stem decay fungi of conifers in Alaska. Left to right, first row, *Echinodontium tinctorium, Fomitopsis pinicola, Ganoderma applanatum*; second row, *Ganoderma tsugae, Phellinus hartigii, Phaeolus schweinitizii, Phellinus pini, Laetiporus sulphureus*

Stem Decays of Conifers

Several fungal species (*Figure 63*)

In mature forests, stem decays (heart rots) cause enormous annual wood volume loss of Alaska's major tree species. Approximately one-third of the old-growth timber board foot volume in Southeast Alaska is defective, largely due to decay from heart rot fungi. This loss estimate comes from two classic studies of defect or cull. Conversely, there is very little decay in young-growth stands unless there is prevalent wounding from commercial thinning activities, wind damage, or animal feeding. By predisposing large old trees to bole breakage and windthrow, stem decays serve as important small-scale disturbance agents in coastal rainforest ecosystems where fire and other large-scale disturbances are uncommon. Stem decays create canopy gaps, influence stand structure and succession, increase biodiversity, and enhance wildlife habitat. Decay fungi also perform essential nutrient cycling functions in forests by decomposing stems, branches, roots, and boles of dead trees. Cavities created by stem decay fungi in standing trees provide crucial habitat for many wildlife species (bears, voles, squirrels, and a number of bird species). The lack of disturbance and longevity of individual trees allows ample time for slow-growing decay fungi to cause significant decay. There is growing interest in acquiring methods to promote earlier development of stem decays in second-growth stands to achieve wildlife and other non-timber objectives.

There are a number of different fungal species that cause stem decay in Alaskan conifers (*Table 6*). In Southcentral Alaska, heart rot fungi such as *Phellinus pini* cause considerable volume loss in mature mountain hemlock, white spruce, and Lutz spruce. The Indian paint fungus (*Echinodontium tinctorium)* was detected on western hemlock on Mitkof Island in Southeast Alaska in 2012, representing the first report of this fungus in Alaska south of Skagway. This fungus has probably been present historically, but may be uncommon. 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 of these decays do not actually interfere with the normal growth and physiological processes of live trees since the vascular system is unaffected. However, some decay pathogens, such as *Phellinus hartigii* and *P. pini* may attack the sapwood and cambium of live trees after existing as a heart rot fungus. Many of the fungi that are normally found on dead trees, such as *Fomitopsis pinicola,* can also grow on large stem wounds, broken tops, and dead tissue of live trees. Root and butt rot fungi, such as *Phaeolus schweinitzii,* can also cause stem decay in the lower bole.

Modern non-destructive techniques can be used to evaluate the extent of stem decay in live, high value trees. Region 10 Forest Health Protection staff can provide training and assistance to clients that would benefit from this service.

Decay fungi are classified as either white rots, which degrade both cellulose and lignin, or brown rots, which primarily degrade cellulose. Wood impacted by brown rot may be more brittle and prone to breakage in high winds, and cannot be used for pulp production. An important cull study conducted by James Kimmey in Southeast Alaska in the 1950s found that brown rots were the most significant source of cull for Sitka spruce, while white rots were most significant for western redcedar (especially *Physisporinus rivulosus* and *Phellinus weirii*) and western hemlock (*Figure 65*).

Table 6. Stem decay fungi on live conifer trees in Alaska. R indicates a rare host.

Heart & butt rot fungi[1]	Western hemlock	Mountain hemlock	Western redcedar	Sitka spruce	White/Lutz spruce	Lodgepole pine	Type of Rot/ Decay
Armillaria spp.	X	X	X	X	X	X	White
Ceriporiopsis rivulosa			X				White
Coniophora sp.		X			X		Brown
Echinodontium tinctorium	R	X					Brown
Fomitopsis pinicola	X	X		X	X		Brown
Fomitopsis officinalis						X	Brown
Ganoderma spp.	X			X	X		White
Heterobasidion annosum	X			X			White
Inonotus tomentosus				R	X		White
Laetiporus sulphureus	X	X	R	X	X		Brown
Phaeolus schweinitzii	X			X	X		Brown
Phellinus hartigii	X	R			R		White
Phellinus pini	X	X		X	X	X	White
Phellinus weirii			X				White

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

For any given size or age class, western redcedar was the most defective species (*Figure 64*), followed by western hemlock and Sitka spruce. This trend is puzzling considering the extreme decay resistance of redcedar wood products, but a possible explanation is that a few species of highly specialized decay fungi are able to overcome the decay resistance of live redcedar but do not affect wood products used as building materials.

Figure 64: A small central rot column in western redcedar near Thorne Bay, AK caused by the fungus *Ceriporiopsis rivulosa.* The current project investigating hidden defect of western redcedar and yellow-cedar will help to determine if this fungus is likely the leading cause of heart rot of redcedar in coastal Alaska as it is in British Columbia.

It is recommended that Kimmey's historic report be validated with a new study using modern genetic techniques to identify decay fungi. Since fungal fruiting bodies (conks) are often absent, Kimmey used the visual characteristics of wood decay to identify the causal species; a very difficult task. Although the designations of brown or white rot fungi are almost certainly correct, it is possible that the causal species were sometimes confused or could not be distinguished. For example, Armillaria is listed as the most important heart rot of western hemlock; however, it is possible that some of the decay attributed to Armillaria was actually caused by another white rot fungus.

A new study of hidden defects was initiated in 2013 that attempts to identify the leading decay fungi and quantify the cull in western redcedar and yellow-cedar that have no visible indicators (e.g., wounds, conks). We now have the tools to distinguish between decays that appear similar and further work would greatly improve our understanding of conifer stem decays in Alaska. This new project will use genetic diagnostic methods to diagnose important stem decays of western redcedar and yellow-cedar and improve cull estimates for these tree species in Southeast Alaska.

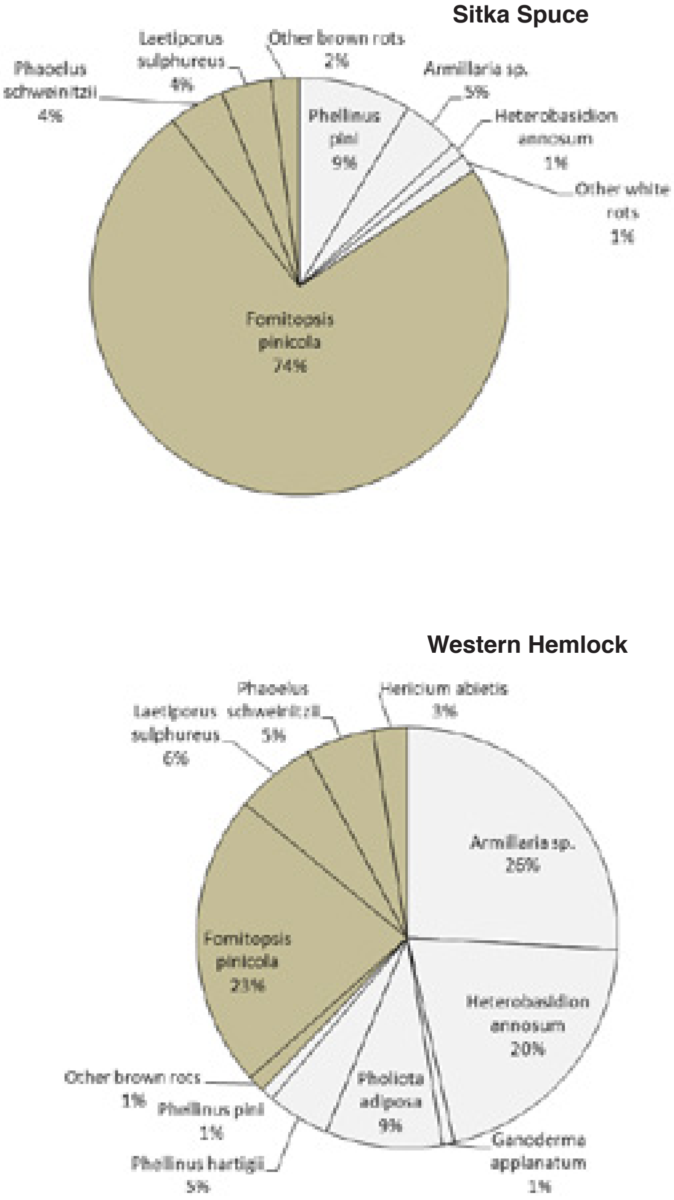


Figure 65: Percentage of white and brown rot stem decay fungi in living Sitka spruce (top) and western hemlock (bottom) in old forests of southeast Alaska. Adapted from Kimmey (1956), with species classifications primarily based on the visual appearance of wood decay.

Stem Decays of Hardwoods

Several fungal species

Heart rots are the most important cause of volume loss in Alaskan hardwoods. Incidence of heart rot (*Table 7*) in hardwood species of Interior and Southcentral Alaska is generally high by the time a stand has reached maturity (about 50 years old), and substantial volume loss can be expected in stands that are greater than 80 years old. Decay fungi will limit rotation age when hardwood forests are managed for wood production. Detailed data on volume losses by stand age class and forest type are currently lacking; and studies are needed to better characterize these relationships.

Armillaria and *Pholiota* spp., which produce annual fruiting bodies, frequently occur on trembling aspen, black cottonwood, and paper birch, but are not as common as heart rot fungi that form perennial conks on these tree species. *Phellinus igniarius* and *Fomes fomentarius* account for the majority of decay in paper birch (*Figure 67*), with the former being the most important in terms of both incidence and volume of decay. *Inonotus obliquus* (*Figure 66*) can be locally common on birch and is occasionally seen on aspen and cottonwood. *Phellinus tremulae* (*Figure 68*) accounts for the majority of stem decay in trembling aspen. A number of fungi cause heart rot in balsam poplar, cottonwood, and other hardwood species in Alaska.

Table 7. Stem decay fungi on live hardwood trees in Alaska. R indicates a rare host.

Heart rot fungi	Paper Birch[1]	Trembling aspen	Cottonwood	Red alder	Type of Rot/ Decay
Armillaria spp.	X	X	X	X	White
Fomes fomentarius	R				White
Ganoderma applanatum	X	X	X	X	White
Inonotus obliquus	X	R	R		White
Phellinus igniarius	X				White
Phellinus tremulae		X			White
Pholiota spp.	X	X	X	X	White
Piptoporus betulinus	X				Brown

1. Including Alaska paper birch, *Betula neoalaskana*, and Kenai birch, *B. kenaica.*

Figure 66: An *Inonotus obliquus* conk, also known as chaga mushroom, on birch.

Figure 67: A single *Phellinus igniarius* conk on paper birch can indicate extensive decay.

Figure 68: A *Phellinus tremulae* conk on aspen.

Western Gall Rust

***Peridermium harknessii* J.P. Moore (=*Endocronartium harknessii*)**

Western gall rust infection causes spherical galls to develop on branches and main boles of 2- and 3-needled pines, and is extremely common throughout the distribution of shore pine (*Pinus contorta* var. *contorta*) in Southeast Alaska. A study of shore pine in Southeast Alaska in 2012 and 2013 found that 85% of pines greater than 4.5 feet in height were infected with gall rust. Twenty-five percent of pines had top-kill associated with galls on the main tree bole, while 34% had at least one gall infection of the main stem that could lead to top-kill or whole tree mortality.

Unlike many other rust fungi, this fungus spreads from pine to pine and does not require an alternate host to complete its lifecycle. In spring, conspicuous orange spores are released from galls and infect pines through newly emerged foliage. The fungus moves from the vascular tissue in the leaf to the branch; where it causes swelling and develops spores for reproduction. In British Columbia and other parts of the Pacific Northwest, gall rust infection occurs sporadically when conditions are cool and wet during sporulation in the spring. This phenomenon has not been evaluated in Alaska, but it is thought that ideal infection conditions occur more regularly in Southeast Alaska compared to other regions. Western gall rust does not usually kill branches directly, but infections facilitate secondary insects (e.g., *Pityophthorus* twig beetles and the Douglas-fir pitch moth) and fungal (e.g., Nectria) attacks that can girdle branches or boles (*Figure 69*). Recent shore pine mortality and dieback in Southeast Alaska observed on the ground and through analysis of Forest Inventory Analysis data has emphasized the need to gain more information about damage agents of shore pine.

Figure 69: Western gall rust seldom causes direct branch or bole mortality, but gall tissue is commonly attacked by secondary insects and pathogenic fungi like *Nectria* (top) that lead to branch mortality (bottom).

Root Diseases

There are three important root diseases on conifers in Alaska: Annosus/Heterobasidion root disease, Armillaria root disease, 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. Fortunately, the type of *P. weirii* that causes laminated root rot in forests of British Columbia, Washington, and Oregon does not occur in Alaska, as several of our native conifers are susceptible. Although root diseases play an important disturbance role in Alaska's forests, these pathogens do not usually create disease centers typically associated with root pathogens throughout North America, and cannot be mapped through aerial survey.

Annosus/Heterobasidion Root & Butt Rot

***Heterobasidion annosum* (Fr.) Bref.**

The spruce type of *Heterobasidion annosum* causes root and butt rot in old-growth western hemlock and Sitka spruce forests in Southeast Alaska. This pathogen causes internal wood decay, but does not typically kill trees, and has not been documented in other parts of Alaska. In Alaska, disease incidence and severity are apparently unaffected by management activities, unlike the situation in other regions, where cut stumps are frequently treated during harvest to prevent disease spread. It has been suggested that the cool, excessively wet climate in Southeast Alaska is not conducive to successful spread and colonization of this pathogen by spores, or that other fungi, such as *Armillaria* species, are antagonistic to *Heterobasidion*. The name of this pathogen is changing. Some pathologists have already started to use the new scientific name for the spruce type of this pathogen, *Heterobasidion occidentale* Otrosina & Garbelotto, and the new disease name, Heterobasidion root and butt rot.

Armillaria Root Disease

***Armillaria* spp.**

All tree species in Alaska are affected by one or more *Armillaria* species (*Figure 70*). Armillaria root disease causes growth loss, butt and root rot, and mortality. However, the species of *Armillaria* present in Alaska are not usually the primary cause of tree mortality, but instead hasten the death of trees that are already under some form of stress. In Southeast Alaska, *Armillaria* was documented as the leading cause of heart rot of western hemlock in an important cull study of the 1950s, and modern genetic techniques could be useful for validating this work. *Armillaria* is also common on dying yellow-cedars in stands experiencing yellow-cedar decline, but its role is clearly secondary to abiotic processes. In 2013, *Armillaria* mycelial fans and rhizomorphs were noted on several dead yellow-cedars that apparently succumbed to the decline phenomenon in a young-growth stand on Zarembo Island (see essay on page 50). A first report was published in 2009 of *Armillaria sinapina* on birch and spruce on the Kenai Peninsula, and *A. sinapina* and *A. nabsnona* are species that have been documented in Southeast Alaska. Additional work is needed to understand the diversity and ecological roles of *Armillaria* species in Alaska.

Figure 70: Black rhizomorphs and mycelial fans are distinctive vegetative structures of *Armillaria*, which less frequently produces fleshy, annual mushrooms. Photo credit: Dave Shaw, Oregon State University.

Tomentosus Root Disease

Inonotus tomentosus* (Fr.) Teng. (= *Onnia tomentosa)

The pathogen *Inonotus tomentosus* is apparently widespread throughout spruce stands of Southcentral and Interior Alaska, but comprehensive surveys have not been conducted due to inaccessibility and obstacles to detection. This pathogen causes root and butt rot of white, Lutz, and Sitka spruce trees of all ages. Symptoms include reduced leader and branch growth, thinning foliage, elevated cone production as a response to stress, and mortality. Disease openings may occur where the disease has spread through root-to-root contact, killing clumps of trees. The pathogen can be identified by its annual conk, which is thick and leathery, with a velvety, yellow-brown cap, and can be shelf-like on wood or stalked on the ground (*Figure 71*). Conks are produced in July, August or September, and are usually less than four inches in diameter. Early decay causes red-brown heartwood discoloration, while advanced pitted decay has a honeycomb appearance in cross section. Affected Sitka spruce trees have been recorded near Skagway and Dyea, but have not been found elsewhere in Southeast Alaska. It is possible that glacial history and geographic barriers have prevented its establishment farther south. Alaska Region Forest Health Protection is interested in additional sightings of this pathogen in Southeast Alaska.

Figure 71: Leathery annual mushrooms of *Inonotus tomentosus*, cause of tomentosus root disease of spruce and pines, at the historic Dyea Townsite near Skagway.

Invasive Pathogens

To the best of our knowledge, there are currently no serious exotic tree pathogens that have been introduced and established in Alaska. Alaska's isolation, climate, natural landscape barriers, low human population density and limited road system have probably lessened invasive pathogen introductions and impacts. In addition, Alaska has been able to escape many of the most devastating invasive plant pathogens in North America because hosts for those pathogens are not native here (e.g., white pines, chestnut, or elm). Nevertheless, Alaska is not safe from invasive pathogen introductions, particularly with increased trade and transportation and changing climate. 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. The vastness of the state and limited transportation may delay detection of invasive pathogens. Symptoms may not be visible 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 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.

A thorough assessment of exotic tree pathogens requires a comprehensive list of native species for context. As tree pathogens are found and identified, they are compared to known native species to determine whether they are native or suspected of being introduced. Unfortunately, mycology and pathology in Alaska is not advanced to the point where such comprehensive lists would be expected to include all or most organisms. 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, and this can make new introductions difficult or impossible to predict.

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 8*). Our approach is mainly based on host taxa; that is, to review scientific literature on the fungal pathogens that infect close relatives (e.g., same genus) of Alaskan tree species. A number of species have been identified from Europe and Asia that are potential threats to Alaska based on the type and severity of the disease that they cause in their native forests, their adaptability to Alaska's climate, their likelihood of introduction, and evidence that they have caused damage to Alaskan species that have been planted overseas. There is an ongoing effort to input this information into "ExFor" (Exotic Forest Pest Information System North America), a national database for invasive forest insects and pathogens (http://spfnic.fs.fed.us/exfor/index.cfm). A proactive strategy that evaluates potential invasive plant pathogen introductions, and likely introduction points and pathways, can be used strengthen programs aimed to prevent introductions and accelerate detection. Importation and movement of live plant material is known to be a major introduction pathway for invasive plant pathogens.

Table 8. 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 in 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 & 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, Viburnum, 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

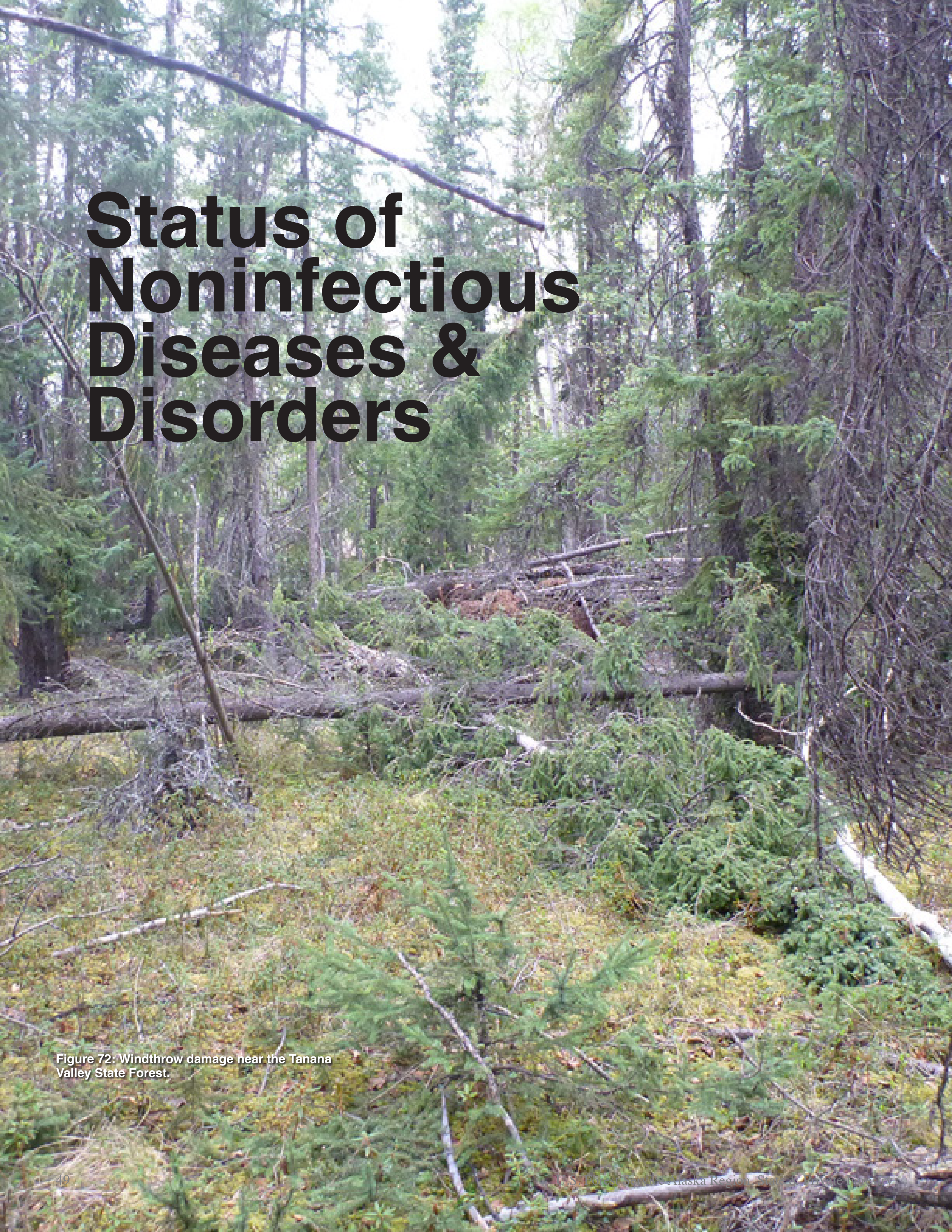


Figure 72: Windthrow damage near the Tanana Valley State Forest.

The First Finding of Yellow-Cedar Decline in a Young Growth Forest

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The widespread mortality of yellow-cedar (i.e., yellow-cedar decline) is a well-known feature in unmanaged forests that has not previously been detected in young managed forests. Silviculturist Greg Roberts of the Wrangell Ranger District in the Tongass National Forest noticed dying yellow-cedar crop trees in a young, regenerating forest on Zarembo Island in the Alexander Archipelago of Southeast Alaska. A forest health team joined him in 2013 to have a closer look to determine if the injury to trees is the same as in mature dying forests, and to discuss silvicultural implications for young-growth management.

Yellow-cedar decline is a freezing injury to the shallow roots of yellow-cedar not protected by snow during late winter cold weather. Along with inadequate snowpack, poor soil drainage is a major risk factor of yellow-cedar decline in unmanaged landscapes because fine roots are shallow on wet sites. Decline has been assumed to be absent in young growth stands that have yellow-cedar because most harvested stands are relatively productive, with well drained and deep soils that promote deeper fine roots which avoid freezing injury. Productive stands also tend to have dense canopies that buffer extremes in soil temperature.

Two young growth stands were examined on Zarembo Island in July 2013. The first stand was logged as a blowdown salvage in 1975 and precommercially thinned (PCT) in 2005. The second stand was clearcut in 1973, partially PCT in 1983, and PCT in 2005. Following thinning, some yellow-cedars growing on the wetter parts of the stands began to develop yellow-red crowns. Some trees slowly developed symptoms, while others turned red rapidly and died quickly. Many healthy yellow-cedar trees remain in the stand. During our 2013 visit to these stands, data were collected on 60 yellow-cedars that ranged from healthy (no crown symptoms) to declining to recently-dead (*Figure 73*). Information collected from trees included: GPS coordinates, live/dead status, diameter at breast height (DBH), estimated height, percent yellow-red crown discoloration (chlorosis), the presence of secondary agents such as Phloeosinus bark beetles and/or Armillaria fungus.

Of the 60 trees selected for monitoring, half were relatively healthy (≤10% crown discoloration), 7 were dead (100% crown and boles dead), and the remaining 23 trees ranged from 15-70% crown discoloration. Phloeosinus bark beetle galleries and mycelial fans of Armillaria root rot fungus were found on dead trees (n= 7 and 5, respectively) (*Figure 75*), but no beetle galleries and only one mycelial fan was found on live excavated trees. This is consistent with observations on mature dying yellow-cedars – these secondary agents attack only trees that are already stressed and nearly dead. Signs of failed bark beetle attacks were observed on healthy trees, whereas active feeding (*Figure 74*) and adult beetles were only found in recently-killed trees. Necrotic lesions moving up the bole from coarse roots, fine root mortality, low density of fine roots, and mottled discoloration of phloem tissue were observed on several excavated trees, including recently-killed trees and trees with >65% crown discoloration (*Figure 76*).

Figure 73: Healthy (left), declining (middle) and dead (right) yellow-cedar trees were flagged and mapped for long-term monitoring. A subsample of trees were excavated at the base to look for necrotic lesions at the root collar, Phloeosinus bark beetle galleries, and signs of Armillaria fungal infection.

Figure 74: Phloeosinus larvae actively feeding on a recently killed yellow-cedar.

Figure 75: Mycelial fans of Armillaria and galleries of Phloeosinus bark beetles are common signs of these secondary agents on yellow-cedar trees stressed by root-freezing injury.

Overall, the stressed and dead trees in these young growth stands exhibit classic signs and symptoms of yellow-cedar decline: necrotic lesions on the roots, root collars and lower boles of trees with pronounced crown symptoms, trees with varying amounts of crown discoloration, secondary agents on freshly killed trees, and a lack of damage to associated tree species. In addition, dead and dying trees were found on wet, unproductive microsites, but appeared vigorous on more productive portions of the stand, mirroring yellow-cedars in mature forests.

This is the first finding of yellow-cedar decline in young growth stands. At this time we do not know how widespread the problem is; it is possibly limited since most harvested sites are at least moderately productive with relatively deeper soils. However, lower productivity stands on a poorly drained site would be expected to be vulnerable to cedar decline because saturated soils result in shallow fine roots that are sensitive to freezing injury. Although it is unknown whether yellow-cedar trees were dead or dying in these stands when they were harvested in 1973 and 1975, we imagine that this was the case based on cedar snags surrounding the cut unit. It is possible that thinning exacerbated the onset of decline in these young growth stands through its impacts on canopy density. Otherwise, it is unclear why symptoms of decline would have been absent from the stands before thinning. It will be important to monitor other regenerating units that contain yellow-cedar and have wet site indicators. We may begin to see the effects of this as these second-growth stands are thinned. We will continue to monitor this stand over time to determine the rate of tree mortality and whether damage continues or worsens. Monitoring trees that are currently healthy will be particularly interesting; these trees may be asymptomatic due to better microsites or higher tolerance to freezing injury.

Figure 76: Necrotic phloem (brown surrounded by white) emerging from the coarse roots to the root collar and lower bole of symptomatic yellow-cedar trees. These symptoms provide compelling evidence that freezing injury to roots is occurring in these young-growth stands on Zarembo Island.

Completion of the regional yellow-cedar strategy document is anticipated in 2014. The last section of the document will focus on using computer modeling to partition the landscape into areas where yellow-cedar is expected to thrive, and areas where it is expected to be maladapted based on soil drainage and snowpack. Our models may corroborate yellow-cedar being maladapted to this site due to wet soils and inadequate snow. Continued monitoring of this site and others like it will help determine the extent and intensity of this problem of mortality to yellow-cedar in young growth forests. As we gain more knowledge about decline in young stands, it is possible that we can provide management recommendations about specific situations in which yellow-cedar should not be favored during thinning (e.g., wet portions of stands). At this point we lack information to make such broad statements and look forward to working with Tongass National Forest silviculturists to accumulate more information to support a recommendation.

2013 Noninfectious Diseases & Disorders Updates

Along with insects and diseases, abiotic factors and animals also influence the forest at all spatial scales. This section describes the most important abiotic and animal damage mapped, monitored, or surveyed in 2013. Hemlock fluting, though not detrimental to the health of the tree, reduces economic value of hemlock logs in Southeast Alaska. Several animals cause damage to forest trees throughout the state; porcupine-caused injury to trees can be severe locally in Interior and Southeast Alaska (*Figure 77*) and brown bears can be particularly damaging to trees at some locations in Southeast Alaska. Windthrow, drought, winter injury, and wildfires affect forest health and structure to varying degrees. Wildfire causes tree mortality in Alaskan forests, and may be especially severe after bark beetle outbreak or in times of drought or high wind. The National Interagency Fire Center reported that Alaska experienced 603 wildfires covering 1.3 million acres. These values represent a significant increase from 2011 and 2012, but are still far lower than during the heavy fire season of 2009 (3 million acres burned).

Figure 77: Localized porcupine damage to western hemlock.

Abiotic Damage

Hemlock Fluting

Hemlock fluting is characterized by deeply incised grooves and ridges that extend vertically along boles of western hemlock (*Figure 78*). Fluting can be distinguished from other defects on tree boles, such as old callusing wounds and root flaring, because fluted trees have more than one groove and fluting extends close to or into the tree crown. This condition, especially common in coastal stands in Southeast Alaska, reduces the merchantable volume of hemlock logs because bark is contained in some of the wood. The cause of fluting is not completely understood, but fluting is associated with increased wind-firmness and sites with shallow soils. Fluting may be triggered during growth release by stand management treatments or natural disturbances, and trees may be genetically predisposed to fluting. The asymmetrical radial growth typical of fluted trees appears to be caused by unequal distribution of carbohydrates, with less allocated near branches and more allocated between branches. After several centuries, fluting may not be outwardly visible in trees, because branch scars have healed over and fluting patterns have been engulfed within the stem.

Figure 78: Deep grooves characteristic of hemlock fluting.

The economic impacts of bole fluting on National Forest System timber harvest are thought to be less significant than in the past, since the most severely fluted trees are often located in beach buffer land management units that are no longer open to timber harvest. Fluting is believed to have few ecological consequences beyond adding to wind firmness; the deep folds on fluted stems of western hemlock may provide important habitat for some arthropods and the birds that feed upon them (e.g., winter wren). Planting seed from severely fluted trees on protected, productive sites with stable soils could help to discern genetic causes of fluting from environmental causes.

Windthrow

In 2013, 3,400 acres of windthrow damage were mapped during the Aerial Detection Survey compared to 6,200 acres in 2012. For follow-up details on the September 2012 windthrow event that occurred in the upper Tanana Valley, see the essay on page 16.

Wind is a common and important small-scale disturbance in Alaskan forests, contributing to bole snap or complete failure of trees (or clumps of trees) rooted on shallow, saturated soils; or with stem, butt, or root decay. Stand-level windthrow may occur on exposed sites when heavy rain is followed by extreme wind. Windthrow occurs when the force of the wind exceeds a tree's stem or anchor strength. Shallow rooting depth, soil saturation, and root disease increase vulnerability to windthrow from uprooting, while stem decays increase vulnerability to windthrow from bole breakage (*Figure 79*). Windthrow potential is predicted by stand characteristics such as tree height to diameter ratios and tree density, as well as mechanical properties such as tree height, diameter, crown size and rooting depth.

Figure 79: Windthrow damage in Anchorage from the September 2012 wind event. Trees were uprooted and boles snapped as a result of the strong winds.

Wind firmness decreases with increased tree height and crown size, and increases with deeper root depth and tree diameter. Although larger diameter trees are more wind firm, the probability of stem decay also increases with tree diameter or age and varies by species. Terrain and stand management activities influence windthrow potential, because wind accelerates as it moves over and around landscape obstacles. Depending on landscape position, thinned stands or stands adjacent to clearcut harvests may experience increased susceptibility to windthrow.

Animal Damage

Beaver Damage

***Castor canadensis* Kuhl**

Beavers considerably alter riparian forests and waterways. Trees are killed directly for food and for use in dam construction (*Figure 80*) or can be killed indirectly by rising water tables and riverbank destabilization. Flooding and high water damage were mapped on 5,400 acres in 2013, although the proportion of this damage due to beaver activity is unknown. Although there are negative impacts to individual riparian trees, stands, and understory vegetation, there are also many ecological benefits to beaver activity. Nutrients, sediment and organic materials are trapped in beaver ponds, filtering water downstream and recharging underground aquifers. Beaver activity may help to stabilize disturbed riparian systems, improving habitat for fish, waterfowl, amphibians and other organisms. Beavers are distributed throughout most of forested Alaska.

Figure 80: Beaver damage to western redcedar near Thorne Bay on Prince of Wales Island. At this site, several conifer species were directly damaged by beaver gnawing, while others were killed by the resultant flooding.

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 late 1980s found that over half of the yellow-cedar 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 girdle trees. Callus tissue slowly develops around bear scars, which can serve as entry points for stem decay fungi that reduce wood volume.

Porcupine Feeding

***Erethizon dorsatum* L.**

Feeding damage to spruce and hemlock boles by porcupines (*Figure 81*) leads to top-kill or tree mortality, reducing timber values, but enhancing stand structure. This form of tree injury can provide thinning services in forests; however, porcupines usually "thin from above," targeting the largest, fastest growing trees.

Figure 81: Porcupines damage hemlock and spruce in many locations in Southeast Alaska, but have not migrated to all islands since the last glaciation. (*Photo Credit: Knut Kielland.*)

In 2013, almost 500 acres of porcupine damage were mapped, compared to 30 acres in 2012, 216 acres in 2011 and 919 acres in 2010. This variability in acreage is likely due to reduced detection, rather than reduced incidence, because porcupine damage was commonly observed on the ground.

Porcupines are absent from several islands in Southeast Alaska, including Admiralty, Baranof, Chichagof and Prince of Wales. Feeding appears most severe on portions of Wrangell, Mitkof and Etolin Islands in central Southeast Alaska. The distribution of porcupines suggests historic points of entry and migration from the major river drainages in Interior British Columbia to mainland Alaska and nearby islands. Feeding is intense in young growth stands that are about 10-30 years of age and on trees that are 4-10 inches in diameter. As stands age, porcupine feeding typically tapers off, but top-killed trees often survive with forked tops and internal wood decay as a legacy of earlier feeding. Porcupines do not feed on western redcedar or yellow-cedar; therefore, young stands with a cedar component provide more thinning treatment options.

Forest Declines

Yellow-Cedar Decline

The term forest decline refers to situations in which a complex of interacting abiotic and biotic factors leads to widespread tree death. It can be difficult to determine and experimentally demonstrate the mechanism of decline; for this reason, the causes of many forest declines throughout the world remain unresolved. Climate has the potential to act as both a predisposing and inciting factor in forest declines. It exerts long-term influence over vegetation patterns, hydrology, and soil development, and relatively shorter-term influence over seasonal precipitation, temperature, and acute weather events. Yellow-cedar decline operates as a classic forest decline and has become a leading example of the impact of climate change on a forest ecosystem. Our current state of knowledge indicates that yellow-cedar decline, which began around 1900, is a form of seasonal freezing injury and occurs on sites on which yellow-cedar has become maladapted to current climate conditions. Yellow-cedar is the principal tree affected, and impacted forests tend to have mixtures of old dead, recently dead, dying, and living trees (*Figure 82*), indicating the progressive nature of tree death. Yellow-cedar is extraordinarily decay resistant and snags often remain standing for 80-100 years, allowing for the long-term reconstruction of cedar population dynamics in unmanaged forests.

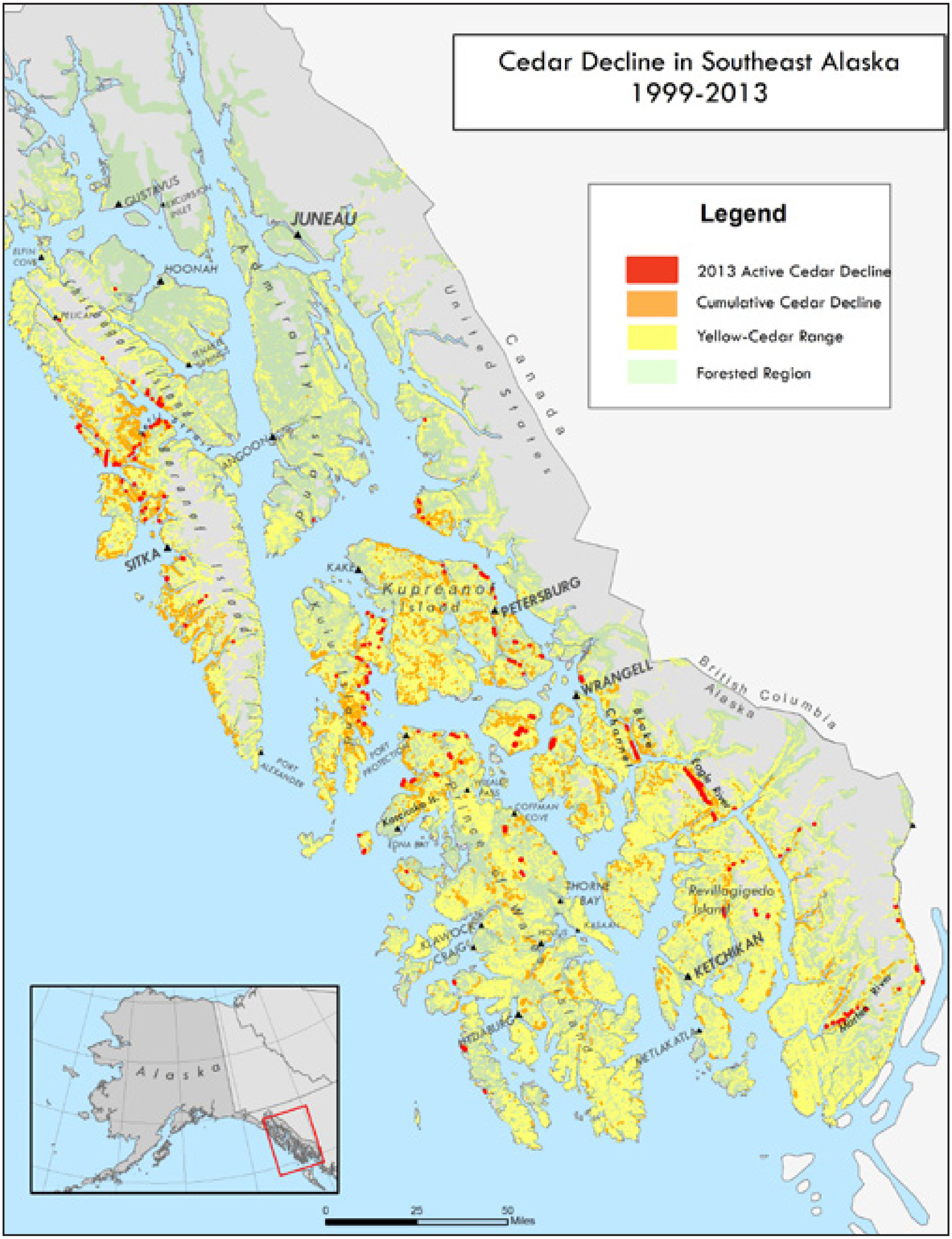
Figure 82: Dead and dying yellow-cedars near the northern extent of cedar decline on Chichagof Island (Slocum Arm, west of Peril Strait).

Distribution of Yellow-Cedar Decline

Over 400,000 acres of decline have been mapped though aerial detection survey since surveys began in the late-80s, with extensive mortality occurring in a wide band from western Chichagof and Baranof Islands to the Ketchikan area. This value may be an overestimate because populations of dead and dying cedar mapped by aircraft may include patches of otherwise unaffected forest. Efforts have been made to refine the estimated acreage, limiting mapped decline to areas where new yellow-cedar distribution models predict that yellow-cedar is present. In 2013, just over 13,000 acres of active yellow-cedar decline (dying trees with red crown symptoms) were mapped through aerial survey. This is lower than the acreages mapped in the past few years (*Table 2 on page 6*). In 2013, active mortality was most dramatic around Peril Strait (the northern extent of decline), along the eastern shore of Kuiu Island, and again in Blake Channel and the Eagle River drainage in Bradfield Canal (*Table 9*, *Map 12*).

Table 9. Cumulative acreage affected by yellow-cedar decline in Southeast Alaska by ownership.

National Forest	384,480	Native	11,101
Admiralty Monument	890	Admiralty Island	50
Admiralty Island	890	Baranof Island	265
Craig Ranger District	18,655	Chichagof Island	751
Dall and Long Islands	655	Dall and Long Islands	541
Prince of Wales Island	18,000	Kruzof Island	47
Hoonah Ranger District	185	Kuiu Island	654
Chichagof Island	185	Kupreanof Island	2,936
Juneau Ranger District	327	Mainland	242
Northern Mainland	327	Prince of Wales Island	4,593
Ketchikan Ranger District	26,062	Revillagigedo Island	1,021
Annette and Duke Islands	498	Other Federal	251
Central Mainland	35	Baranof Island	3
Gravina Island	808	Etolin Island	10
Revillagigedo Island	13,733	Kuiu Island	174
Southern Mainland	10,988	Kupreanof Island	64
Misty Fjords Monuments	23,961	State & Private	15,562
Revillagigedo Island	7,429	Baranof Island	2,285
Southern Mainland	16,532	Chichagof Island	1,026
Petersburg Ranger District	134,638	Gravina Island	687
Central Mainland	6,236	Heceta Island	14
Kuiu Island	65,366	Kosciusko Island	19
Kupreanof I	57,998	Kruzof Island	226
Mitkof Island	3,245	Kuiu Island	569
Woewodski Island	1,793	Kupreanof Island	1,018
Sitka Ranger District	103,769	Mainland	1,864
Baranof Island	46,768	Mitkof Island	897
Chichagof Island	33,604	Prince of Wales Island	2,985
Kruzof Island	23,397	Revillagigedo Island	2,811
Thorne Bay Ranger District	36,714	Wrangell Island	1,161
Heceta Island	341		
Kosciusko Island	9,518	Grand Total	411,394
Prince of Wales Island	26,854		
Wrangell Ranger District	39,279		
Central Mainland	12,708		
Etolin Island	12,942		
Southern Mainland	15		
Woronofski Island	541		
Wrangell Island	7,180		
Zarembo Island	5,893		



Map 12: Current (2013) and cumulative cedar decline mapped by Aerial Detection Survey in Southeast Alaska.

In 2013, personnel from Wrangell Ranger District and Alaska Region Forest Health Protection examined dead and dying yellow-cedars in young growth and found similar symptoms and characteristics that occur in unmanaged stands experiencing yellow-cedar decline. This appears to be the first observed instance of yellow-cedar decline developing in managed young growth forests (See essay on page 50).

At the southern extent of decline in Southeast Alaska (55-56° N), mortality occurs at relatively higher elevations, while farther north, decline is restricted to relatively lower elevations. Yellow-cedar forests along the coast of Glacier Bay and in Prince William Sound appear healthy, presumably protected by deeper and more persistent snowpack. In 2004, a collaborative aerial survey with the British Columbia Forest Service found that yellow-cedar decline extended at least 100 miles south into British Columbia. Since that time, continued aerial mapping around Prince Rupert and areas farther south have confirmed more than 120,000 acres of yellow-cedar decline in BC.

Causes of Yellow-Cedar Decline

Research at multiple spatial and temporal scales, along with extensive evaluation of the role of biotic agents (insects and disease), has helped to unravel the causes of yellow-cedar decline. This work has demonstrated that Phloeosinus beetles and the decay fungus *Armillaria* play only minor roles in yellow-cedar mortality, attacking nearly-dead trees stressed by other factors. We now know that yellow-cedar decline is associated with freezing injury to fine roots that occurs where snowpack in early spring is insufficient to protect roots from late-season cold events. Yellow-cedar trees appear to be protected from spring freezing injury where snow is present, insulating tree roots and preventing premature de-hardening of root tissue.

On the broadest spatial scale, overall elevation and latitude patterns of decline suggest climate as a trigger; with mortality concentrated in areas with mild winters and limited snowpack. On a more localized landscape scale, upper-elevation limits to yellow-cedar decline are also consistent with patterns of snow deposition and persistence. Within declining yellow-cedar stands, dead and dying trees are concentrated on and around muskeg sites (peatlands with poor drainage) that restrict rooting depth, experience extreme soil temperature fluctuations, and have open crown conditions. Decline can also be found on steep slopes, but tree rooting is shallow on these sites, which frequently have thin, wet organic soils over unfractured bedrock. On the finest spatial scale, root injury on individual dying trees indicates that root damage is an important mechanism of decline. Research on seasonal cold tolerance of yellow-cedar has demonstrated that yellow-cedar trees are cold-hardy in fall and mid-winter, but are highly susceptible to spring freezing. This research showed that yellow-cedar roots are more vulnerable to freezing injury, root more shallowly, and de-harden earlier in the spring than other conifer species in Southeast Alaska. The hypothesis that has emerged is consistent with patterns observed on all of these spatial scales: conditions on sites with exposed growing conditions and inadequate snowpack in spring are conducive to premature root tissue de-hardening, resulting in spring freezing injury to fine roots and gradual tree mortality.

Temporal patterns are also important to understanding yellow-cedar decline, and help to explain why yellow-cedar occurs on sites where it is currently maladapted. Our information on tree ages indicates that most of the trees that have died within the last century, and continue to die, regenerated during the Little Ice Age (~1400 to 1850 AD). Heavy snow accumulation is thought to have occurred during this period, giving yellow-cedar a competitive advantage on low elevation sites in Southeast Alaska. Trees on these low elevation sites are susceptible to exposure-freezing injury during a warmer climate. An abnormal rate of yellow-cedar mortality began around 1900, accelerated in the 1970s and 1980s, and continues today. These dates roughly coincide with the end of the Little Ice Age and a warm period in the Pacific Decadal Oscillation, respectively. Although there is continued activity of yellow-cedar decline, mortality has subsided somewhat in the last decade or so. On a finer temporal scale, recent analysis of 20th century weather station data from Southeast Alaska documented increased temperatures and reduced snowpack in late winter months, in combination with the persistence of freezing weather events in spring. From the time crown symptoms appear, it takes 10 to 15 years for trees to die, making it difficult to associate observations from aerial surveys to weather events in particular years.

Ecological Impacts

Yellow-cedar is an economically and culturally important tree. The primary ecological effects of yellow-cedar decline are changes in stand structure and composition. Snags are created, and succession favors other conifer species, such as western hemlock, mountain hemlock and western redcedar. In some stands, where cedar decline has been ongoing for up to a century, a large increase in understory shrub biomass is evident. Nutrient cycling may be altered, especially with large releases of calcium as yellow-cedar trees die. The creation of numerous yellow-cedar snags is probably not particularly beneficial to cavity-nesting animals because its wood resists decay, but may provide branch-nesting and perching habitat. 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 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.

Salvage Logging

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. Cooperative studies between the Wrangell Ranger District, the USDA FS Forest Products Laboratory in Wisconsin, Oregon State University, the PNW Research Station, and Forest Health Protection have investigated the mill-recovery and wood properties of yellow-cedar snags that have been dead for varying lengths of time. This work has shown that all wood properties are maintained for the first 30 years after death. At that point, bark is sloughed off, the outer rind of sapwood (~0.6” thick) is decayed, and heartwood chemistry begins to change. Decay resistance is altered somewhat due to these chemistry changes, and mill-recovery and wood grades are reduced modestly over the next 50 years. Remarkably, wood strength properties of snags are the same as that of live trees, even after 80 years. Localized wood decay at the root collar finally causes sufficient deterioration that standing snags fall about 80 to 100 years after tree death. The large acreage of dead yellow-cedar, the high value of its wood, and its long-term retention of wood properties suggest promising opportunities for salvage. An economic and operational assessment is needed to determine if and where it is feasible to conduct salvage recovery of dead yellow-cedar.

2013 Yellow-Cedar Projects

Lauren Oakes, a PhD candidate from Stanford University, has completed the field portion of a project to characterize succession in dead cedar forests. This study has primarily focused on the outer coast area of Chichagof Island, along the northern margin of the decline, but has also evaluated healthy yellow-cedar stands in Glacier Bay. Yellow-cedar snag classes are being used as indicators of time-since-decline. This project has provided a network of permanent monitoring plots that will be invaluable to our long-term understanding of succession and other processes in forests experiencing yellow-cedar decline. In conjunction with this project, Corey Radis, for her senior thesis project at Stanford, is analyzing foliage from western hemlock and understory plants in these stands to determine how foliar nutrient concentrations are altered as a response to the intense mortality of yellow-cedar.

Forest Health Protection is working with colleagues from the Forest Service Alaska Regional Office and National Forest System to develop a comprehensive conservation strategy for yellow-cedar in Southeast Alaska (expected 2014). The strategy will serve as a one-stop resource on the distribution, life history, and biology of yellow-cedar as well as the distribution and causes of yellow-cedar decline. The first step in this strategy is partitioning the landscape into areas where yellow-cedar is no longer well adapted (i.e., declining forests), areas where decline is projected to develop in a warming climate, and areas where decline is unlikely to occur. Snow and hydrology models coupled with aerial survey data are used to achieve this landscape partitioning. Key management treatments include promoting yellow-cedar through planting (*Figure 83*) and thinning in areas suitable for the long-term survival of this valuable species.

Figure 83: A recently-planted yellow-cedar seedling.

Status of Invasive Plants

Figure 84: The invasive aquatic plant Elodea in Martin Lake, as photographed by an FHP staff member standing on the pontoons of a floatplane and looking down at the plane's reflection on the water's surface.

2013 Invasive Plant Program Updates

Invasive plant program activities

In 2013, the Region 10 FHP Invasive Plant Program continued our partnerships with a variety of organizations and began to work with two new groups. The section below describes some of the year's highlights.

Workshop jump starts activity in rural western Alaska

In April, the University of Alaska Fairbanks (UAF) Cooperative Extension Service (CES) partnered with the UAF Biology and Wildlife Department and the Kuskokwim River Watershed Council (KRWC) to host a three-day invasive plant workshop in Bethel, Alaska. KRWC invited environmental and land managers to the workshop, and the mining company Donlin Gold covered participants' travel expenses. The 17 participants (*Figure 85*) learned basic plant and weed identification, inventory and management principles, and how to build awareness of invasive plants through outreach and education.

The workshop format and the fact that participants were part of established environmental programs in their communities fostered a highly motivated atmosphere. This energy was sustained after the workshop ended: when summer came, participants began actively surveying for invasive weeds in their communities and along the Yukon and Kuskokwim Rivers. CES was available throughout these activities, confirming identification of plants via email, and providing advice on control and prioritization strategies.

Figure 86: Patrick Samson, of the Kuskokwim River Watershed Council, discusses yellow toadflax with Bethel workshop participants. (Photo Credit: Katie Villano)

Figure 85: The workshop's participants came from small communities all over the Yukon-Kuskokwim Delta. Western Alaska is one of the most remote areas in North America. (Photo Credit: Katie Villano)

The summer ended but the energy and motivation of western Alaskans has continued. One workshop participant, Patrick Samson of the KRWC (*Figure 86*), attended the Alaska Invasive Species Conference in October and was elected to the statewide board of the Alaska Committee for Noxious and Invasive Plant Management. Patrick and the other workshop participants are forming a working group that will meet monthly through the winter to plan education, inventory and management activities. Discussions have included promoting the use of certified weed-free straw by dog mushers (where straw is used for dog bedding), cleaning heavy equipment, controlling weeds at points of entry and exit from communities to reduce their spread, and prioritizing species to eradicate. Because western Alaska has very few invasive plants compared to the parts of the state accessible by road, eradication is a realistic goal for a number of different species.

The group is organizing to pursue funding from grant programs and private foundations for these types of activities. CES will facilitate their process of developing a plan and acquiring funding to support their efforts.

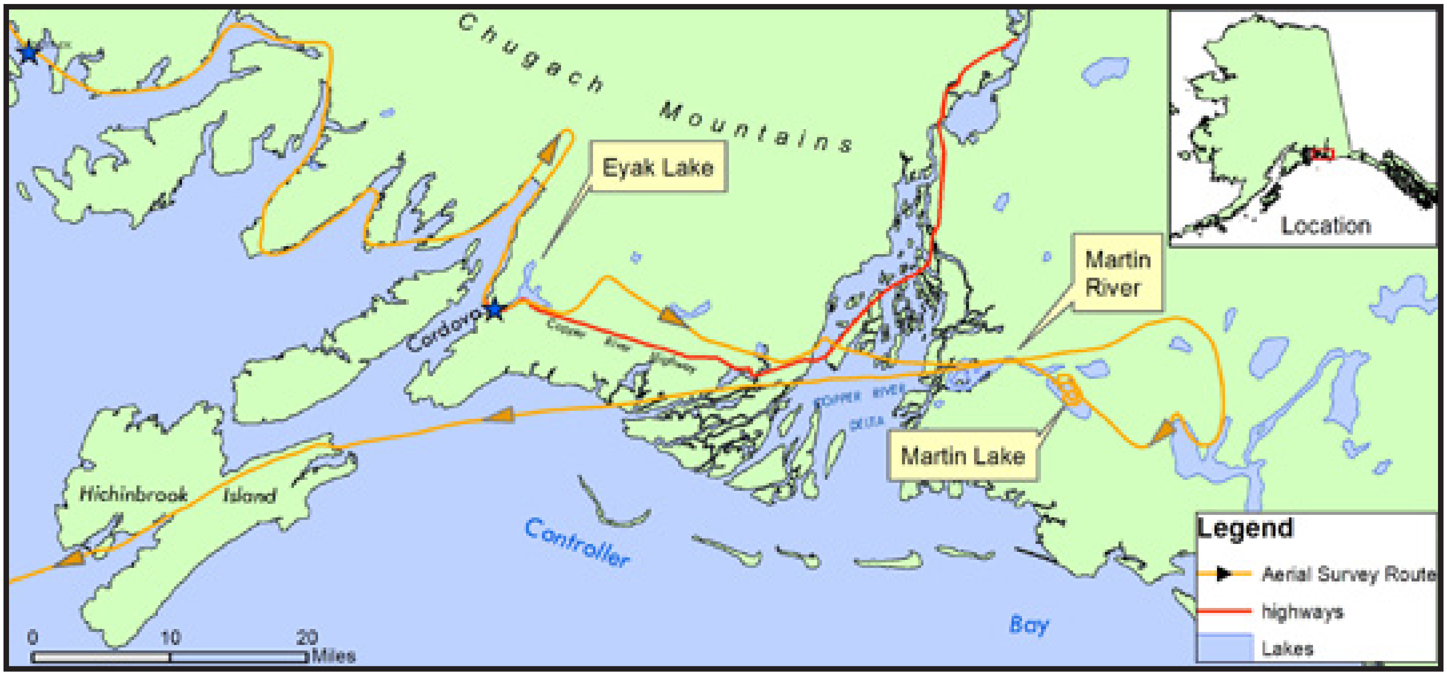
Alaska DOT&PF puts some skin in the game

The stars seem to be aligning. In early 2013, new and much improved pesticide permitting regulations were finalized by the Alaska Department of Environmental Conservation (See 2012 Conditions Report at www.fs.usda.gov/detail/r10/forest-grasslandhealth/ for a discussion of what prompted these changes). In June, the Alaska Department of Transportation and Public Facilities (ADOT&PF) released a new integrated vegetation management plan for the state that stems directly from the adoption of these new regulations (www.dot.alaska.gov/stwdmno/documents/ADOTPF_IVMP.pdf). ADOT&PF oversees 5,619 miles of highway and 720 public facilities throughout the state of Alaska. The plan will assist ADOT&PF in "its responsibility to manage the vegetation upon its lands to improve safety and control invasive plant species."

The plan is short and to the point, and it sure seems to mean business. ADOT&PF states its intention to "work cooperatively with adjacent landowners and state and federal agencies, such as the… Forest Service… BLM… and others to control the spread of noxious weeds." It goes on "Noxious weeds, such as Canada thistle (*Cirsium arvense*) ….along the Seward Highway in Anchorage for example, may be controlled by ADOT&PF maintenance personnel or other federal or state agencies in compliance with this IVMP." One of FHP's longstanding goals is getting control of rapidly spreading Canada/creeping thistle in the Anchorage bowl. The plan will be in effect through July, 2015, and people all over the state are looking forward to contributing to its implementation. Hats off to ADOT&PF!

FHP aerial survey staff snaps important photograph

In September, FHP staff finished up the 2013 aerial survey effort of the Prince William Sound area using a Cessna 206 floatplane. During one trip they took a rest stop and landed on Martin Lake, which flows into the Martin River, which flows into the Copper River. There is no road access to Martin Lake, but there is a Chugach National Forest (CNF) public use cabin just downstream from the lake. People seeking to use the cabin must travel there by boat from the town of Cordova, 42 miles to the west, or more commonly, they travel by floatplane from Eyak Lake, also in Cordova (*Map 13*).



Map 13: The Chugach National Forest public use cabin at Martin River is a short floatplane trip from Eyak Lake.

Eyak Lake has Alaska's oldest known population of the invasive aquatic plant Elodea, dating from 1982. At the time of its discovery, the Elodea in Eyak Lake was not growing aggressively and its status as an invasive species was not yet recognized in Alaska. No one paid any attention to it. But fast-forward thirty years. Between 2009 and 2012 several aggressively-spreading populations of Elodea were found in other parts of Alaska, and CNF staff began keeping an eye out for this species. In 2012, they found a population of Elodea in the Martin River near Martin Lake (*Figure 87*). This find was significant: it was the first known instance of this invasive aquatic plant in a place with no road access. How did it get there?

Figure 87: In September, portions of Martin Lake were found to be heavily infested with the invasive aquatic plant Elodea.

When FHP staff landed on Martin Lake last September, their pilot taxied to the NW shore. Near the shoreline, staff photographed dense patches of Elodea beneath the plane. Later, before taking off to continue their survey, they carefully removed the Elodea that had collected on the plane's rudder assemblies. Fifteen minutes into the flight, a staff member glanced back and saw a single strand of Elodea clinging to one of the plane's rudders. The plant fragment must have gotten caught on the rudder during take-off. He quickly snapped a photo (*Figure 88*), and in doing so he ended any debate about whether Elodea might be spread in Alaska by float plane. The plane continued on towards Hinchinbrook Island, and before getting there, the staff looked back again to find that the Elodea was gone.

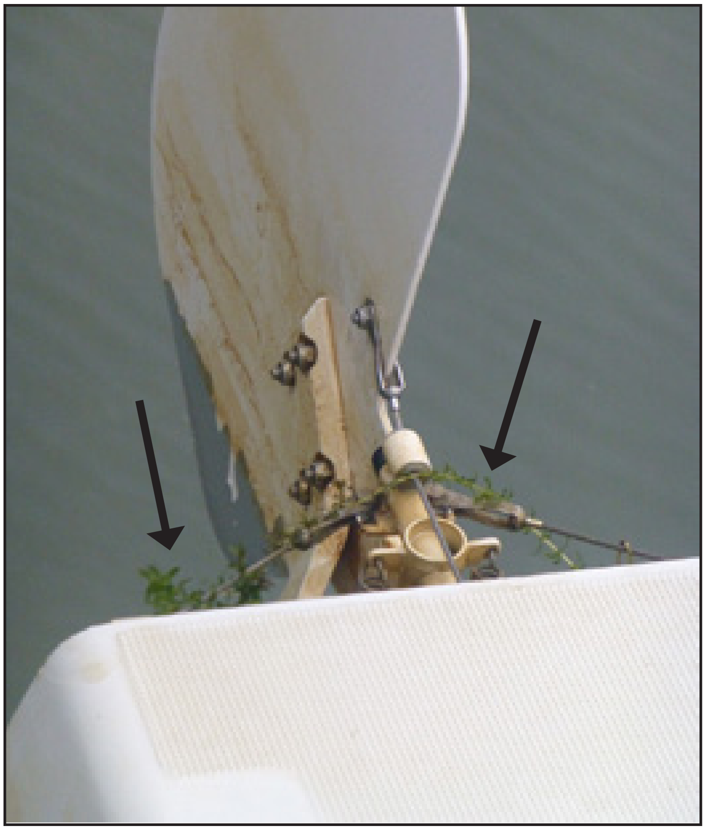


Figure 88: Elodea fragment caught on the rudder of a floatplane in flight. A single plant fragment can start a whole new infestation.

One reason that Elodea is such a successful invasive plant is that it spreads by fragmentation. A single plant fragment is all that is required to start a new population; if the fragment comes in contact with a suitable substrate it will quickly put down roots. Quick thinking by FHP staff this year conclusively documented the potential of floatplanes to act as vectors in our state. Lakes far off the road system and formerly assumed to be safe from invasion can no longer be viewed that way.

A November, 2013 article in Alaska Dispatch recounted the Elodea-caught-on-floatplane story and went on to describe the Elodea situation in Alaska as "a looming statewide catastrophe." (www.alaskadispatch.com/article/20131128/noxious-aquatic-weed-threatening-alaskas-prime-fishing-waters-science-and-local). On 03/15/2014, the State of Alaska established a quarantine for the two Elodea species, as well as three other aquatic plants.

Progress on a variety of fronts in Southeast Alaska

In 2013, staff from the Alaska Association of Conservation Districts (AACD) continued its garlic mustard (*Alliaria petiolata*) eradication program in Juneau. An early June herbicide application to about a third of the infestation area was very effective. In August, a seven-person youth crew (*Figure 89*) from Southeast Alaska Guidance Association (SAGA) worked with AACD to hand-pull all the garlic mustard plants on the remaining portions of the infestation.

Figure 89: Members of a SAGA crew hand-pulling garlic mustard seedlings in Juneau. After several years of hard work, the garlic mustard infestation in Juneau finally seems to be on the decline. (Photo Credit: Brian Maupin)

Additional property owners in or near the downtown infestation were contacted so the situation could be discussed. The site was visited twice more during the growing season and many additional newly-emerged seedlings were pulled. Overall the infestation appears to be declining.

AACD staff visited the town of Hoonah to work with local government and local organizations to coordinate efforts and promote education on invasive plant control. AACD continues its effort to form CWMAs in underserved Southeast Alaska communities. Staff members are currently writing invasive plant management plans for the communities of Haines and Sitka.

For the last 8 years, members of the Juneau Cooperative Weed Management Area (JCWMA) have worked steadily to control a nasty patch of perennial sowthistle (*Sonchus arvensis*) on Douglas Island, near Juneau. The patch is located at Outer Point, at least a mile from any road, and occupied nearly half a mile of beach fringe habitat when first discovered in 2005. That year, volunteers began pulling plants before flowering, trying to help the native vegetation compete. Because perennial sowthistle typically resprouts from broken root fragments, special efforts were made to remove the roots along with the plant tops. In 2013, a survey of this area showed that the JCWMA's hard work is paying off. The original patch has been reduced to several small patches that are clearly struggling to survive. This project demonstrates that in this wet, cool region, meticulous and persistent pulling of perennial sowthistle can dramatically reduce its population.

Fairbanks Weed Smackdown

The fourth annual Fairbanks Weed Smackdown was held on June 15th. This year the event was held at the Fairbanks Dog Park, and the targeted species was foxtail barley (*Hordeum jubatum*). The seeds of foxtail barley have a sharp and raspy awn that can cause serious health problems in dogs that inadvertently swallow or inhale them. Foxtail barley is one of the few invasive plants that can be managed solely by pulling, as most of the roots come up with the plant tops and the species does not seem able to sprout from root fragments. Eleven teams composed of 84 people pulled 1,244 pounds of weeds at the Smackdown event. As in previous years, church groups, service organizations, businesses, and Boy Scout and Girl Scout troops participated (*Figure 90*).

Figure 90: These trusty Girl Scouts have participated in every Fairbanks Weed Smackdown to date. (Photo Credit: Laurel Devaney)

Integrated Pest Management webinar series continues

Alaska is a large state with more remote locations than big cities and towns. Invasive plant managers, Alaska certified pesticide applicators and others interested in learning Integrated Pest Management techniques have problems travelling to conferences to acquire training in these topics. Difficulty travelling is particularly pertinent for certified pesticide applicators who must acquire continuing education units (CEU) to maintain their certifications.

Using Elluminate Live software, Cooperative Extension Service (CES) staff taught or arranged five webinars on different invasive plant management topics in 2013. Three webinars addressed particular species and appropriate control practices; these were worth one CEU each for Alaska certified pesticide applicators. Other topics were pesticide residues in the environment and new National Pollution Discharge and Elimination System permit requirements.

The 117 participants reported being pleased with the webinars, their content, and ability to acquire CEUs towards their Alaska Certifications. Entrance surveys were used for registration and exit surveys were required for those attendees that needed a CEU. These evaluations indicated that participants became more confident in species identification and learned a suite of control techniques. On average, participants reported increased comfort level with the subject matter as a result of attending the webinar.

Working with Anchorage-Area Youth and Public to Determine if Density of Invasive Chokecherry Trees is Associated with Moose Winter Damage to Native Trees

Gino Graziano, Invasive Plants Instructor, UAF Cooperative Extension Service

Educators around the country are encouraged to involve youth in relevant studies of science, technology, engineering, and math (STEM). Invasive species issues as they relate to interactions with natural areas and recognized resources are excellent candidates for STEM classroom projects. In Anchorage, schools are challenged with a highly urban, ethnically and economically diverse and sometimes transient population. Regimented teaching standards and the challenging population make it difficult for teachers to implement relevant STEM lessons in the classroom. Still, Anchorage youth have unique opportunities for stimulating ecology-based lessons because of easy access to natural areas near their school campuses and wildlife that roam the city's greenbelts and venture into developed urban areas.

Moose are an iconic species in Alaska that draw tourists and are popular with hunters. The urban moose is commonly found throughout Anchorage interacting with people, pets, and landscape plants. Moose eat branch tips of trees and shrubs during the winter, and sometimes severely damage preferred trees and shrubs causing gardeners and landscapers to fence almost any tree they grow. The European bird cherry tree (*Prunus padus*), also known as May day tree or chokecherry, was promoted decades ago as a fast growing, cold hardy, showy flowered, bird attracting, moose resistant tree.

Figure 91: One of the three moose calves that ADF&G reported died from cyanide poisoning after consuming ornamental chokecherry trees. (Photo courtesy: ADF&G).

Chokecherry trees discourage herbivory because they contain cynaide and occasionally cause cyanide poisoning in some animals, and on rare occasions cause death. However, during the winter of 2010 and 2011 the Alaska Department of Fish and Game (ADF&G) reported that three moose calves died of cyanide poisoning after consuming ornamental chokecherry trees (*Figure 91*). ADF&G suspects the deaths could be due to an unusual freeze/ thaw cycle temporarily increasing the toxicity of the trees, but do not know how often these deaths or spikes in toxicity might occur.

Chokecherry trees have spread in forests around Anchorage and Fairbanks, with plants found in many other parts of the state. In urban Alaska forests, chokecherry trees form dense colonies which reduce diversity of vegetation growing on the forest floor and mid-story. The Cooperative Extension Service (CES) developed an ecological study and class lesson in which students survey areas with high and low abundance of chokecherry trees and record the amount of moose browse on native trees and shrubs.

Moose winter browse (woody vegetation that moose eat) is commonly used by ecologists to associate moose browse intensity with bites taken from branch tips, the size of the bites and the architecture of the tree due to consumption by moose. The ADF&G monitors moose winter browse in Alaska to determine if moose are over-browsing an area, indicating a need to lower the moose population through hunting and avoid a population crash. Other ecologists use similar evaluations to assess a variety of ecosystem functions as they relate to moose. CES used these methodologies in an ecological field study, incorporating the abundance of chokecherry trees (*Figure 92*) in the plot to address the research questions.

Figure 92: Chokecherry trees are often encountered by moose in the forested areas of Anchorage.

During the winter of 2013, CES hosted a teacher workshop in Anchorage introducing the project and how to teach it in a classroom. From late February through mid-April teachers worked with CES to implement the lesson in their classroom. These months were chosen to maximize the time moose have to spend browsing, but avoid spring green-up when diets start to change. Students and participants evaluated browse intensity on trees with two measures: the bite ratio (number of moose bites per twigs available to bite) and the structural damage a moose has caused to a tree, referred to as "brooming" (when moose browsing has formed a tree to look like an upside down broom, *Figure 93*).

Figure 93: Broomed trees have an obvious shape noted here by middle school students selecting a tree to evaluate.

Using these measures, participants can ascertain differences in damage and consumption of trees in areas of low and high abundance of chokecherry in the forest. From these data we discuss if moose browse resulting from high abundance of the non-native chokecherry disproportionally damages native trees and shrubs.

Students initially focus on developing an understanding of the research problem, learning winter tree identification and how data is collected in the field. When ready, students go to the plot and work in groups to collect data on assigned tree species, completing no more than three of each species present in the plot. (The often cold temperatures and deep snow also teach valuable lessons about snowshoes and proper winter attire!) As students collect data, CES faculty and teachers check their data for accuracy before they leave the tree they are evaluating. Sometimes one class can finish a plot in a class period, and sometimes multiple classes work to finish a plot. CES determined chokecherry abundance in each 15-meter radius plot by counting all trees of each species present and calculating the ratio of chokecherry to all other trees.

After data collection, students enter their data into a Google form. We set up the forms to instantly pool data collected throughout the study area allowing multiple schools and classes to share data. Google spreadsheets were set up to sort the data into tables and figures that address the research question, and the spreadsheet automatically updates tables and figures anytime new data is added. The project, from introduction of the subject to summarizing the data, takes four to five class periods to finish.

In 2013, 487 youth and adults participated from Begich and Hanshew Middle Schools, East High School, University of Alaska Anchorage Conservation Biology course, the Alaska Native Plant Society, and the Eagle River Nature Center. These participants completed 21 plots and evaluated browse intensity of 234 trees. Nine of the plots had chokecherry trees in high abundance (25% or more of the trees are chokecherry), while 12 plots had low chokecherry abundance (less than 25% chokecherry).

From these data we found that Anchorage area moose browse most trees, with an apparent preference for willow and the non-native mountain ash (*Sorbus aucuparia*). While moose do browse chokecherry trees; it appears to not be a sought-after tree species.

To determine differences in browse intensity based on chokecherry abundance; cottonwood, mountain ash, birch and willow were analyzed as one "desirable species" because not all plots contained three of each desirable tree species. Aspen were excluded because they were present in only a few of the plots sampled. In plots that had high chokecherry abundance, the desirable tree species (birch, cottonwood, mountain ash, and willow) had an average of 34% of their available browse bitten compared with areas of low chokecherry abundance, which average 23% bitten (*Figure 94*). Meanwhile individual chokecherry trees were consumed at a higher rate when at lower abundance with 15% bitten in high-abundance plots versus 26% bitten in low-abundance plots. When looking at the tree architecture caused by moose browsing, the four desirable trees were broomed 50% of the time when found in plots with high chokecherry abundance while only 27% of the time in plots with low chokecherry abundance. Chokecherry trees were broomed about 4% of the time in high abundance plots and 13% in the low.

Moose appear to damage willow, cottonwood, birch and mountain ash when the abundance of chokecherry trees is high. Broomed trees which are representative of significant damage by moose occur nearly twice as often in high chokecherry abundance plots than in low chokecherry abundance plots (*Figure 95*). Chokecherry trees, while browsed more intensely in low chokecherry abundance plots, still do not experience the browse intensity that the desirable trees experience. The damage may be more problematic for shorter stature tree species like willow than the already ubiquitous and mature cottonwood and birch trees that are able to reproduce unhindered by moose. We have not considered if the increase in damage to trees is due to fewer native trees present or an increase in chokecherry, or which comes first, the absence of native trees or the presence of chokecherry. We intend to collect another year of data this winter, and expand to other areas of Anchorage and the state. Increasing the sample size may allow us to determine impacts to individual tree species which we suspect are higher with willow trees.

Investigating ecological interactions of moose and invasive chokecherry trees is very rewarding for CES, the Forest Service, the Anchorage School District and participants. Objectives to prepare youth for entry into STEM careers are met while maintaining a real world science experience. Because data are checked for accuracy, participants are directly participating in the understanding of invasive species ecology and development of appropriate management objectives. Knowing they are contributing to science is a rewarding experience for all participants.

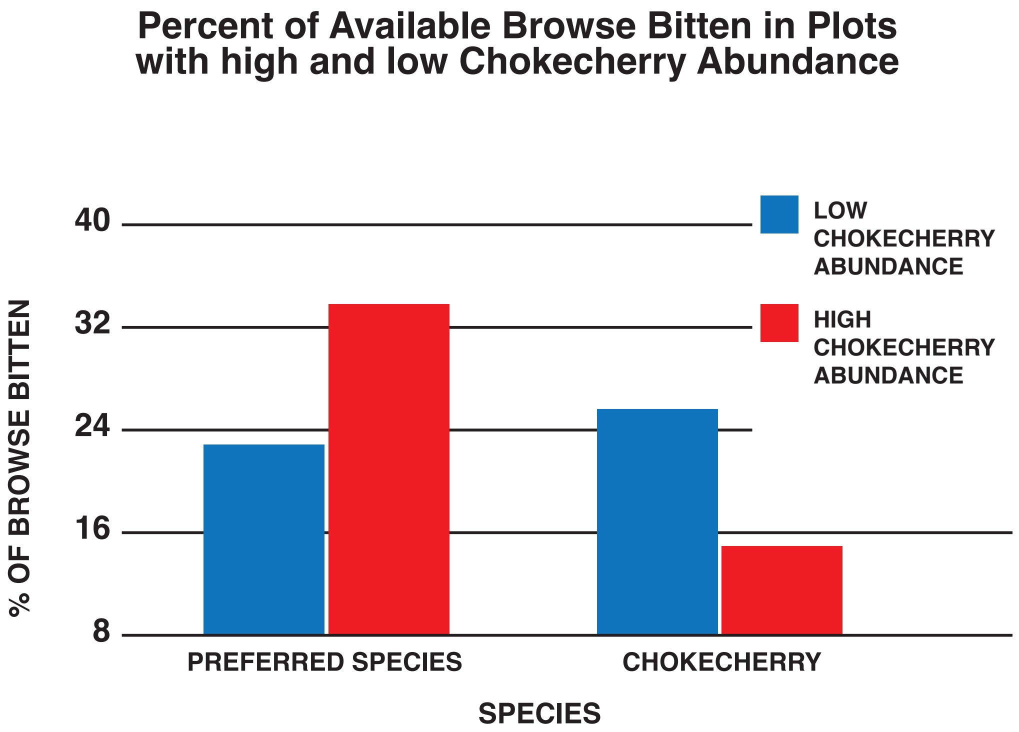


Figure 94: Moose browsed a larger percentage of a preferred browse species in plots with high abundance of chokecherry trees than plots with low abundance of chokecherry trees. The opposite is true for chokecherry.

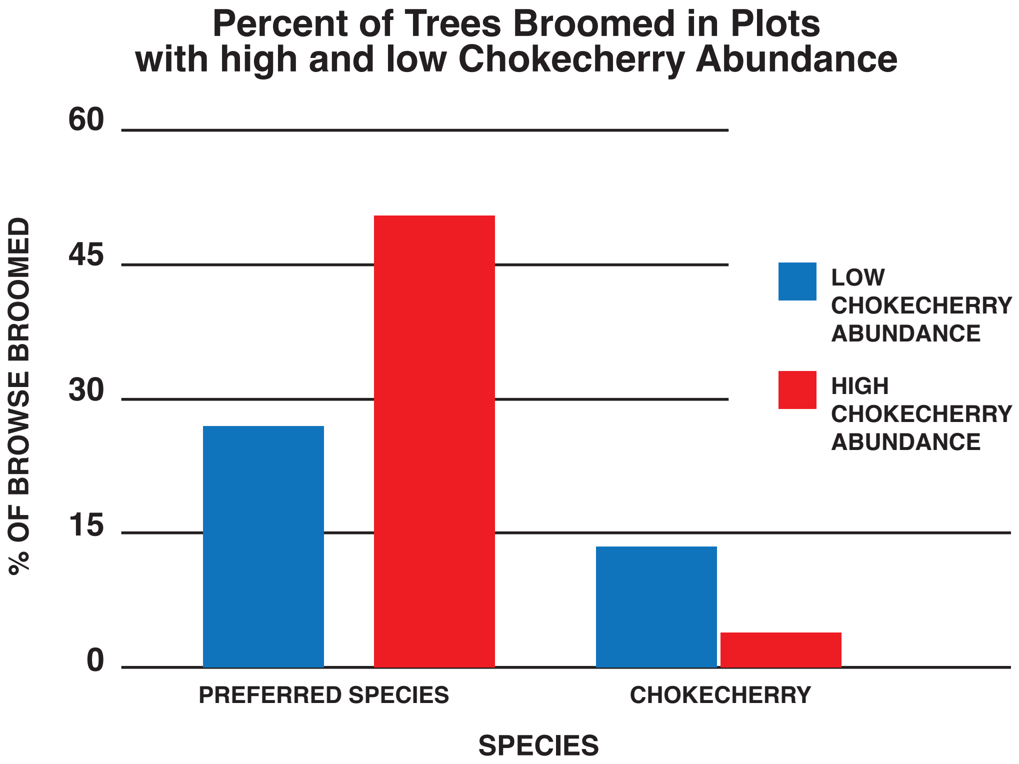


Figure 95: Broomed trees represent significant damage to the trees structure. Moose broomed preferred tree species more often in plots with high abundance of chokecherry trees.

Ubiquitous moss and lichen mats promote forest health

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The Forest Health Protection program in Alaska shares a common goal with the USDA Forest Service's Forest Inventory and Analysis (FIA) program in that both seek to detect changes in forest attributes and processes. The FIA approach uses standardized sampling methods to provide a nationwide inventory of forest health and trends through time. Although previous FIA monitoring within Alaska had largely been limited to the state's coastal forests, newly proposed sampling efforts will more accurately represent the forests of Interior Alaska. Interior forest lands (*Figure 96*) are commonly carpeted with highly productive moss and lichen mats (collectively referred to as the "ground layer") which previous measurements had neglected. As FIA monitoring efforts expand to include the landscapes of Interior Alaska, we are now developing a new protocol to include recognition of the functional importance of moss and lichen ground layers and to provide long-term tracking for the resource.

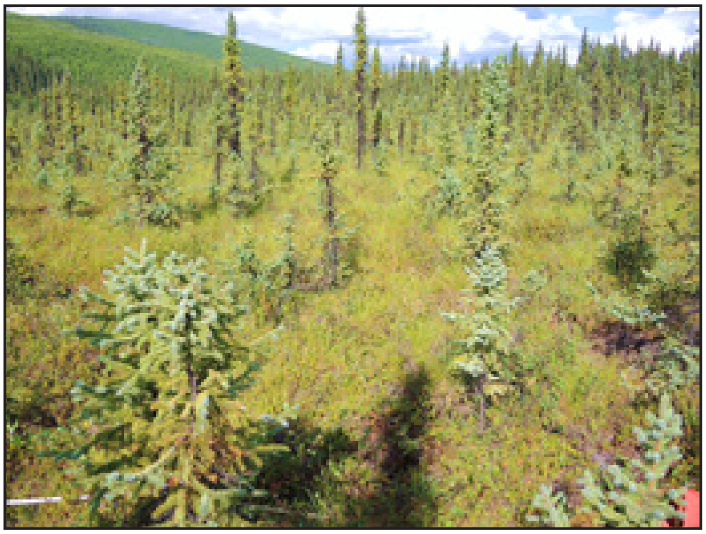

Figure 96: Black spruce peatland deeply carpeted with mosses and peat in Interior Alaska. Peatlands represent vast stores of global carbon, yet they are increasingly vulnerable to climate fluctuations and land use changes.

Moss and lichen ground layers are critical for providing caribou forage, storing carbon, fixing nitrogen, regulating local water tables, moderating wildfire severity, and decreasing rates of permafrost melt and decomposition (Turetsky et al. 2012). As mosses and lichens grow and die, they add organic material to the soil to a depth of many meters (*Figure 97*), eventually forming thick peat horizons that are substantial carbon sinks.

Yet, despite the fact that peatlands sequester one-third of the global soil carbon budget (Yu et al. 2011) and that carbon release from peatlands is highly sensitive to changes in climate and fire regimes (Turetsky et al. 2011), we previously lacked reliable tools for quantifying terrestrial carbon in ground layers at landscape scales. There was also no consistent method for assessing the functional importance provided by key groups of mosses and lichens. To address such gaps, we developed a protocol for evaluating biomass, carbon, nitrogen and functional groups in moss and lichen ground layers called the Ground Layer Indicator.

The Ground Layer Indicator is an FIA protocol for rapidly measuring the functional importance of ground layers in forests and peatlands of Interior Alaska (and elsewhere). The method is based on the premise that simple measurements of the depth and area covered by mosses and lichen can be scaled into landscape-level estimates of biomass and elemental content based on prior calibrations. The critical component for carbon estimates is measuring peat depth beneath living mosses and lichens, especially in high-latitude areas where peat may be locked within frozen permafrost. Functional importance is assigned to several easily recognizable morphological groups, examples of which include soil stabilizers, nitrogen fixers, water regulators and wildlife forage.

Figure 97: A typical surface deposit of Sphagnum peat-moss, a desirable keystone species responsible for regulating water levels, soil temperature and rates of decomposition. The sampling frame (lower center) is 20 × 20 cm.

Uncertainty regarding future climate makes it difficult to project trends for Alaskan landscapes. We know that changing climates have the potential to shift species ranges, resulting in the gain or loss of major functional groups. For example, a warming and drying climate can promote shrub expansion into boreal tundra that excludes forage lichens (*Figure 98*); while in wetlands, lowered water tables coupled with more severe wildfires can eliminate critical peat deposits as well as the live Sphagnum peat-mosses which form them (Turetsky et al. 2011).

Figure 98: Several lichens (*Cladonia* spp.) are critical winter forage for ungulates in the tundra and forests of Interior Alaska. Small mosses and lichens in the ground layer are responsible for accruing large ecosystem effects.

Climatic change also affects carbon exchange between ground layers and the atmosphere, as decomposing thawed peat releases greenhouse gases in a feedback loop that may amplify further carbon losses (McGuire et al. 2009). Alternatively, longer and warmer growing seasons might promote the growth of peat-forming mosses thereby promoting soil cooling and permafrost retention, as well as slowing decomposition rates (Chapin et al. 2010). The wide range of uncertainty among possible outcomes highlights the necessity of monitoring ground layers as vital contributors to ecosystem functioning and global carbon budgets.

National, state and local resource managers stand to benefit from FIA implementation of the method because its data can provide the basis for understanding how landscapes might be modified via land use changes. For example, wildfire prescription/suppression, invasive species control, and groundwater withdrawal each represent potential impacts to ground layers. Status and trend information will also serve as a useful reference point for guiding policy decisions that impact private land owners. Implementation of the protocol by FIA and others will provide a baseline from which we might detect future deviations due to climate, wildfires or other causes.

The ground layer sampling protocol arose from a most pressing need in Interior Alaska because of the development of a thick ground layer, but it is not constrained to any geographical region. Its simplicity means that the method has the flexibility to be implemented anywhere – not only in high-latitude terrestrial systems, but also in forest, steppe, grassland and wetland habitats throughout all regions. Recent trials (2012-2013) of the method, conducted in cooperation with Forest Health Protection associates in Fairbanks, have generated preliminary estimates of biomass, carbon and nitrogen within ground layers of the Tanana and Chatanika River drainages (Benavides et al. 2013). Similar findings are also emerging from the coastal, montane and dry forests of Oregon and Washington.

Ongoing field work will use deep coring methods to investigate carbon storage in peat layers locked in permafrost, which often comprise the bulk of carbon storage in boreal areas (Yu et al. 2011). We are also refining remote sensing techniques that will relate plot-level data to landscape scales. As the FIA program is implemented in Interior Alaska, we hope that Alaskan stakeholders, e.g. heritage programs, state agencies, and native corporations, will help identify future needs, and we look forward to continuing constructive relationships with the Region 10 Forest Health Protection Program.

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Collaborating with Private Property Owners to Limit the Spread of Bird Vetch in the Fairbanks Area

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The bird vetch problem in Interior Alaska is getting worse.

It has been 70-some years since bird vetch (*Vicia cracca*, *Figure 99*) was first introduced to the interior by University of Alaska Fairbanks (UAF) researchers for testing as a forage crop. In that time, the plant now recognized as a problematic invasive species has spread from UAF Experiment Farm to roadsides, utility easements, and private property in many parts of the Fairbanks area. The infestation is most pronounced near the university, and radiates out from there like the points of a star.

Figure 99: Bird vetch (*Vicia cracca*) grows among fireweed (*Chamerion angustifolium*) plants on a Fairbanks roadside.

The plant's common name comes from the shape of the flower; birds neither eat the seeds nor spread the plant. There are two ways in which bird vetch does spread: underground rhizomes and seeds. New patches of bird vetch often pop up on roadsides and in utility easements a long distance from the nearest known seed source, suggesting that seeds are being spread unintentionally by road and utility easement maintenance or during snowplowing. These new patches then expand in size, begin producing seed, and start to function as infestation centers themselves.

In addition to spreading outward along disturbance corridors, bird vetch has begun to spread off the corridors and into undisturbed forest, particularly on south-facing slopes. Around the university, some south-facing slopes are heavily infested, with bird vetch covering the forest floor and climbing up shrubs and trees as high as six feet (*Figure 100, Figure 101*). Such dense infestations are likely to seriously impact the native understory vegetation as well as drive property values down, leading some in the community to ask "Is this what our highest-value residential property is going to look like in the future?"

Figure 100: Bird vetch has invaded some south-facing slopes near the University of Alaska Fairbanks.

Figure 101: In some places in the Fairbanks area, bird vetch forms a continuous ground cover.

Attempts by members of the Fairbanks Cooperative Weed Management Area (FCWMA) to engage the University's facilities services, the borough government, or Golden Valley Electrical Association in this issue have been largely unsuccessful. In contrast, in recent years the Alaska Department of Transportation and Public Facilities (ADOT&PF) has stepped up its roadside mowing in the area around UAF. Mowing alone will not kill bird vetch, but if it is done before the seeds mature, it can dramatically slow the spread of this plant. (See "2013 Invasive Plant Updates" section for more on ADOT&PF.)

Failing to get much traction with the relevant agencies, the FCWMA decided to shift its focus to private property owners. It is known that many private citizens in Fairbanks are concerned about bird vetch because every summer the Forest Service and Cooperative Extension Service offices receive numerous phone calls and emails about it. Some people sound downright desperate: "How do I control this stuff?!" Last year, FHP worked with the Cooperative Extension Service to develop a simple two–page guide to bird vetch identification and control: www.uaf.edu/files/ces/publications-db/catalog/anr/PMC-00341.pdf. This year, a program was initiated to support and encourage residents to rally their neighbors around the bird vetch cause: Vetch Busters.

The idea behind the Vetch Busters program is simple: neighbors working together to keep bird vetch from encroaching on their neighborhoods via roadsides and utility easements. Learning to correctly identify bird vetch, understanding how quickly it spreads, and knowing what options exist to control it can empower people to keep it out of their neighborhoods. Volunteers can keep an eye out for new patches of bird vetch as they walk their dogs, ride their bikes, or drive home from work. Newly established patches of bird vetch can be easily controlled if they are addressed promptly, via pulling, tarping or spraying.

After property owners in two neighborhoods expressed enthusiasm, Vetch Buster groups were established in Musk Ox and Vista Gold subdivisions. Residents organized neighborhood meetings, at which FCWMA members described the bird vetch problem and taught residents how to identify the plant and distinguish it from desirable native plants. Spirited conversations about control options and engaging more volunteers followed. Some residents were already pulling or spraying the bird vetch on their own properties; these meetings gave us the opportunity to answer questions on their strategies. Most residents wanted to participate in the program individually, when it was convenient for them, rather than coming together for scheduled events. An understanding of the extent of the existing infestation and the layout of the road and utility network helps people to think strategically about invasive plant control, therefore the FCWMA agreed to map the distribution of bird vetch on road rights-of-way in both subdivisions. But because utility easements cross private property, it was not possible to include those corridors in our maps.

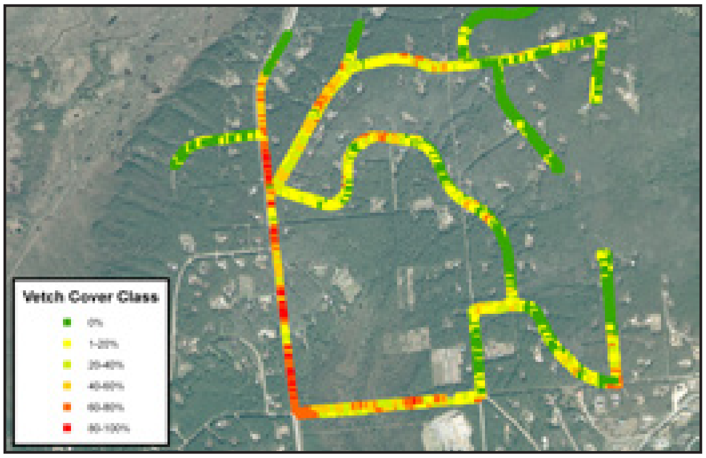

Figure 102: The distribution of bird vetch on roadsides in Musk Ox Subdivision, September, 2013.

At the end of the first year of the Vetch Busters program, results are mixed. Because residents worked individually, it is difficult to determine how much effort they expended. Small piles of hand-pulled bird vetch were observed along subdivision roads on several occasions. The results of the mapping effort were also mixed. It was found that most of the roadsides of Musk Ox Subdivision were already heavily infested with bird vetch (*Figure 102*). Barring a very significant and expensive effort, it appears to be too late to protect any but small portions of that subdivision from continued bird vetch encroachment. One of the leaders of the Musk Ox Vetch Busters group communicated that she had been pulling vetch on the road where she lives for the past ten years; the mapping effort found that particular road to be conspicuously free of bird vetch, suggesting that pulling alone can keep bird vetch in check when it is done consistently. Vista Gold Subdivision, being located farther away from the UAF campus, has far less bird vetch already distributed along its main access road, as well as a simpler road network (*Figure 103*). Property owners in Vista Gold Subdivision have an excellent opportunity to prevent the further spread of bird vetch into their subdivision, and to eradicate it from some areas entirely. Addressing this problem as a group, in a coordinated and systematic fashion, would improve the likelihood of success.

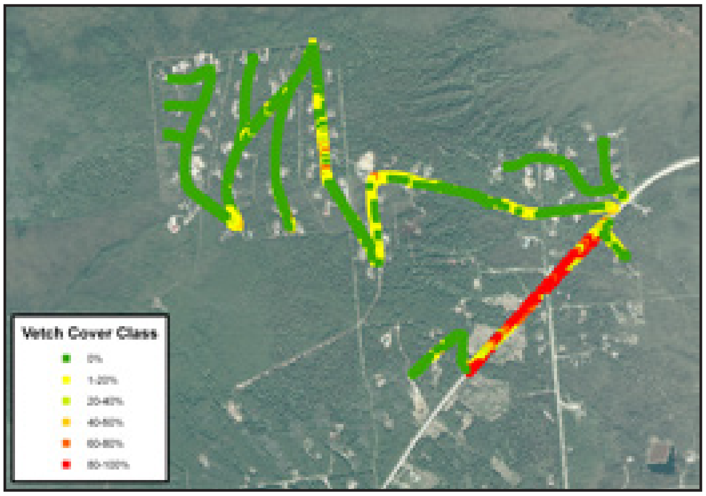

Figure 103: The distribution of bird vetch on roadsides in Vista Gold Subdivision, September, 2013.

The Vetch Busters program undoubtedly raised the profile of this issue with a small number of Fairbanksans. Our job in the future will be to communicate this issue with residents of subdivisions beyond the current infestation zone, because it's clear that the Vetch Busters model is best suited to places bird vetch is just beginning to invade. The challenge will be to get these property owners to understand what is headed their way.

Every year this report highlights selected invasive plants from a different region of the state. This year we're focusing on southeast Alaska (*Table 10*).

Table 10. Select invasive plants of Interior Alaska. Species in this table are pictured on the next page.

Species	Growth Form	Annual/ Perennial	Primary mode of spread	Primary Mode of Introduction	Distribution in Southeast AK	AKEPIC ranking[1]
Bohemian knotweed *Fallopia x bohemicum*[2]	Tall herb	Perennial	Vegetative rhizomes	Planted as an ornamental hedge. Now spreads along ditches and beaches as soil is moved.	Primarily found along roadways and along beaches where native plants such as salmon and thimble berries are traditionally found.	87
Bull thistle *Cirsium vulgare*	Tall, very prickly herb	Biennial	Seed	Likely introduced in southeast on soil attached to heavy equipment.	Found along roads and in waste places in several communities in southeast Alaska	61
Garlic mustard *Alliaria petiolata*	Tall herb	Biennial	Seed	Possibly planted as a garden herb	Limited to 3 patches in Juneau, AK where it goes under dense native shrubs and herbs that it will displace if left uncontrolled	70
Ornamental jewelweed *Impatiens glandulifera*	Tall herb	Annual	Seed	Planted as an ornamental for its showy flower	Found escaping gardens and has the most noticeable impact where it colonizes the beach fringe in Juneau and Haines.	82
Orange hawkweed *Hieracium aurantiacum*	Short-statured herb	Perennial	Seed & vegetative rhizomes	Introduced as an ornamental flower and previously found in flower seed mixes	Widespread along roadways and found in open meadows and muskegs near roads in southeast Alaska	79
Perennial sowthistle *Sonchus arvensis*	Tall herb	Perennial	Seed (wind dispersed) & rhizomes	Likely originally introduced in contaminated hay or other agricultural products	Found on roadsides and along the beach fringe competing with native forbs	73
Reed canarygrass *Phalaris arundinacea*	Tall grass	Perennial	Seed and rhizomes	Introduced as a roadside stabilizer in road building projects and as forage	Found along the majority of roadways in southeast Alaska and is often found invading wetlands and riparian areas	83
Spotted knapweed *Centaurea stoebe*	Short-statured herb	Biennial	Seed	Likely introduced on soil attached to vehicles and heavy equipment and machinery.	Dispersed through southeast Alaska but in limited patches found near roads.	86
Sweetclover *Melilotus alba*	Tall herb	Biennial	Seed	Continues to be sown as a soil-enhancing crop, roadside stabilizer, in mine revegetation efforts and as a nectar source for honeybees	Found along the Stikine river and along roads in a few southeast Alaska communities	81

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, see the AKEPIC website at aknhp.uaa.alaska.edu/botany/akepic/.
2. *Fallopia x bohemicum* is a hybrid between *F. japonica* and *F. sachalinensis* both of which are also found in southeast Alaska.

Figure 104: Left to right, top to bottom: Bohemian knotweed (*Fallopia bohemicum*), Bull thistle (*Cirsium vulgare*), Garlic mustard (*Alliaria petiolata*), Ornamental jewelweed (*Impatiens glandulifera*), Orange hawkweed (*Hieracium aurantiacum*), Perennial sowthistle (*Sonchus arvensis*), Reed canarygrass (*Phalaris arundinacea*), Spotted knapweed (*Centaurea stoebe*), Sweetclover (*Melilotus alba*).

Appendices

Figure 105: Taking a break during aerial survey on an unnamed lake north of the Arctic Circle, not far from Fort Yukon.

Appendix I

Aerial Detection Survey

Aerial surveys are an effective and economical means of monitoring and mapping insect, disease and other forest disturbance at a coarse scale. In Alaska, Forest Health Protection (FHP) and the Alaska DNR Division of Forestry monitor 30 to 40 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 that should be recognized, 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 forest change events from an aircraft and document the events on a map. When an observer identifies an area of forest damage, a polygon or point is delineated onto a paper map or a computer touch screen. Together with ground surveys, trained observers have learned to recognize and associate damage patterns, discoloration, tree species and other subtle 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 ft 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, or prevent some areas from being surveyed altogether due to safety concerns.

During aerial surveys in Alaska, forest damage information has traditionally been sketched on 1:250,000 scale USGS quadrangle maps. At this scale, one inch represents approximately four miles of distance on the ground. Finer scale maps are sometimes used for specific areas to provide more detailed assessments. A digital sketch-mapping system was first used in Alaska in 1999 and is now used in place of paper maps for recording forest damage. This system displays the plane’s location via GPS input and allows the observer to zoom to various display scales. The many advantages of using the digital sketch-map system over paper sketch-mapping include 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, and represents 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 presents cartographical challenges. Damaged areas are often depicted with thick borders so that they are visible, but this has the effect of exaggerating their size. The maps depict 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 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. 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) are ephemeral and do not coincide with the timing of the survey.

Each year we survey approximately 25 percent of Alaska’s 127 million forested acres, which equates to our surveying approximately 5 percent of the forested land in the United States. Unlike some regions in the United States, we do not survey 100 percent of Alaska’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 given available resources. The surveys we conduct 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. We encourage interested parties to request aerial surveys (see request form on page iv), and our surveyors use this 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.

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 necessarily 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. For a complete listing of quadrangle areas flown and agents mapped during 2012 statewide aerial detection surveys please visit our website at http://www.fs.usda.gov/goto/r10/fhp/conditions. Digital data and metadata can be found at http://agdc.usgs.gov/data/projects/fhm/.

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.

Appendix II

Damage type by host species grouping referred to in Table 2 (page 6).

Alder Defoliation

Alder defoliation

Alder leaf roller

Alder sawfly

Alder Dieback

Alder canker (dieback)

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

Spear-marked black moth

Cottonwood Defoliation

Cottonwood defoliation

Cottonwood leaf beetle

Cottonwood leaf miner

Cottonwood leaf roller

Hemlock Defoliation

Hemlock looper

Hemlock sawfly

Hemlock Mortality

Hemlock canker

Hemlock mortality

Larch Defoliation

Larch budmoth

Larch sawfly

Larch Mortality

Larch beetle

Lodgepole Pine Damage

Western gall rust

Dothistroma leaf blight

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 beetle/engraver combination

Spruce/Hemlock Defoliation

Black-headed budworm

Subalpine Fir Mortality

Subalpine fir beetle

Willow Defoliation

Willow defoliation (WID)

Willow leaf blotch miner

Willow rust

Appendix III

Publications

Aguayo J., G.C. Adams, F. Halkett, M. Catal, C. Husson, Z.Á. Nagy, E.M. Hansen, B. Marçais, and P. Frey. Strong genetic differentiation between North American and European populations of *Phytophthora alni* subsp. *uniformis*. Phytopathology. 2013; 103:190-199.

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Withrow J.R., J.E. Lundquist, and J.F. Negron. Spatial dispersal of Douglas-fir beetle populations in Colorado and Wyoming. ISRN Forestry, Article ID 543280: 2013. 10p. published on line at http://dx.doi.org/10.1155/542380.

Presentations

Barrett T.M., P.E. Hennon, G. Latta, [and others]. Simultaneous climate envelope modeling for western hemlock and hemlock dwarf mistletoe. Oral presentation at: 60th Annual Western International Forest Disease Work Conference; October 2012; Tahoe City, CA.

Graham E.E. Developing an improved trapping tool to survey cerambycids: evaluation of trap type, trap height, habitat, and lure composition. Oral Presentation at: Alaska Entomological Society Meeting; January 2013; Fairbanks, AK.

Graham E.E and J.J. Kruse. 2012 Season Highlights in Alaska. Oral Presentation at: Western Forest Insect Working Group Conference; March 2013; Coeur d'Alene, ID.

Graham E.E. Green Alder Sawfly Found in Southeast Alaska. Radio interview by: KCAW Radio. Sitka, AK; July 2013; Sitka, AK.

Graham E.E and T.M. Poland. The Emerald Ash Borer: Lessons Learned From Managing an Exotic Forest Insect. Society of American Foresters Cooks Inlet Branch Meeting. April 24-27, 2013.

Graham E.E. Southeast Alaska Forest Pests. Oral presentation at: Wrangell Ranger District; August, 2013; Wrangell, AK.

Graham E.E. Diseases of Alaskan Forests. Insect and Disease Training at: Ketchikan Mistry-Fiords Ranger District; July 2013; Ketchikan, AK.

Graham E.E. Forest Pests in Southeast Alaska. Oral presentation at: Wrangell Campfire Sessions; August 2013; Wrangell, AK.

Graham E.E. Forest Pest of the Tongass Updates. Oral presentation at: Annual Tongass National Forest Silviculture Meeting; September 2013; Hoonah, AK.

Graham E.E. Insects in the Forest. Oral presentation at: Southeast Alaska Discovery Center; December 2013; Ketchikan, AK.

Hennon P.E. Changing forests of coastal Alaska: how climate influences the coastal rain forest ecosystems of Alaska. Oral presentation for: University of Alaska Fairbanks Cooperative

Extension and University of Alaska Southeast; December 2012; Juneau, AK.

Hennon P.E. An optimistic view of climate effects on the forests of coastal Alaska. Oral presentation for: City of Wrangell, Chautauqua lecture series and a similar oral presentation to the USFS Ranger District; January 2013; Wrangell, AK.

Hennon P.E. Forests living on the edge…of a climate threshold. Oral presentation for: University of Alaska Southeast, Environmental science seminar series; March 2013; Juneau, AK.

Hennon P.E. Considerations for managing forests at tree species' range limits in an altered climate. Oral presentation at: SAF chapter meeting; April 2013; Juneau, AK.

Hennon P.E. and R.L. Mulvey. Managing heart rots for wildlife habitat in coastal Alaska. Oral presentation for: University of Alaska Southeast, Forest Ecology Lecture; October 2013; Juneau, AK.

Hennon P.E. and R.L. Mulvey. Ecology and management of forest fungi. Oral presentation at: Alaska Coastal Rainforest Center, Brown bag presentation series; November 2013. Juneau, AK.

Heutte T.M. Mobile weed mapping tools: Low tech to high tech. Oral presentation at: Alaska Invasive Species Conference; November 2013; Fairbanks, AK.

Kruse J.J. Forest insect conditions in Alaska. Oral presentation at: Alaska Entomological Society Sixth Meeting; January 2013; Fairbanks, AK.

Lundquist J.E. and R.M. Reich. Use of climate zones to model the distribution of insects in remote areas of Alasks. Oral presentation at: Alaska Forum on the Environment; February 2013; Anchorage, AK.

Lundquist JE, C.J. Fettig, D. McCollum, J.F. Negron, R. Cain, A.M. Lynch, S.J. Seybold, E. Smith, and R.A. Progar. Assessing impacts of western bark beetles – Scoping. Oral presentation at: Pacific Branch of the Entomological Society of America Annual Convention; April 2013: Lake Tahoe, NV.

Lundquist J.E. Insects and climate on the Chugach. Oral presentation at: Chugach National Forest Climate Change Vulnerability Committee Meeting; April 2013; Anchorage, AK.

Lundquist J.E. Organized and moderated session on invasive forest pests in Alaska. Annual Alaska Branch of the Society of American Foresters; April 2013; Anchorage, AK.

Lundquist J.E. and L.M. Winton. Identification of Alaskan Forest Insects and Diseases. USFS R10 Forestry Inventory Analysis field crew training; May 2013; Anchorage, AK.

Lundquist J.E. Review of Insect and Disease Issues on the Kenai Peninsula. Oral presentation for: University of Alaska Lecture NRM 270; May 2013; Anchorage, AK.

Lundquist J.E. Forest Health Trail at the AB Garden. Oral presentation for: Alaska Botanical Gardens; May 2013; Anchorage, AK.

Mulvey R.L. *Fomitopsis pinicola* in Southeast Alaska: Harmless saprophyte or aggressive stem decay? Oral presentation at: Western Hazard Tree Workshop; May 2013; Sedona, AZ.

Mulvey R.L. Southeast Alaska Pathology. Oral presentation for: Petersburg Ranger District, Wrangell Ranger District and Hoohah Ranger District; June and August 2013; Petersburg, Wrangell and Hoohah, AK.

Mulvey R.L. Diseases of Alaskan Forests. Oral presentation for: Insect and Disease Training, Ketchikan Mistry-Fiords Ranger District; July 2013; Ketchikan, AK.

Mulvey R.L. Pathology Update & Managing Stem Decays for Wildlife Habitat. Oral presentation for: Annual Tongass National Forest Silviculture Meeting; September, AK; Hoonah, AK.

Winton L.M. and S.W. Swenson. Arborsonic Acoustic Tomography Demonstration. Oral presentation at: Alaska Society of American Foresters annual meeting; April 2013; Anchorage, AK.

Winton L.M. Exotic Pathogens and Abiotic Conditions with which to be concerned. Oral presentation at: Alaska Society of American Foresters annual meeting; April 2013; Anchorage, AK.

Winton L.M. Arborsonic device for detecting hidden tree damage. Oral presentation at: Alaska Society of American Foresters annual meeting; April 2013; Anchorage, AK.

Wurtz T.L. Threat vectors for Alaska: How invasive species are getting here. Oral presentation at: Annual Meeting, Society of American Foresters, Alaska Chapter; April 2013; Anchorage, AK.

Wurtz T.L, D.D. Etcheverry, and N.J. Lisuzzo. Vetch Busters: Collaborating with property owners to limit the spread of bird vetch in the Fairbanks North Star Borough. Oral presentation at: Alaska Invasive Species Conference; November 2013; Fairbanks, AK.

Posters

Hennon P.E. and N. Turner. Vitality and defense mechanisms in bark-stripped cedar trees. Poster and abstract presented at: Western International Forest Disease Work Conference; Sepember 2012. Tahoe City, CA.

Adams G.C. and L.M. Winton. Building an index of pathogens of alder. Poster presented at: American Phytopathological Society and Mycological Society of America Joint meeting; August 2013; Austin, TX.

Trip Reports

Lundquist J.E. and J.C. Reese. Black bud of blue spruce. USDA Forest Service R10- Forest Health Protection, Trip Report. June 2013.

Lundquist J.E. and J.C. Chumley. Leaf rollers on the Central Kenai Peninsula 2013. USDA Forest Service R10- Forest Health Protection, Trip Report. June 2013.

Lundquist J.E. Devil's Creek Vegetation Project – Follow-Up. USDA Forest Service R10- Forest Health Protection, Trip Report. July 2013.

Lundquist J.E. Forest health observations of the Tribal Lands east of Ninilchik. USDA Forest Service R10- Forest Health Protection, Trip Report. July 2013.

Lundquist J.E. Copper River Basin Pest Survey. USDA Forest Service R10- Forest Health Protection, Trip Report. July 2013.

Lundquist J.E. Kenai Peninsula spruce beetle impact restoration-Phase II. USDA Forest Service R10- Forest Health Protection, Trip Report. August 2013.

Lundquist J.E, Douse J. Upper Tanana Windstorm WBB Initiative Project Site Visit. USDA Forest Service R10- Forest Health Protection, Trip Report. July 2013.

Mulvey R.L. and C. Cleaver. Forest Health Assessment of A foliage Disease Outbreak on Shore Pine in Gustavus and Glacier Bay National Park. USDA Forest Service R10- Forest Health Protection, Trip Report. June 2013.

Biological Evaluation

Kruse J.J. and N.J. Lisuzzo. Mississippi Creek Biological Evaluation. Delta Junction, AK. USDA Forest Service R10- Forest Health Protection, Biological Evaluation. December 2013.

Kruse J.J. and N.J. Lisuzzo. Stuart Creek Biological Evaluation. Fort Wainwright, AK. USDA Forest Service R10- Forest Health Protection, Biological Evaluation. December 2013.

Mulvey R.L., E.E. Graham, P.E. Hennon, C. Cleaver. Forest Health Assessment of Yellow-cedar Mortality and Dieback on Zarembo Island. USDA Forest Service R10- Forest Health Protection, Biological Evaluation. August 2013.

www.fs.usda.gov/main/r10/forest-grasslandhealth
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