United States Department of Agriculture

Forest Health Conditions in Alaska - 2019

A Forest Health Protection Report

Forest Service
Alaska Region

State of Alaska
Department of
Natural Resources
Division of Forestry

R10-PR-45

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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: ______________________________

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

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____

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

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____

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:

Garret Dubois, USDA Forest Service
S&PF/FHP, 3700 Airport Way, Fairbanks, AK 99709
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Do corrections need to be made to your physical or electronic address? Has the contact person for your organization changed? Please update any details here.

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

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

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Forest Health Conditions in Alaska - 2019

FHP Report R10-PR-45

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Introduction

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

We are excited to present the *Forest Health Conditions in Alaska—2019* report. This report summarizes monitoring data collected annually by our Forest Health Protection team, the Alaska Division of Forestry team, and some other key partners.

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

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

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

Betty Charnon

New Arrivals: Please join us in welcoming **Betty Charnon** who is joining Forest Health Protection as the new Invasive Plants, FHM and Pesticides Specialist. Betty, who replaces Trish Wurtz, was the zone ecologist for the Kenai Peninsula Zone on the Chugach National Forest where she worked for the past 16 years. Betty has more than 25 years of professional experience and has also worked on the Fremont National Forest and the Kootenai National Forest. Also welcome to **Martin Schoofs** who joined the Alaska Division of Forestry – Forest Health Program in 2018 as a Forest Health Forester based out of Anchorage. Martin came to the Division of Forestry shortly after finishing his Master's degree in Environmental Science at Alaska Pacific University.

Martin Schoofs

Recent Departures: Tricia Wurtz retired in June 2019 after an illustrious career with Alaska Forest Health Protection. Trish started with FHP as a Plant Ecologist and Invasive Plant Program Coordinator in 2007. Prior to that, she worked for a number of years for the Institute of Northern Forestry at the University of Alaska Fairbanks. Her advocacy for early detection and rapid response programs to address emerging invasive plant issues and her tireless work forming partnerships and facilitating grants and agreements to support invasive plant control and remediation has been an incredible asset to Alaska and the US Forest Service. She bridged the gap between the Alaska Region, Alaska DNR, University of Alaska Cooperative Extension Service, Soil and Watershed Councils, Tribes and National Parks to recognize and support critical invasive plant work. These connections, projects and "grass root" groups she has been involved with over the years not only helped develop jobs and natural resource management value, but have motivated others and created a lasting legacy. Trish has also helped produce and contributed to a number of important publications and research manuscripts dealing with non-native plants such as bird vetch, Elodea, European bird cherry, sweet clover and others, as well as many related to boreal forest ecology and the ecology and management of morel mushrooms. We hope you enjoy your well-earned retirement and will miss you Trish! Our Entomologist for the Interior, **Stephen Burr** has taken a position in Region 9 as Forest Health Coordinator based in Milwaukee, WI. During his time in Alaska he has worked to expand monitoring and trapping for key insect pests using both ground and aerial survey to better assess forest health in the Interior. We wish them both the very best!

Trish Wurtz

Stephen Burr

Seasonal Technicians: Isaac Davis returned for a fourth season, bringing his ever expanding skillset back to our Juneau office. **Alex Wenninger** and **Dana Brennan** returned for their second season to our Anchorage and Fairbanks offices (respectively) but also worked together to monitor insect traps throughout the Interior and Southcentral. Thank you Isaac, Alex and Dana!

Did you know that you can **request our aerial survey team to examine specific forest health concerns** in your area? To do this, please contact Karen Hutten (karen.hutten@usda.gov) or other members of our forest health team.

Additionally, this report is available online at https://www.fs.usda.gov/detailfull/r10/forest-grasslandhealth/?cid=fsbdev2_038884&width=full or in print by contacting Biological Science Technician, Garret Dubois (garret.d.dubois@usda.gov).

2019 ALASKA REGION HIGHLIGHTS

Digital Media

Alaska Forest Health Protection has been working hard to increase timely stakeholder access to forest health information and resources: We've created user-friendly Story Maps (an ESRI product) as a fast and fun way to learn about Forest Health Highlights in Alaska,

Users can explore and manipulate maps of our ground and aerial survey data.

- The 2019 Story Map (Figure 1), https://storymaps.arcgis.com/stories/150e94edf7ce4e84808b55a487cde528, and past year's Story Maps are also linked on our website.
- Our continually updated website has a menu of new webpages for the most common and important forest damage agents in Alaska: https://www.fs.usda.gov/main/r10/forest-grasslandhealth.
- An interagency spruce beetle website was developed as a one-stop shop for spruce beetle information in Alaska to provide resources to homeowners and land managers: www.alaskasprucebeetle.org.
- We are sharing forest health information on social media through Facebook (ChugachNF and TongassNF) and Twitter (@AKForestService, #alaskaforesthealth).

Figure 1. The Forest Health Highlights in Alaska 2019 Story Map was published in November 2019. It includes interactive aerial and ground survey maps and summarizes key forest health issues in Alaska.

Aerial Survey

In 2019, aerial surveyors mapped over 1.1 million acres of forest damage from insects, diseases, declines, and abiotic agents on the 24.4 million acres surveyed (Map 1 and Map 2; Table 1 and Table 2). The damage agents with the highest mapped acres were hemlock sawfly, birch leafminer, spruce beetle, aspen leafminer, and spruce needle rust. Southcentral and Interior Alaska were impacted by smoke and temporary flight restrictions from numerous wildfires in 2019. As a result, some survey missions were incomplete or less thorough than previous years due to poor visibility or inability to access. See Appendix I on page 62 for more information about the survey.

Insects

The 69th annual Western Forest Insect Work Conference was held in Anchorage, AK in April 2019, the first time ever in Alaska. Entomologists and forest health specialists from universities, state and federal agencies, and private industry across western U.S. and Canada were in attendance for the conference that featured several breakout sessions with an Alaska focus, including two sessions on spruce beetle. A joint fieldtrip with the Alaska Chapter of the Society of American Foresters took place with stops between Anchorage and the Begich, Boggs Visitor Center. The joint fieldtrip was an excellent opportunity for entomologists and foresters to interact and discuss forest health issues with experts from different disciplines (Figure 2).

Figure 2. Gino Graziano of UAF Cooperative Extension Service addressing the Western Forest Insect Work Conference and the Alaska Chapter of the Society of American Foresters joint fieldtrip at Earthquake Park in Anchorage.

Southcentral Alaska continues to be in the midst of a spruce beetle outbreak, estimated to be in its fourth year. Damage decreased considerably in 2019, with 139,500 acres observed statewide during aerial detection surveys, compared to 593,000 acres mapped in 2018. In some areas white spruce host material is near exhaustion and an increase in spruce beetle attacks on black spruce has been observed. Spruce beetle activity continues to expand in nearly all directions along the periphery of the outbreak area.

The hemlock sawfly outbreak that began in 2018 has continued throughout Southeast Alaska with over 380,000 acres of damage to western hemlock recorded during aerial detection surveys (Figure 3). Defoliation is extensive in some areas, especially Prince of Wales, Mitkof, and Kupreanof Islands, and extending

Figure 3. Hemlock sawfly defoliation near Angoon, Admiralty Island.

north to Juneau. In ground surveys, hemlock sawfly was the most common defoliator detected on beating sheets, with low numbers of western blackheaded budworm. Mortality typically occurs when both hemlock sawfly and western blackheaded budworm are in outbreak together. The low number of western blackheaded budworm larvae indicate the trees should recover, but some topkill and mortality is expected. We also found that areas heavily defoliated in 2018 had a high rate of sawfly larvae infected with fungal disease, indicating the outbreak may be winding down.

In 2019, special late-season aerial surveys were scheduled in both Southcentral and Interior Alaska to better assess the impacts of invasive birch leafminers (Figure 4). Over 280,000 acres of impacted forests were mapped; 17,000 acres in Interior, over 170,000 acres in Matanuska-Susitna Borough and more than 80,000 acres on the northern Kenai Peninsula. Additionally, a small area of birch leafminer activity was noted in the Big River Lakes area across Cook Inlet from the northwestern Kenai Peninsula. Based on the extent of the damage in this area and its geographic isolation and separation from other known infestations of birch leafminers in the region, this appears to be a more recent introduction.

The non-native balsam woolly adelgid was found damaging ornamental subalpine fir planted in Juneau, AK. This is the first known introduction of balsam woolly adelgid in Alaska. Surveys are underway to determine the extent of the infestation.

Diseases

Aspen running canker has been documented throughout Alaska's boreal forest. It is most damaging on small diameter trees within older stands, yet almost absent from similar-sized trees in abutting fire scars, which are young, vigorously growing with reduced competition. Our partners at the University of Nebraska Lincoln and University of Alaska Fairbanks are helping us to identify the causal fungus, investigate factors influencing its distribution, and determine tree response.

Brown crumbly rot, caused by *Fomitopsis pinicola*, was found on many white spruce trees recently killed by spruce beetle in the Matanuska-Susitna Valley. Nearly all of the bole-snapped trees had diagnostic fruiting bodies and brown crumbly rot on the butt log. The extensive advanced decay suggests that the trees had been infected long before they snapped and before attack by spruce beetle. Two popular state campgrounds, Byers Lake and South Rolly Lake, were closed due to hazardous trees (Figure 5).

Spruce needle rust is a fungal disease that infects new needles of spruce and gives the spruce tree crowns an orange tinge (Figure 6). This summer, an outbreak was aerially mapped across nearly 115,000 acres in southwestern Alaska, with pronounced activity in Wood-Tikchik State Park and south along the Nushagak River to Bristol Bay. Spruce needle rust damage was also common and severe in Southeast Alaska. Peak damage occurs in August after most surveys are complete.

Noninfectious Disorders & Declines

Yellow-cedar decline, caused by freezing injury to the fine roots of yellow-cedar in the absence of insulating snowpack, is the most significant threat to yellow-cedar populations in Alaska. In October 2019, Federal protection for yellow-cedar under the Endangered Species Act was deemed unwarranted. The U.S. Fish and Wildlife

Figure 4. Birch leafminer defoliation in the Matanuska-Susitna Valley observed during special surveys in August 2019. Photo by Jason Moan.

Figure 5. Red belt conks on the stump of a bole-snapped white spruce located at South Rolly Lake Campground. Various ages of conks and mycelial felts are visible.

Figure 6. Spruce needle rust near Juneau, Alaska in 2019.

Service's decision is available in the Federal Register (Vol. 84, No. 194, https://www.govinfo.gov/content/pkg/FR-2019-10-07/pdf/2019-21605.pdf). The Species Status Assessment was completed in March 2018. We continue to monitor yellow-cedar decline in old-growth forests and in stands managed for timber. About 20,000 acres of actively dying yellow-cedar forests were mapped in 2019. Young-growth yellow-cedar decline is a relatively new management issue, particularly in 35- to 45-year-old managed stands with wet or shallow soils. In monitoring plots installed last year in the most severely affected managed stands, one-third of yellow-cedar crop trees had crown discoloration damage from yellow-cedar decline (Figure 7). The condition of symptomatic trees is expected to worsen, since declining trees tend to die gradually in old-growth forests. Some affected trees will die more rapidly if they are attacked by secondary bark beetles.

Figure 7. A yellow-cedar crop tree on Wrangell Island with a thin, discolored crown.

Notable topkill (Figure 8) and mortality of western redcedar has occurred in the southern panhandle since 2017. This damage, which is most common on Prince of Wales Island, worsened in 2019. It is thought that drought, or drought combined with winter injury, are key causal factors, but further investigation is warranted. Similar drought damage to western redcedar is known from other parts of the Pacific Northwest.

Figure 8. Western redcedar topkill, common on Prince of Wales Island since 2017.

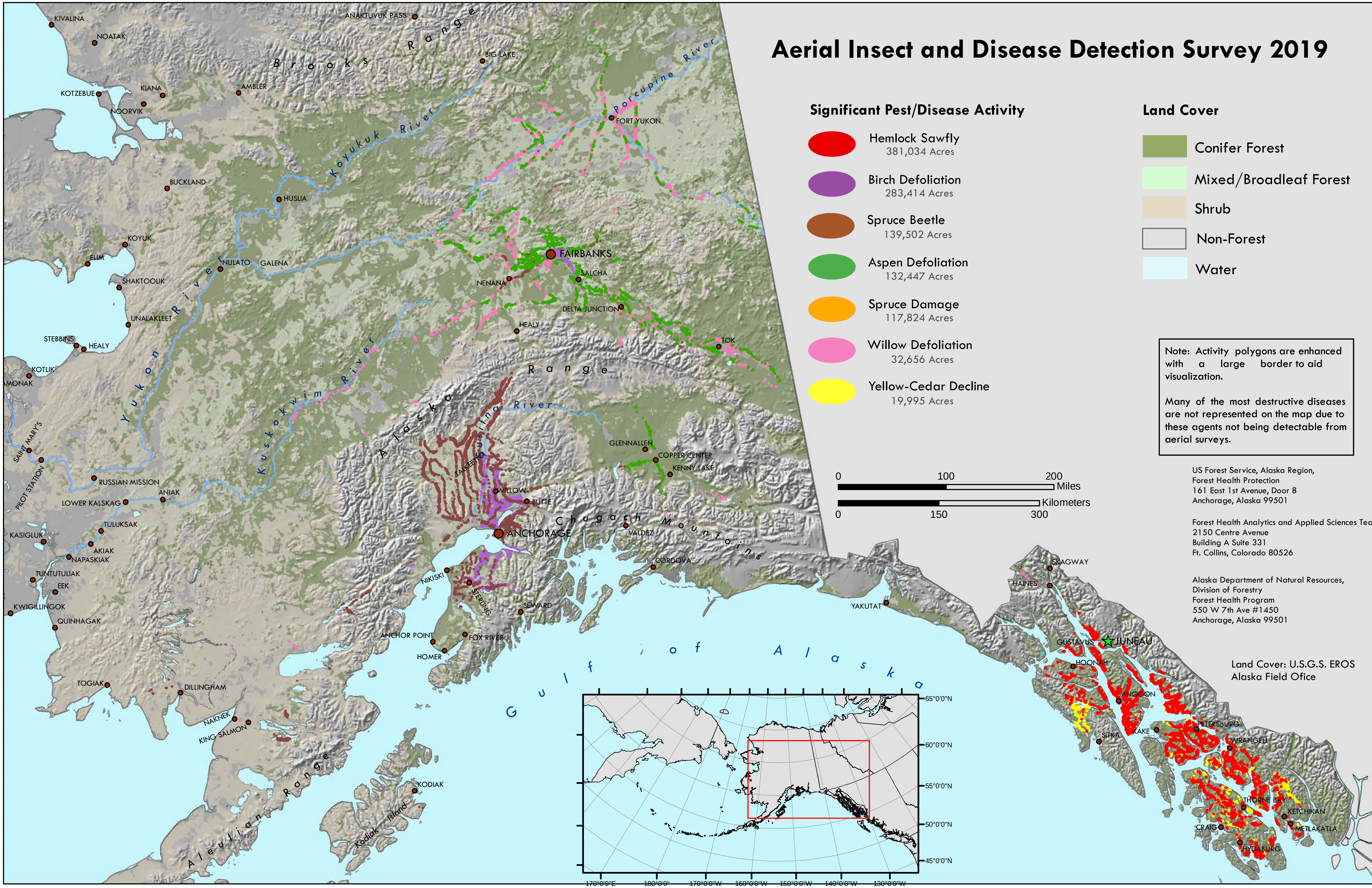
Invasive Plants

Successful Elodea treatments have occurred across the state. On the Kenai Peninsula, the Cooperative Weed Management Area partners adopted an Early Detection and Rapid Response model that has successfully led to the eradication of Elodea in five of six lakes. The latest infestation was found this fall and there are plans to treat this infestation in spring, 2020. In the Interior, the Fairbanks Soil and Water Conservation District found no new infestations and treated four sites with herbicide. Overall, their treatments have greatly reduced the infestations in all of the treated sites.

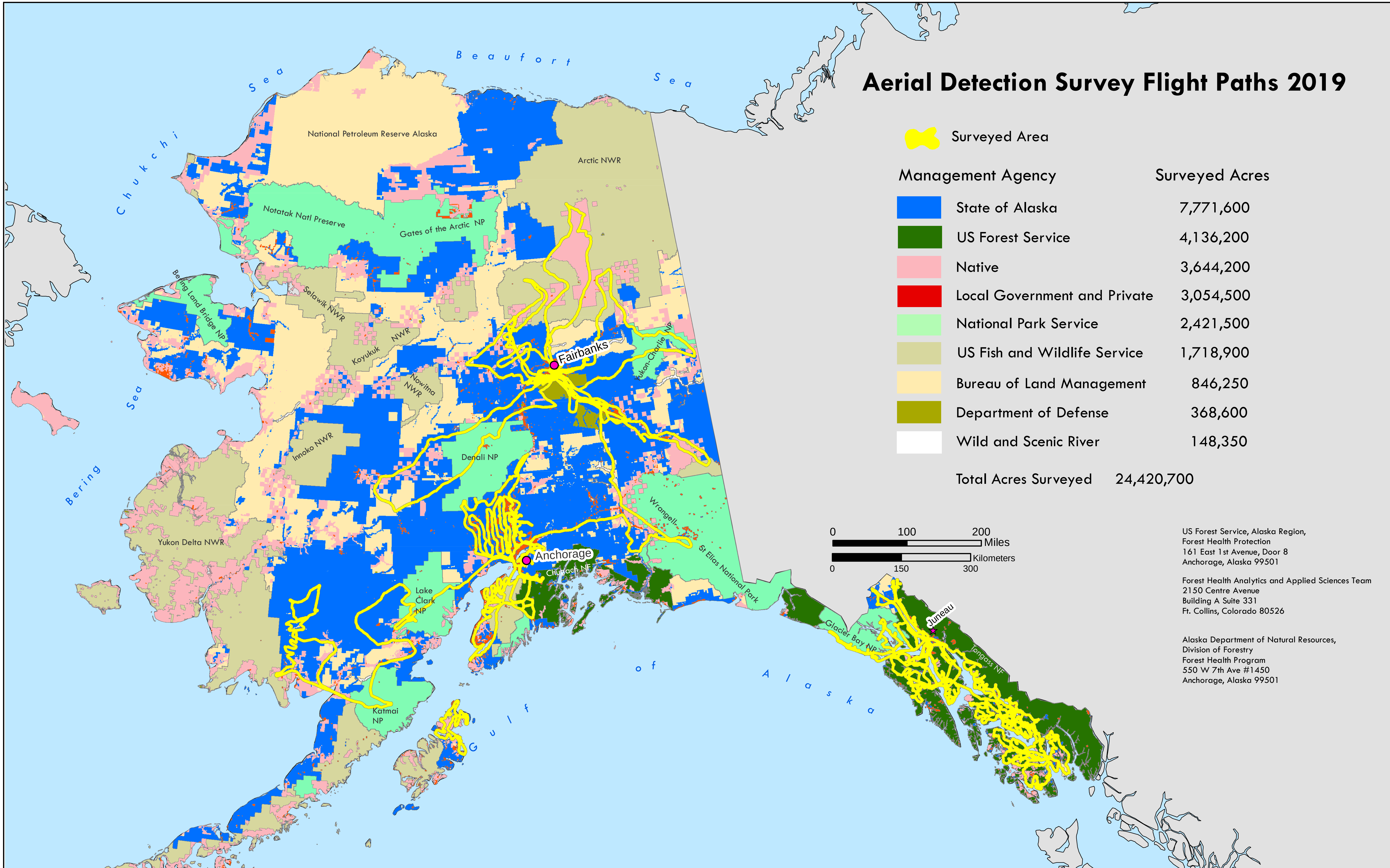
In Girdwood, Alaska, local partners along with the contractor Alien Species Control, have initiated treatment on over 30 acres of orange hawkweed at Alyeska Ski Resort (Figure 9). Overall this project achieved an estimated 90% reduction in this large hawkweed infestation. However, future efforts will be needed to find and control additional plants, especially those that are isolated.

European bird cherry has been a hot topic in Alaska from Juneau to Talkeetna. New infestations have been found in Juneau. Large mother trees have essentially been removed from the town of Hope thanks to community involvement. The Cooperative Extension Service is completing a study on the effectiveness of basal bark treatments. The Anchorage group Citizens Against Noxious Weeds Invading the North is continuing chemical treatments in Anchorage as well as numerous public outreach events such as the Anchorage Weed Smackdown. Community members in Talkeetna are reaching out to specialists to assist them with developing plans to survey and control bird cherry trees in natural areas and on private properties.

Figure 9. Orange hawkweed (*Hieracium aurantiacum*) near Girdwood, Alaska.



Map 1. Aerial Insect and Disease Detection Survey 2019.



Map 2. Aerial Detection Survey Flight Paths 2019.

Table 1. Forest insect and disease activity detected during aerial surveys in Alaska in 2019 by land ownership and agent. All values are in acres[1].

Category	Agent	Total Acres	National Forest	Native	Other Federal	State & Private
Diseases	Spruce needle rust	116,232	76	6,478	380	109,298
	Alder dieback	1,222	0	121	386	715
	Spruce broom rust	559	0	203	95	262
	Dothistroma needle blight	346	65	0	184	97
Defoliators	Hemlock sawfly	381,034	322,895	13,596	1,469	43,075
	Birch leafminer	281,888	1,584	13,313	77,677	189,314
	Aspen leafminer	132,084	0	25,664	19,316	87,104
	Willow leafblotch miner	31,761	0	11,845	10,556	9,360
	Hardwood defoliation	3,890	41	419	825	2,605
	Alder defoliation	2,597	270	68	467	1,792
	Birch defoliation	1,526	18	2	170	1,337
	Cottonwood defoliation	1,180	277	6	37	861
	Spruce aphid	976	509	217	0	250
	Willow defoliation	895	0	98	74	724
	Cottonwood leaf beetle	473	2	0	387	84
	Aspen defoliation	364	0	26	114	223
	Spruce defoliation	58	0	0	58	0
Mortality	Spruce beetle	139,502	235	6,001	19,058	114,208
	Northern spruce engraver	1,071	0	99	24	948
	Western balsam bark beetle	106	22	0	3	81
	Aspen running canker	71	0	11	4	56
Noninfectious and Miscellaneous Damage	Yellow-cedar decline	19,995	17,542	985	90	1,379
	Winter damage	8,655	0	0	8,655	0
	Drought	2,596	0	5	2,137	454
	Porcupine damage	1,858	226	1,489	0	143
	Flooding/high-water damage	1,578	43	2	1,302	231
	Willow dieback	550	0	161	218	171
	Windthrow/blowdown	431	184	31	206	10
	Hemlock flagging	289	283	0	0	6
	Western redcedar topkill	99	38	43	0	19
	Landslide/avalanche	13	0	0	0	13

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

Table 2. Mapped affected area (in thousands of acres) from 2015 to 2019 from aerial survey. Note that the same stand can have an active infestation for several years. For detailed list of species and damage types that compose the following categories, see Appendix II on page 66.

Damage Type	2015	2016	2017	2018	2019
Abiotic damage	11	3.3	5.6	5.0	10.8
Alder defoliation	26	2.9	3.4	0.9	2.6
Alder dieback	12	8.4	1.0	3.2	1.2
Aspen defoliation	118	229.3	168.5	259.7	132.4
Aspen mortality	0.0	0.0	0.0	5.7	0.1
Birch defoliation	42	85.5	7.2	132.8	283.4
Cottonwood defoliation	9.2	2.3	1.0	3.6	1.7
Fir mortality	0.02	0.03	0.04	0.1	0.1
Hardwood defoliation	190	161.9	38.7	15	3.9
Hemlock defoliation	0.1	0.0	0.0	48.6	381
Hemlock mortality	0.5	0.0	2.7	0.1	0.0
Larch mortality	*	*	*	0.01	0.0
Porcupine damage	1	3.5	1.5	2.5	1.9
Shore pine damage	3.4	4.9	0.3	3.7	0.4
Spruce damage	8.8	36.2	36.1	2.5	117.8
Spruce mortality	42.3	204.5	411.4	594.3	140.6
Spruce/hemlock defoliation	3.1	3.1	1.1	4.2	0.0
Willow defoliation	67	156.3	113.2	39.9	32.7
Willow dieback	1.2	2.8	1.0	0.0	0.6
Yellow-cedar decline	39	39.3	47.4	17.7	20.0
Other damage	*	*	*	0.7	9.5
Total damage acres	**574.6**	**949.8**	**840.3**	**1139.9**	**1140.8**
Total acres surveyed	32,938	26,876	27,540	27,954	24,421
Percent of acres surveyed showing damage	1.70%	3.50%	3.05%	4.08%	4.67%

* not documented in previous reports

Yellow-cedar Salvage Logging in Southeast Alaska: Case Studies Reveal Large Variation in Producer Efficiency and Profitability

Molly Tankersley, Science Communications Specialist, Alaska Coastal Rainforest Center & Alaska Climate Adaptation Science Center, University of Alaska Southeast

As climate change rapidly alters conditions in Southeast Alaska, lower snowpack levels have caused a massive decline of yellow-cedar trees. Without an insulating blanket of snow, the shallow roots of yellow-cedar trees freeze during late spring cold snaps. Left behind is a growing expanse of "ghost forests" of dead yellow-cedars, affecting more than 600,000 acres (nearly the area of Yosemite National Park) (Figure 10). The decay-resistant properties of yellow-cedar allow the trees to remain standing for decades after death. Alaska Coastal Rainforest Center Director Allison Bidlack, and collaborators Brian Buma (University of Colorado, Denver), Sarah Bisbing (University of Nevada, Reno), and Brian Vander Naald (Drake University), set out to determine whether these ghost stands might provide an economic opportunity for small lumber mills in Tongass National Forest. The potential benefits of yellow-cedar salvage logging are numerous. As an alternate source of lumber, dead yellow-cedar could remove logging pressure on live trees and old-growth forests. It may also have a lesser impact on the surrounding ecosystem when removed, as dead yellow-cedar typically does not provide much wildlife habitat (aside from some use by nesting bats when the bark is loose but has not yet sloughed off). Yellow-cedar's decay-resistant properties give it natural value for outdoor materials like decks and playgrounds, where other types of wood must be chemically treated for the same use. As the harvest allowance of live trees is restricted and the timber industry in Southeast Alaska continues to decline, an additional wood source could help sustain jobs at small, family-run logging and milling operations (Figure 11).

Figure 10. The gray "ghost" trees visible on North Kupreanof Island are dead yellow-cedar in forests affected by yellow-cedar decline.

In reality, it's more complicated. Because the dead tree stands are often scattered, remote, and more difficult to process, there can be higher logging and transportation costs with salvage logging. Access to quality dead tree stands through micro-sales is determined by the US Forest Service, and the supply can be inconsistent. And while live-harvest yellow-cedar lumber is sold widely in Asian markets, the market for salvaged dead trees is not yet established.

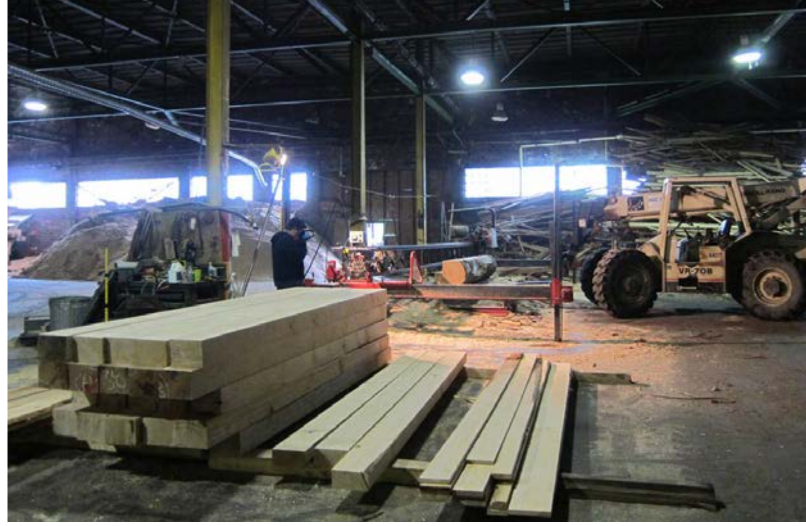


Figure 11. Yellow-cedar lumber in a mill warehouse.

Over several years, Bidlack and her colleagues met with researchers, agency managers, and mill operators to find out how dead yellow-cedar salvage could provide a profitable timber source for Southeast Alaska mills. The researchers tracked operating cost and sales data from several small-scale lumber mills on Kupreanof and Prince of Wales Islands. In some cases, inaccurate cost-tracking made it hard to quantify the true costs and benefits associated with yellow-cedar salvage. The revenue from salvaged yellow-cedar varied widely among mills in the study, as did the reported milling costs and product values.

Despite the lack of quality data on the harvesting and transporting costs and market value of yellow-cedar products, their findings showed that logging dead cedar stands can be profitable. In their recently published report (see link below), the authors found that the most common and profitable use for salvaged yellow-cedar in the study was dimensional lumber, or wood cut into predefined, standard sizes. A few mills primarily used the lumber for firewood, which was the least profitable product created. But there may be a significant opportunity and profit in creating value-added specialty products with the salvaged wood, such as furniture, musical instruments, or specialty building materials.

"Our new climate reality, driving yellow-cedar mortality across much of the Tongass, presents an opportunity for a new approach to forest management and a forest products industry in Southeast Alaska," said Bidlack in the report.

Over the next 15 to 20 years, the US Forest Service will transition away from old-growth tree harvesting towards young-growth management and harvest in the Tongass. Mills will need to find alternate lumber sources during this transition. To sustain this emerging industry, access to quality dead tree stands through micro-sales, and training opportunities for business owners to track and limit their costs, are needed. ଓ

Read the full report: http://acrc.alaska.edu/docs/Yellow-cedar-salvage-report.pdf.

Youth Outreach: The Future of Success in the Metlakatla Indian Community

Genelle Winter, Invasive Species Program Director Climate & Energy Grant Coordinator, Metlakatla Indian Community, Metlakatla, Alaska

Figure 12. Youth pulling Himalayan knotweed during Alaska Invasive Species Awareness Week, June 2019.

Metlakatla Indian Community (MIC) has been conducting invasive species work on Annette Islands Reserve (AIR) since 2008, and early on we developed a clear sense that to be successful we must incorporate a dynamic community outreach component to our program. This would increase Early Detection and Rapid Response effectiveness, improve survey accuracy and potentially facilitate long-term behavior changes that would prevent invasive species introduction and spread on AIR. After our first attempt to conduct invasive species outreach to the Tribal Council it became apparent that while everyone understood the problem, very few saw any real need to modify or adopt any new behaviors. At the time, I had young children in school, so we used that as an opportunity to make an impression on those young minds.

From the very beginning it was evident, that we could reach the hearts and minds of these future stewards of the natural resources on AIR. That is really the message that has been at the core of our outreach. Preventing and controlling invasive species protects the resources that all MIC residents love and rely on. By physically engaging the youth in identification of target invasive species, demonstrating the potentially devastating impacts of those invasive species and stressing that each and every student gets to be a champion of the resources of AIR. They can report weeds to us, they can pull those that they have learned how to in our weed pull events and they can spread the message to their parents and grandparents (Figure 12). Those youth can bring a much more compelling message into their homes and effect long lasting behavior changes in more homes than we could ever reach with a standard community outreach program.

We have seen the effectiveness of this approach over the years, with people reporting sightings of weeds that their child or grandchild told them about, or that they saw our youth group working on. The adult supervisors in the youth weed pull events also walk away feeling empowered by their knowledge and understanding of the impacts of invasive species on our community and their role in helping to prevent the spread of invasive species.

A case that we present is the state of conditions in Ketchikan where there are no established consistent controls and the weeds can be identified by informed MIC members. During the summer, we receive many concerned reporting's of orange hawkweed, Japanese knotweed and tansy ragwort seen in Ketchikan and the concern of those weeds getting out of hand on AIR. This results in tremendous community support for the invasive species program and ongoing support in the school year and during the summer from youth led activities to educate and conduct control work on invasive species.

In conclusion, it is apparent that to effect true change in behavior, the best method is to empower the next generation, our youth, by providing factual information and hands-on activities to give them the desire to be the stewards of all the natural resources that provide them with the way of life they love and enjoy. ☙

Summary of Key Points

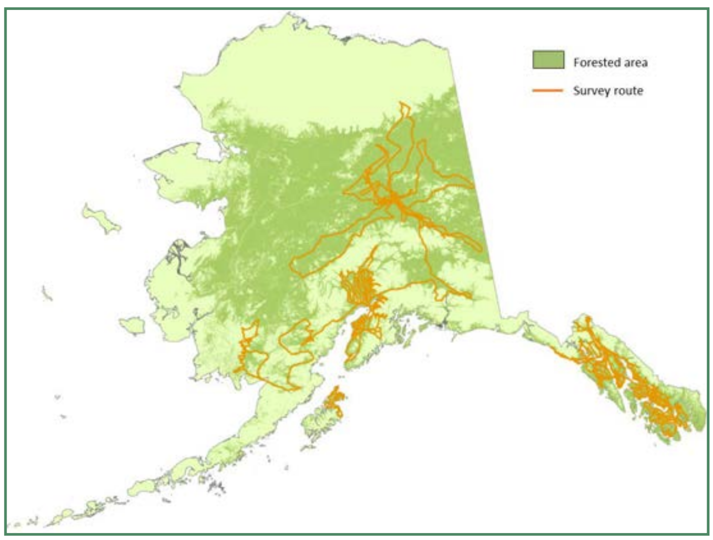
- Alaska Forest Health Protection is collaborating with partners to apply and test satellite-based remote sensing applications to detect and quantify the extent of specific types of forest damage in Alaska.
- We have partnered with: (1) the Forest Health Assessment and Applied Sciences Team (FHAAST) using Operational Remote Sensing (ORS) (2) the Kennedy Lab at Oregon State University using LandTrendr (LT), and (3) the Geospatial Technology and Applications Center (GTAC) using the Landscape Change Monitoring System (LCMS).
- We hope to use satellite-based remote sensing: (1) to identify areas of recent forest change for aerial survey route planning, (2) to determine the extent and severity of damage after the damage type has been identified by aerial and ground surveys, and (3) to explore past disturbance trends and patterns with the help of historic aerial survey data.
- By testing various remote-sensing tools, we come to understand the applications, strengths and weaknesses of each approach, and where improvements are needed. Some tools met specific objectives better than others, and the timing of image acquisition relative to the timing of damage onset was very important. We assessed how well the output from each of our partners' products corresponded to damage from hemlock sawfly mapped by aerial survey.
- Remote sensing of forest change is intended to complement, not replace, our aerial detection survey. Some types of forest damage are well-suited to remote detection, while others are not. An extensive hemlock sawfly outbreak in Southeast Alaska caused highly synchronous, homogenous tree crown color change, making it ideal for detection at a 30 m pixels size. Detection of yellow-cedar decline has been hampered by the progressive, heterogeneous nature of crown color change in declining forests. Incorporating reflectance signals common to the surrounding forest, such as abundant white yellow-cedar snags, might enhance remote detection capabilities.
- As technology improves, we will continue to learn the potential and limitations of new tools and their applications using an interdisciplinary approach.

Satellite-Based Remote Sensing in Alaska

Karen Hutten, Aerial Survey Coordinator, USDA Forest Service

Need for satellite-based remote sensing

With over 200,000 square miles of forest and few roads, Alaska is a challenging place to monitor forest conditions. We do not have the resources to travel everywhere and must prioritize our aerial and ground survey efforts (Map 3). See Appendix I on page 62 and our webpage for a description of aerial detection survey (ADS). Satellite-based remote sensing has the potential to augment our survey effort by detecting possible forest damage prior to survey. We may also eventually be able to calculate total area damaged by a particular agent post-survey using landscape-level attributes associated with an insect or disease agent. This year, surveyors were able to fly over satellite-detected areas of forest damage in Southeast Alaska, determine if damage was present, and identify the host tree and damage agent by observing damage patterns and tree characteristics (a.k.a. damage signature). Next year we may expand satellite detection into Interior and Southcentral Alaska. We continue to explore the potential of satellite-based remote sensing to detect forest change related to forest health by applying and testing new tools and comparing results to observations made by trained aerial surveyors.



Map 3. Aerial survey routes map 2019.

How satellite-based remote sensing works

Satellite-based remote sensing uses imagery (e.g., pictures) downloaded from satellites that orbit the earth at a regular frequency, providing predictable and reliable snapshots of the planet (Figure 13). When one or more images from the same location are compared, it is possible to quantify changes that have occurred between image dates (Figure 14). Satellites record reflectance wavelengths in visible light frequencies (e.g., red, green, blue) as well as near infra-red, shortwave infra-red and other spectral regions. Because soil, water and vegetation absorb and reflect these wavelengths differently (Figure 15), wavelengths can be used in combination to hone in on vegetation change. Two examples are Normalized Difference Vegetation Index (NDVI) and the Normalized Burn Ratio (NBR) which use a combination of near-infrared and red bands, and near-infrared and shortwave infrared bands, respectively. The Tasseled Cap transformation represents another more complex suite of indices that is able to detect changes in 'wetness', 'greenness', and 'brightness' (TCW, TCG, and TCB).

Two common types of imagery used in remote sensing are Landsat and MODIS (Moderate Resolution Imaging Spectroradiometer). Landsat imagery has a resolution of 30 m; that is, every 30 m pixel has a unique set of reflective band values which allows one to discern vegetation coverage, but not individual trees. MODIS, on the other hand, has a 250 m, 500 m, or 1000 m resolution depending on the band, and is therefore much less detailed than Landsat. Imagine a square of forest that is 250 m on a side with all colors blended into one value for the whole image square/pixel (Figure 16). The advantage that MODIS has over Landsat is that a new image is obtained every 1-2 days for any one location, whereas Landsat frequency is once every 8 days. Because of high temporal frequency, several MODIS images can be compared to detect broad-scale change within one season (e.g., defoliation of a large group of deciduous trees), whereas Landsat is better for detecting more detailed, persistent annual change (e.g., defoliation of conifers, tree mortality, harvest, fire, and landslides) using just one best image per year.

Landsat-based remote sensing development for Alaska

The USFS has made great strides in the development of satellite-based remote sensing tools for use in Alaska this year with three independent efforts: (1) Operational Remote Sensing (ORS; https://www.mdpi.com/2072-4292/10/8/1184/htm) by Forest Health Assessment and Applied Sciences Team (FHAAST); (2) LandTrendr (LT) by the Kennedy Lab at Oregon State University (http://emapr.ceoas.oregonstate.edu/projects.html), and (3) Landscape Change Monitoring System (LCMS; https://www.fs.usda.gov/rmrs/projects/landscape-change-monitoring-system-lcms) by the Geospatial Technology and Applications Center (GTAC). Each of these developers used Landsat imagery and specialized methods to detect landscape change in Alaska. All methods harnessed the increased computational power available through Google Earth Engine (GEE; https://earthengine.google.com/) which provides a platform for processing Landsat data and building and sharing script and user-interface tools. Landsat imagery is a good choice for detecting change at the scale of Alaskan forests because the 30 m resolution is detailed enough to detect damage, but not so detailed that the data become unmanageable. Landsat has been reliably collected since 1999 for northern regions, providing a 21-year window for viewing past change. Landsat-based tools are also compatible with the newer (2015) Sentinel imagery which has a finer spatial resolution (10 m and 20 m depending on the

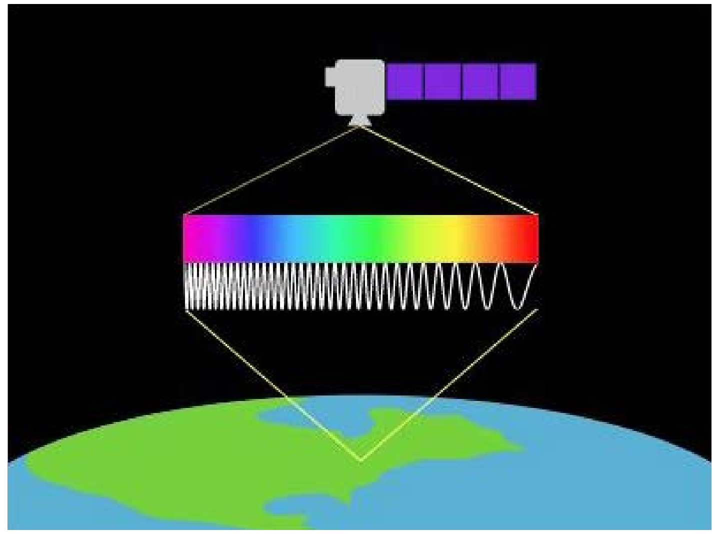


Figure 13. Landsat sensors in satellites orbiting Earth collect reflected radiation, which is translated into image data. Figure from OSU eMapR Lab (http://emapr.ceoas.oregonstate.edu).

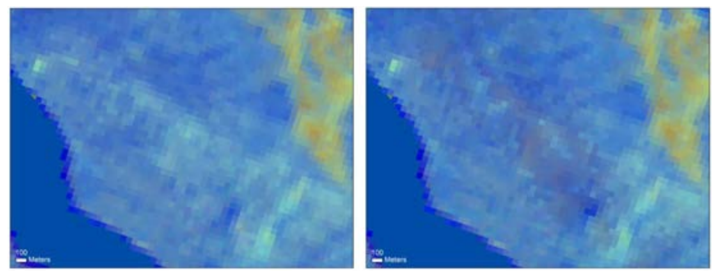


Figure 14. A comparison of 2017 and 2018 Tassled Cap data derived from Landsat imagery for forest along Sandborn Canal near Port Houghton, Alaska. The subtle change in color is due to defoliation from hemlock sawfly activity.

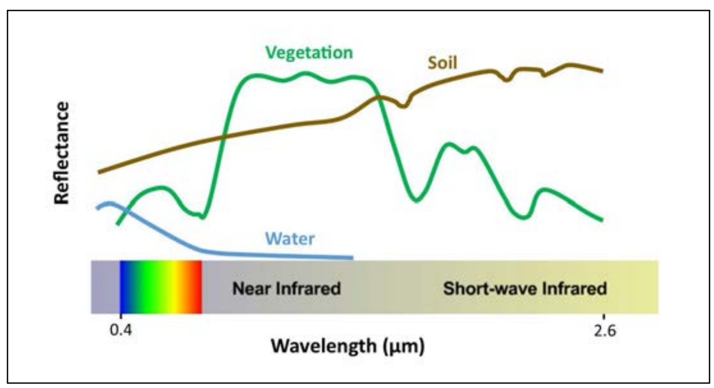


Figure 15. Wavelengths of light are reflected and absorbed differently by vegetation, soil and water, creating a different spectral signature for each.

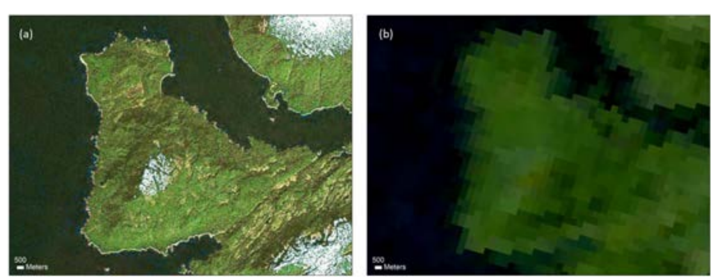
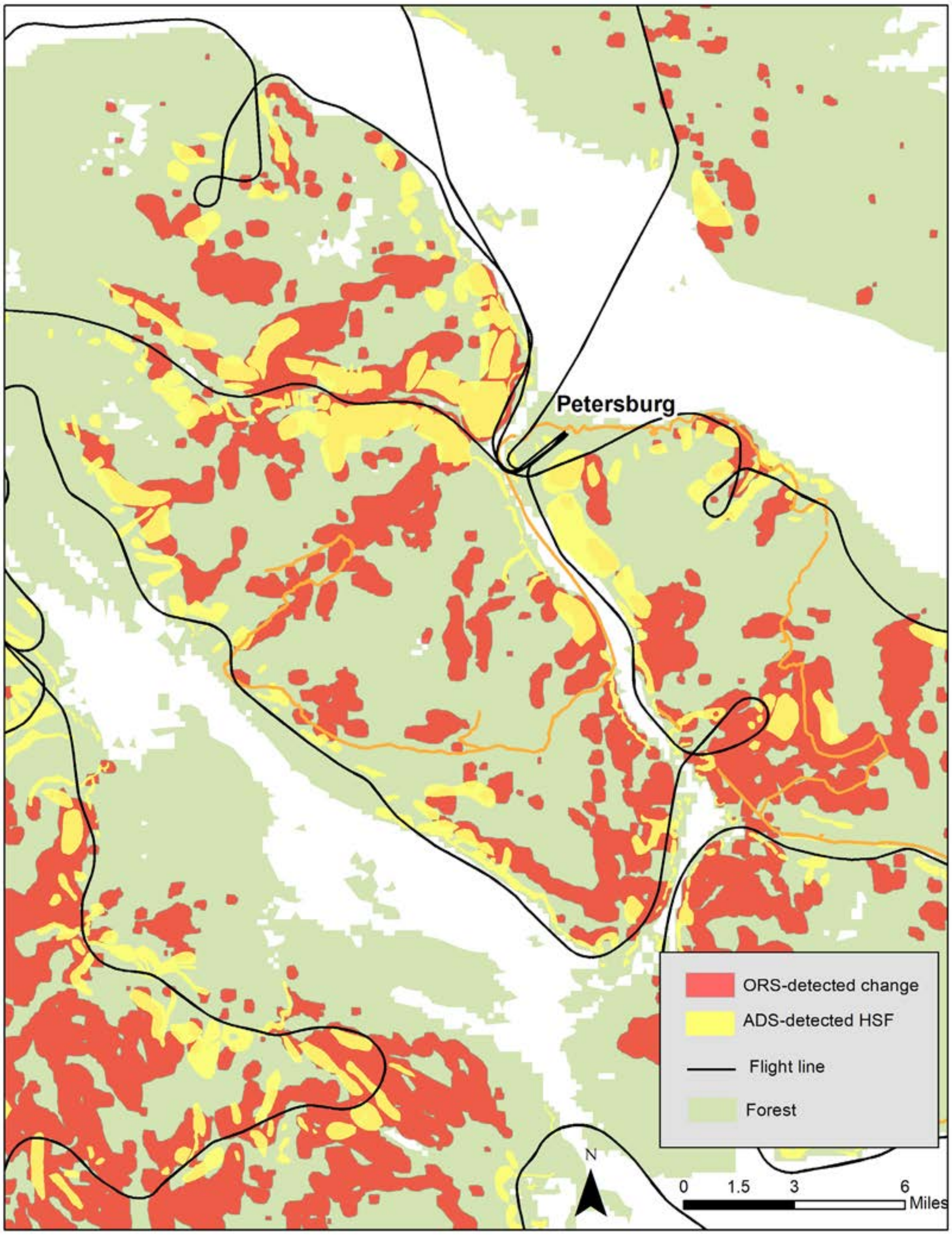


Figure 16. Spatial resolution is 30 m for Landsat (a) and 250 m for MODIS (b) satellite imagery.

band) and a more frequent revisit cycle (every 5-6 days). FHAAST has incorporated both Landsat and Sentinel imagery into ORS models.

We envision using satellite-based remote sensing to monitor Alaska forest health in three ways: (1) as a pre-survey guide for survey flights; (2) post-survey to determine extent and severity of damage after the damage type has been identified and characterized; and (3) as an investigative tool to explore past disturbance trends and patterns with the help of historic ADS data. We accomplished the first objective this summer. We notified FHAAST of a hemlock sawfly outbreak in Southeast Alaska and they used our ADS-mapped locations from 2018 to adjust ORS parameters to maximize the detection of hemlock sawfly damage with satellite imagery. FHAAST provided us with a GIS map layer of likely outbreak locations for survey route planning (Map 4). FHAAST has been working with other regions to develop Landsat and MODIS tools for several years with some success. The GEE scripts are available upon request and could allow us to produce ORS change maps from our FHP offices in Alaska.

With the help of a USDA Forest Service, Forest Health Protection, Special Technology Development Program (STDP) grant, the Kennedy Lab has provided our Alaska Forest Health Protection team with the ability to create change maps in GEE as well. They use an algorithm and segmentation process (LandTrendr), which results in a time-series line of reflectance values for any band or index. This LandTrendr trajectory smooths over small changes in vegetation or atmosphere (noise) and responds to dramatic change associated with disturbance events. The magnitude of change for each year is calculated for each pixel and available as a map layer and associated attribute table. LandTrendr performance depends on cloud-masking, thresholds, and other parameters that are set by the user.



Map 4. Comparison of hemlock sawfly damage mapped during aerial survey (yellow) and forest change detected by ORD (red).

In addition to script and instructions for producing change maps, the Kennedy Lab also provided a set of powerful spatial and temporal exploration/observation tools (e.g. http://emapr.ceoas.oregonstate.edu/tools.html). Specialized tools, like the Red Green Blue (RBG) tool in GEE Code Editor Platform, allow users to quickly and easily observe satellite-detected change on a map for any set of years anywhere in Alaska within the 21-year window (1999-2019). The user adjusts the years and spacing between years that will be represented as red, green, or blue, selects the reflectance index, and adjusts parameters or accepts default options. When no change is detected, the map pixel retains a grey to white tone. Locations that experience a decrease or increase in reflectance value display a color representative of the year(s) change occurred. A color key helps with interpretation (Figure 17).

A second tool provided by the Kennedy lab compliments the RGB map by creating time-series graphs beside the map (Figure 18). Each graph displays band or index values over time for a pixel or a group of adjacent pixels that are selected by the user. Reflectance values are represented by a blue line, and LandTrendr values are delineated in red. Time-series graphs can be created for any location that has been processed by LandTrendr (e.g., the entire state of Alaska and the contiguous United States). This tool allows you to view how well change is detected using LandTrendr with different bands or indices.

A third tool displays time-lapse Landsat imagery for the location and time period selected by the user. It can be accessed at https://emaprlab.users.earthengine.app/view/lt-gee-time-series-animator.

Script provided by the Kennedy Lab in GEE allows the user to process Landsat imagery and create visual layers and change maps that can be saved to Google Drive and brought into GIS for further processing and examination. Raster layer properties may be adjusted to display colors of pixels according to their values. Being able to observe the relative change in reflectance that has occurred for a location is important for understanding how it relates to the change that is seen by aerial surveyors. Changes in reflectance values can range from low-magnitude (noise and subtle defoliation) to mid-magnitude (defoliation and tree mortality) to high-magnitude (fire, landslides, and harvest). It may be possible to relate the magnitude of change to both the severity of the disturbance and, with enough supplemental information about disturbance timing and forest attributes, the cause of damage.

The third independent effort in remote sensing is the Landscape Change Monitoring System (LCMS). The LCMS model uses an ensemble of Landsat-derived data inputs to a random forest model to determine if vegetation has changed (gain or loss); the data consist of outputs from LandTrendr and another similar change-

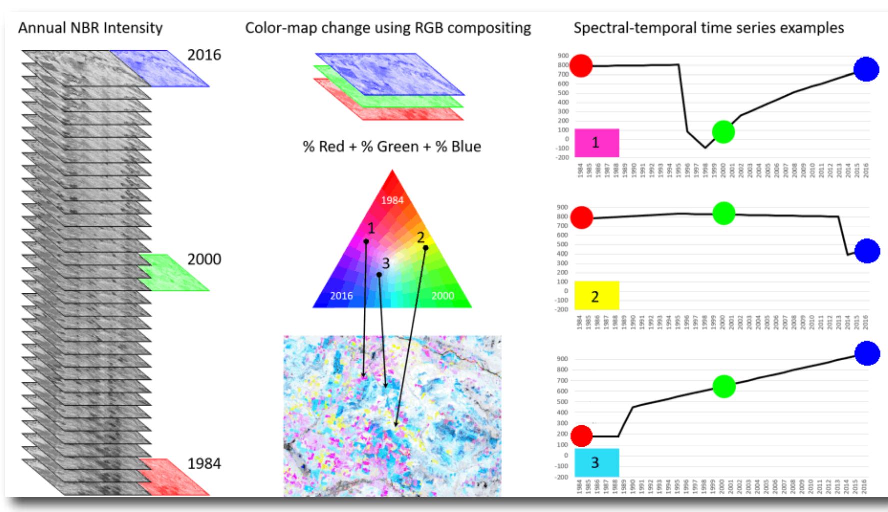


Figure 17. A triangular color key to aid interpretation of the RGB map. Figure from OSU eMapR Lab (https://emapr.github.io/LT-GEE)

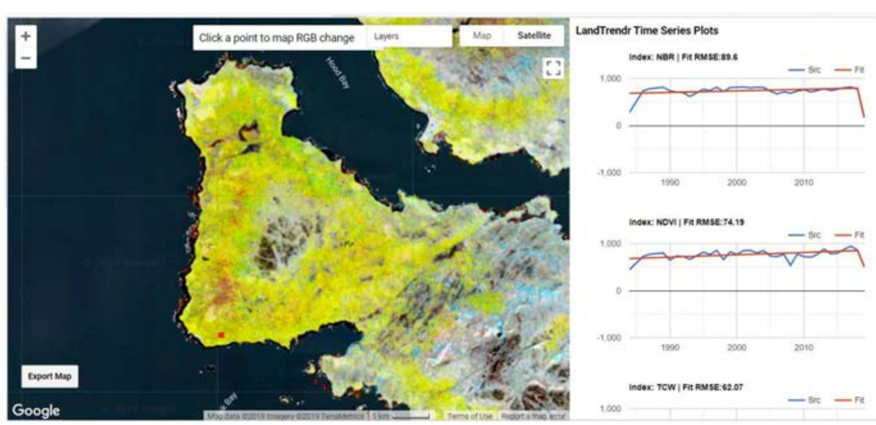


Figure 18. Example results from the RGB and time-series tools (Gorelick et al., 2017).

detection algorithm, Verdet, applied over many spectral bands. This represents a more complex change-detection process than either ORS or LandTrendr and it has potential to more accurately detect change based on probability. LCMS models vegetation loss and gain for every year in the modern Landsat data record, back to 1985 (although, as noted earlier, there are many data gaps before 1999, especially in Alaska). The modeling system's strength lies in its ability to represent the history of change in an area, rather than serving as an alert system for change in real-time. Therefore, this approach would not meet objectives related to route-planning for ADS based on early indicators of forest change within a survey season.

In Alaska, the LCMS project focused specifically on the Kenai Peninsula and Chugach National Forest. Project results and user interface can be found at https://lcms-data-explorer.appspot.com/ (use the Title drop-down arrow to select Chugach National Forest – Kenai Peninsula). This online data viewer allows you to view vegetation loss or gain for each year in the data record and includes pixel query and area summarization tools. The data may also be downloaded from the website for use in a different environment. We have not yet used LCMS data for forest health monitoring, but we would like to test its utility. LCMS is being produced by the Resource, Mapping, Inventory, and Monitoring (RMIM) group at the Geospatial Technology and Applications Center (https://aps.fs.usda.gov/gtac/).

Limitations and error

Using these tools, we come to understand the applications, strengths and weaknesses of each approach, and where improvements are needed. For our first objective: a pre-survey change map that guides aerial survey, the data is not required to be error-free; it is useful if it simply indicates areas that should be investigated during survey. Moreover, disturbance agents do not require differentiation because determinations are made during aerial or ground surveys by surveyors, who assess tree damage at a finer scale than is possible with satellite imagery. Nevertheless, we learn through application: when the first ORS change map was compared with 2019 ADS results, we noted a large discrepancy and discovered that much of the difference was because the imagery lagged behind the survey by as much as one month. New damage created by hemlock sawfly became visible in mid-July, but the latest Landsat and Sentinel imagery that could be obtained at that time was from May and June. Cloud cover prevented the use of more current imagery. The result was that ORS did not detect much of the recent 2019 damage prior to our survey in late July. This kind of error is called omission error, and it highlights the importance of image date when comparing imagery for change detection. MODIS is sometimes considered best for "real-time" change detection because new images become available every 1-2 days.

Commission error, the inclusion of change that is not forest damage, has also been observed in change-detection results. This year ORS detected expansive change across a sparsely treed area on Prince of Wales that was not supported by ADS observations. We have yet to thoroughly investigate the cause of this discrepancy. Trees or shrubs may have been damaged but not obvious to surveyors, the damage may be very light, or the change could be related to the presence of surface or atmospheric moisture. Commission error is commonly caused by clouds, cloud shadows, and surface water or snow that are detected as change by remote sensing tools. This kind of error is typically reduced by using a masking and mosaicking process to replace compromised imagery pixels with clear pixels. Region-specific knowledge is helpful in this case as well. For example, the Kennedy lab extended cloud-shadow mask area for Alaska because longer cloud shadows are cast at higher latitudes, and variable amounts of surface water can be as problematic as snow, requiring development of a surface-water mask.

Even with reductions in omission and commission error, there are some forest damages that we may never be able to detect at the spatial resolution or frequency of Landsat imagery. On one hand, hemlock sawfly defoliation created a blanket of brown trees that was easily detected in mid to late summer. On the other hand, detecting the slow and scattered change associated with yellow-cedar decline has proven more challenging. Color change in the individual crowns of dispersed actively dying trees does not register in a 30 m pixel relative to other variation, especially since yellow-cedar is commonly outnumbered by other tree species. In other words, the heterogeneous color change of forests progressively dying from yellow-cedar decline impedes detection. Yet, there may be other associated attributes we have not incorporated that could improve yellow-cedar decline detection, such as the abundance of silver snags (representing past impacts from yellow-cedar decline). As technology continues to improve we will learn the potential and limitations of new tools and their applications as we go.

Moving forward

To determine the extent, severity, and trends for past disturbances (our second and third objectives), we need a thorough understanding of the remote sensing methods, including limitations and error. We also need to understand regional landscape characteristics; local climate/weather patterns; active disturbance agents; host plant distributions; and how damages are expressed (e.g., the pattern, timing, color change, and magnitude of symptoms); and numerous other attributes that will allow us to differentiate change caused by a specific agent or agent complex. In the next year, we would like to consider how multi-variate statistical methods can relate satellite-detected change to disturbances documented by ADS so that we can estimate the extent and severity of known outbreaks in Alaska, such as the hemlock sawfly in Southeast Alaska. One advantage of satellite imagery is that it provides a consistent, enduring record of the landscape. Change-detection methods that use satellite imagery inputs can be documented, repeated, revisited, and adapted with new information as needed at any time. We are fine-tuning and testing these methods in hopes of harnessing the power of this incredible tool.

Collaboration

Collaboration has been critical to the development of remote sensing methodologies. Through networking, communication across disciplines, and grant funding opportunities, we have been able to corral much needed and diverse skillsets. GIS specialists/mapmakers and statisticians are helping to create the tools that will aid forest health monitoring, but not without feedback from entomologists, pathologists and aerial surveyors, who understand the regional landscape patterns, forest dynamics, and the biology and behavior of forest pests. We must pool our resources and work together to develop tools and innovative solutions that will improve the work we do.

If you would like more information or a demonstration of these tools, please contact Karen Hutten by email at karen.hutten@usda.gov or by phone at (907) 586-7807.

STATUS OF DISEASES

US Forest Service Biological Technician Dana Brennan uses a staple gun to wound aspen trees for inoculation trials. We are inoculating healthy trees with candidate fungi that we isolated from diseased trees.

2019 PATHOLOGY SPECIES UPDATES

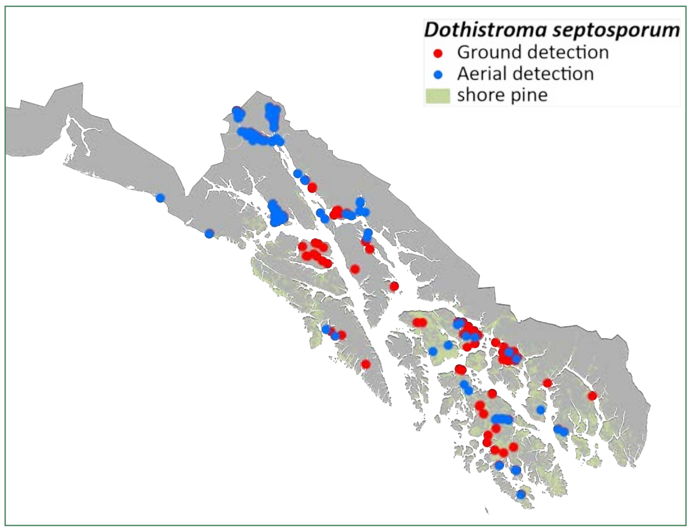
Foliar Diseases

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

In 2019, aerial surveyors mapped about 350 acres of Dothistroma needle blight (Figure 19) damage of shore pine in Southeast Alaska, only one-tenth of the acreage mapped in 2018. Southeast Alaska's recent dry summer weather likely reduced disease pressure. Damage was aerially mapped on central Prince of Wales Island, northern Gravina Island and near Gustavus. A few other places are localized hotspots for Dothistroma needle blight, particularly muskegs near Juneau (Pt. Bridget State Park and Douglas Island), Petersburg (Hungry Point Trail) and Sitka (Gavin Hill Trail). This disease occurs throughout the range of shore pine in Alaska (Map 5).

The red-brown crown discoloration mapped near Gustavus in 2018 and 2019 may be residual mortality from the 2010-2016 outbreak that killed 57% of shore pine in heavily affected forests. Many dominant and codominant pines only had foliage in the upper 1-3ft of tree crowns in established monitoring plots. Preliminary results from a genomics study of the pathogen across western North America suggest that the Gustavus population of *Dothistroma septosporum* is more closely related to populations in British Columbia than to all other populations in Southeast Alaska. This may be due to the timing and pathway of pathogen migration into Alaska, this is one of the questions that Renate Heinzelmann is investigating at the University of British Columbia. Consecutive rainy days and temperatures > 62°F are known to cause Dothistroma outbreaks; therefore, deadly outbreaks are strongly linked to climate trends. Outbreaks in managed lodgepole pine forests in British Columbia have been linked to climate change.

Figure 19. Fruiting structures of *Dothistroma septosporum* and the symptomatic orange bands it causes.



Map 5. Dothistroma needle blight cumulative mapped locations and modeled host tree distribution(s).

Hemlock-Blueberry Rust

Naohidemyces vaccinii (Wint.) Sato, Katsuy et Hiratsuka

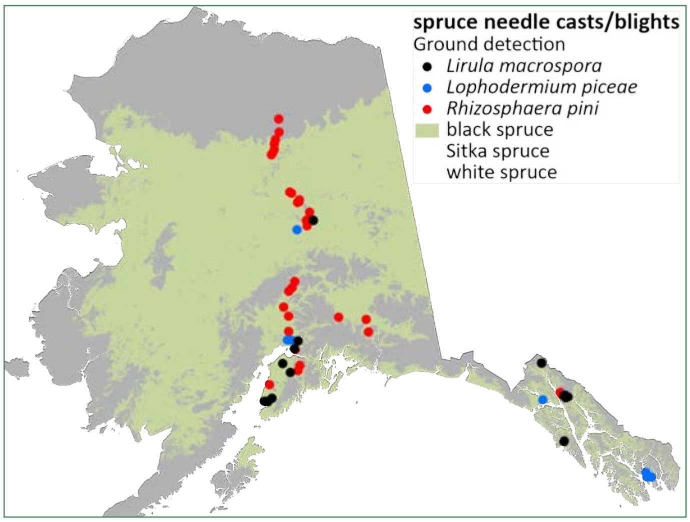
Hemlock-blueberry rust is usually a disease of minor importance that can be difficult to find on both blueberry leaves and hemlock needles. However, in 2019, this disease was widespread on multiple blueberry species and western hemlock needles in Southeast Alaska (Figure 20). Warm, dry weather may have facilitated more successful spore dissemination. Another conifer needle rust, spruce needle rust, was also in outbreak mode in 2019. Other fungi, such as *Exobasidion maculosum*, also caused blueberry leaf spots this year.

Figure 20. Hemlock-blueberry rust, causes yellow leaf discoloration symptoms on blueberry leaves (left) and orange fruiting structures of the causal agent *Naohidemyces vaccinii* on hemlock needles (right).

Spruce Needle Casts/Blights

Lirula macrospora (Hartig) Darker
Lophodermium piceae (Fuckel) Höhn
Rhizosphaera pini (Corda) Maubl.

Three fungi cause needle blight of spruce throughout much of Alaska (Map 6). In fall 2019, notable Rhizosphaera needle blight damage was noted on Sitka spruce in Juneau in the Mendenhall Valley, around Auke Lake, and north along the road system (Figure 21). Lirula needle blight caused pronounced damage to spruce species from 2014–2017 but was less prevalent in 2019. Lophodermium needle cast is another common but minor foliage disease of spruce in Alaska.



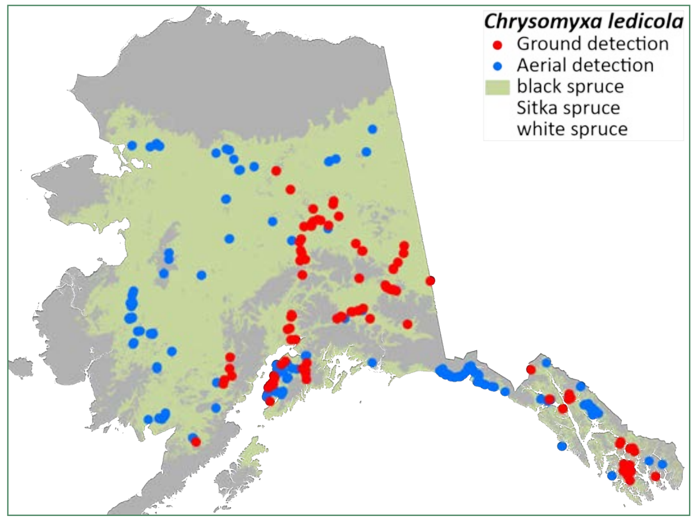
Map 6. Spruce needle casts/blights cumulative mapped locations and modeled host tree distribution(s).

Figure 21. Black fruiting structures of *Rhizosphaera pini* on Sitka spruce needles collected near Juneau in November 2019 and the red-brown needle discoloration symptoms.

Spruce Needle Rust

Chrysomyxa ledicola Lagerh.

Spruce needle rust has historically been observed throughout much of Alaska's spruce forests (Map 7). In 2019, a major outbreak was mapped across 116,000 acres, especially in Wood-Tikchik State Park and south along the Nushagak River to Bristol Bay (Figure 22). It is one of few diseases discernible from the air when severe damage coincides with the aerial survey, which it did this year in western Alaska. Ground observations were common throughout most of the state. There was especially impressive damage in Southeast Alaska near muskegs with the alternate host, Labrador tea. This disease rarely results in tree mortality since severe damage does not typically occur at the same locations year after year. Moderate to high levels of disease also occurred in many parts of the state in 2017 and 2018.



Map 7. Spruce needle rust cumulative mapped locations and modeled host tree distribution(s).

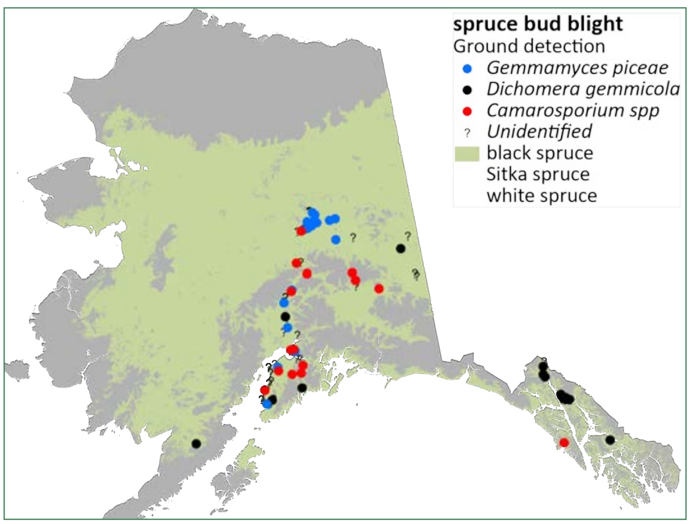
Figure 22. Spruce needle rust caused large areas of white spruce forest in southwestern Alaska to appear orange from the air in 2019.

Shoot, Twig, and Bud Diseases

Spruce Bud Blights

Camarosporium sp.
Dichomera gemmicola A. Funk & B. Sutton
Gemmamyces piceae (Borthw.) Casagrande

We continued to document numerous findings of spruce bud blight throughout Southcentral and Interior Alaska (Map 8). Although many (17) of these sightings remain unidentified (due to the need of a microscope to distinguish causal fungi), we did identify several instances of *G. piceae* (14; Figure 23) from Kenai to Fairbanks and *Camarosporium* (3) south of the Alaska Range. We did not find *D. gemmicola* in 2019. No bud blight was detected in Southeast Alaska in 2019, consistent with apparently lower disease incidence and severity. In 2017, Dr. Gerard Adams (University of Nebraska Lincoln) determined that identical signs and symptoms were caused by three different fungal pathogens. All three of these fungi had not previously been reported from Alaska, although *D. gemmicola* and *Camarosporium* have been known for decades in other parts of North America. *G. piceae* is known as a tree killer in Colorado blue spruce plantations in Central Europe, but we have not seen mortality in Alaska. Despite an effort to collect sexual fruiting structures of *G. piceae* in Alaska in 2017/2018 for a population genetics study, this fungal pathogen has proven extremely difficult to obtain pure cultures. This work was intended to provide insight as to how long the fungus has been present in Alaska based on genetic diversity.



Map 8. Spruce bud blight cumulative mapped locations and modeled host tree distribution(s).

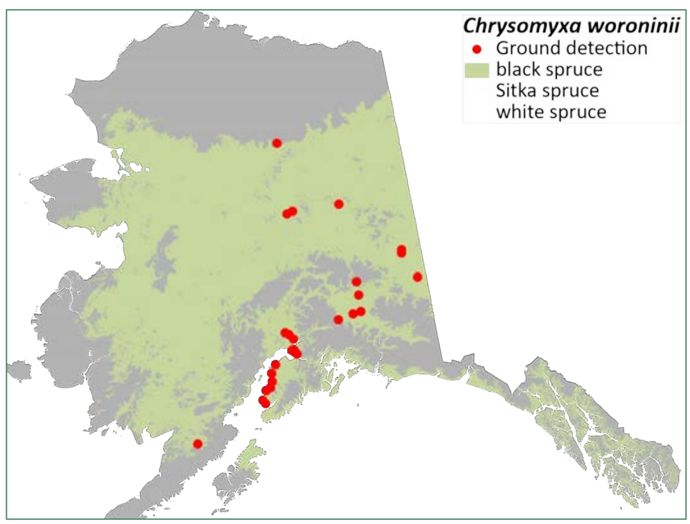
Figure 23. *Gemmamyces piceae* on white spruce buds near Anchorage.

Spruce Bud Rust

Chrysomyxa woroninii Tranz.

Spruce bud rust was noted in 21 locations from Homer, north to the Brooks Range, and east to the Canadian Border in 2019. Since its first report in Alaska on white spruce near Fairbanks in 1979, we have recorded its occurrence on white, black, Lutz, and Sitka spruce throughout Southcentral and Interior Alaska (Map 9). Nearly all observations occurred in 2018 and 2019. We have found it as far north as Coldfoot in the southern Brooks Range, as far southwest as Katmai National Park, and east to the Tetlin National Wildlife Refuge near the Canadian Border. The disease results in stunted shoot formation due to infection of buds and female cones (Figure 24). The disease also has life cycle stages on Labrador tea (*Ledum* spp.).

Figure 24. Spruce bud rust caused by *Chrysomyxa woroninii* found on white spruce along the Top of the World Highway.



Map 9. Spruce bud rust cumulative mapped locations and modeled host tree distribution(s).

Yellow-Cedar Shoot Blight
Kabatina thujae Schneider & Arx

In 2018, we received samples of yellow-cedar cones infected with a fungal pathogen on Prince of Wales Island near Naukati (Figure 25). We sent fungal cultures and diseased cone tissue to Dr. Jane Stewart at Colorado State University for molecular diagnosis. The cultures were identified as *Kabatina thujae* and further work with infected tissue will help to confirm this fungus as the causal agent. The truest confirmation will come from intentionally inoculating healthy yellow-cedar cone buds with the fungus to reproduce the disease. It is interesting that *Kabatina thujae* is the likely cause of this cone disease, since the fungus commonly causes shoot blight; the damage to cones has not been previously observed or documented in Alaska. Terminal and lateral shoots of yellow-cedar seedlings and saplings typically die from this disease in early spring, and symptoms can be confused with frost damage. Long-term tree structure is not thought to be compromised by leader infections. Jeff Stone at Oregon State University identified the causal fungus in 2013.

Figure 25. Diseased, blackened yellow-cedar cones were collected near Naukati on Prince of Wales Island. The causal fungus appears to be the shoot blight fungus, *Kabatina thujae*.

Stem and Branch Diseases

Alder Canker
Valsa melanodiscus Otth.
Valsalnicola spp. D. M. Walker & Rossman
And other fungi

Alder dieback, usually caused by canker-causing fungi, was aerially mapped across about 1,200 acres throughout Southcentral and Interior Alaska in 2019. This continues a generally decreasing trend since peaks in 2011 and 2014 (Figure 26). Ground observations have also greatly decreased and were negligible in 2019. Significant alder dieback began in 2003 on thin-leaf alder and since then we have mapped it on all alder shrub species throughout most of the state (Map 10). *Valsa melanodiscus* was identified as the main causal fungus; however, several other canker fungi also contribute to thin-leaf alder dieback. Dieback on Sitka alder in Southcentral and Siberian alder in the Interior became noticeable around 2014. When alder canker roadside surveys were repeated in 2016 after the inaugural survey in 2006, alder canker was detected at twice as many monitoring sites and showed a marked increase in canker incidence on Sitka and Siberian alder. Alder canker has also been confirmed on Sitka alder in Southeast Alaska, but damage there has not been severe.

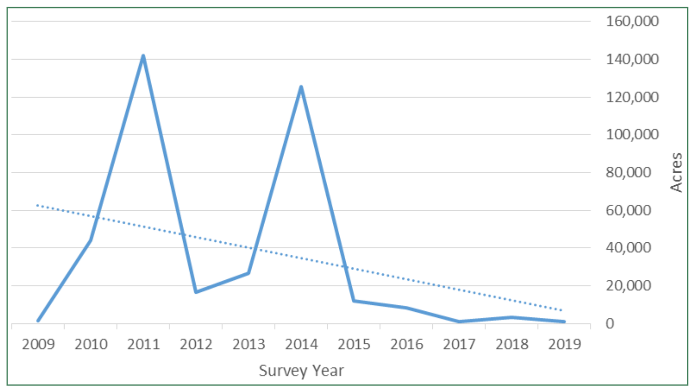
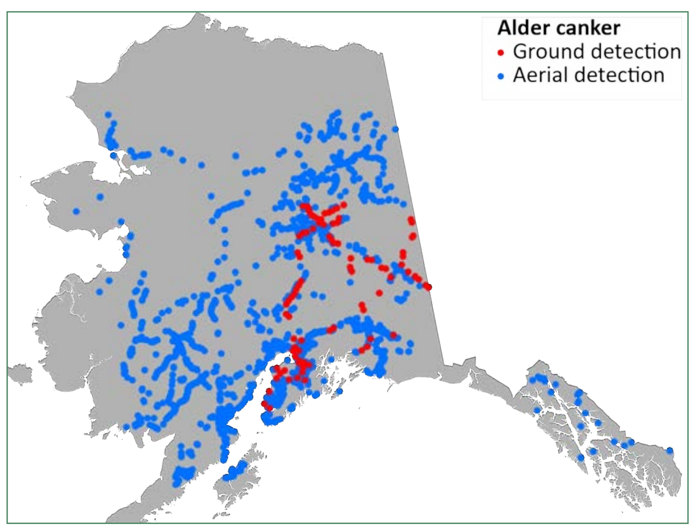


Figure 26. Alder dieback mapped by the Aerial Detection Survey since 2009. Peak years were in 2011 and 2014. A general trend (dotted line) of declining mapped acreage corresponds with ground observations.

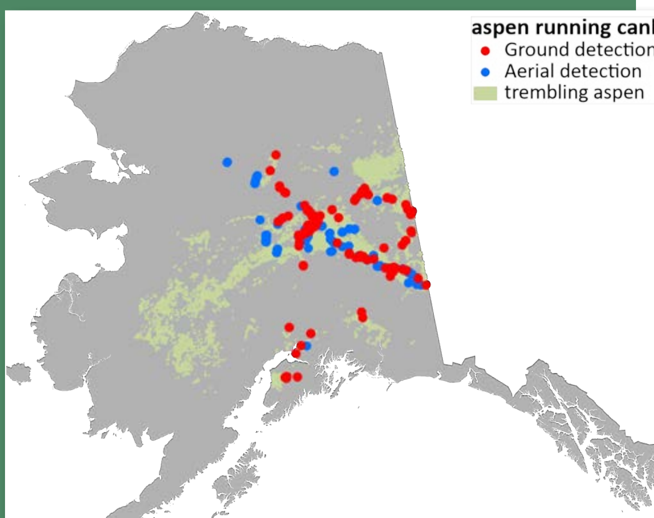


Map 10. Alder canker cumulative mapped locations and modeled host tree distribution(s).

Aspen Running Canker

Formal fungal description in progress

Aspen running canker has been mapped throughout the boreal forest of Interior and Southcentral Alaska since it was first noted in 2015 (Map 11). Most of these locations were found during ground surveys, but we also began mapping this disease in the aerial detection survey in 2018. Because it is so widespread and often found far from roads and population centers, this disease is most likely caused by a native pathogen that is favored by current conditions of its host and/or environment. The organism that causes the disease does not form diagnostic fruiting bodies. Therefore, we have partnered with Dr. Gerard Adams (University of Nebraska Lincoln) and isolated several fungi from diseased tissue. We then inoculated healthy aspen trees with these candidate pathogens. We have preliminarily identified the causal agent using this technique.



Map 11. Aspen running canker cumulative mapped locations and modeled host tree distribution(s).

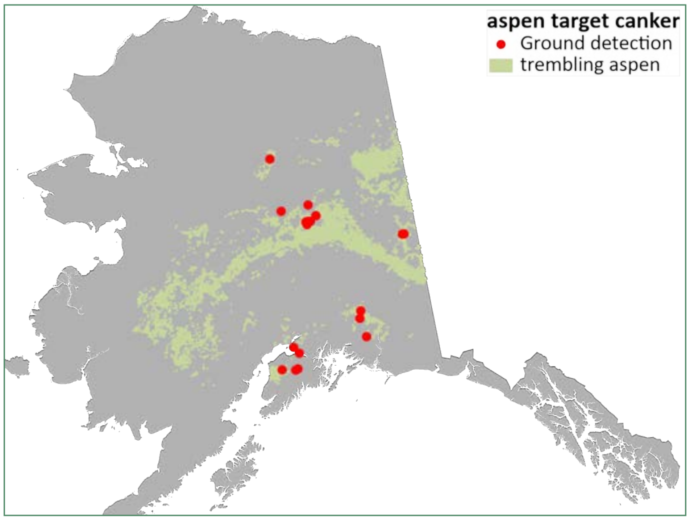
This is a very aggressive canker disease that can rapidly kill the cambium as it spreads along the tree bole (Figure 27). In smaller trees in older stands, the lesions can girdle and kill trees within a single season with no apparent host defenses. However, young, even-aged abutting stands which have plenty of resources and growing vigorously have almost no disease. We initiated a joint venture with Dr. Roger Ruess (University of Alaska Fairbanks) in 2016 to gain a better understanding of the factors influencing disease distribution and tree responses to infection. A shading experiment was installed to test the hypothesis that vigorous trees have defenses to combat the disease. We are further exploring whether defenses are constitutive or induced by using transcriptomics to compare gene expression differences between diseased and healthy tree.

Figure 27. Aspen running canker on trembling aspen near Ester. The fast moving lesion is discolored orange whilst the healthy bark is green.

Aspen Target Canker

Cytospora notastroma Kepley & F.B. Reeves
And other fungi

We have mapped aspen target canker at 22 locations from the Kenai Peninsula, to Chicken near the Canadian border, and north to the White Range (Map 12). In contrast to the aspen running canker, it occurs in relatively small, localized pockets. This disease progresses slowly, and individual canker length and breadth is limited by tree response. The cankers are distinctively target-shaped with flaring bark (Figure 28). It takes many years until numerous cankers form on a tree bole and effectively disrupt vascular transport to kill a tree. We have isolated the fungus *Cytospora notastroma* from these cankers. *C. notastroma* is a newly described pathogen that has been found to be a major contributor to Sudden Aspen Decline in the Rocky Mountains. Further work is needed to determine whether this is the only pathogen involved in aspen target canker in Alaska.



Map 12. Aspen target canker cumulative mapped locations and modeled host tree distribution(s).

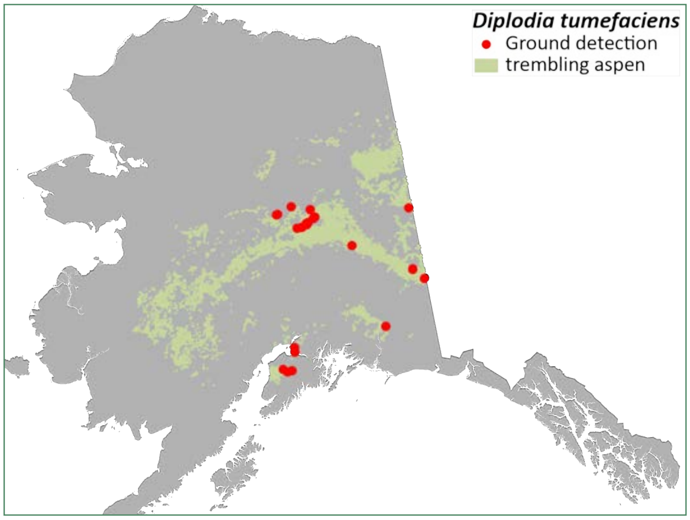
Figure 28. Aspen target canker on trembling aspen in the Bonanza Creek Long-Term Ecological Research site.

Diplodia Gall

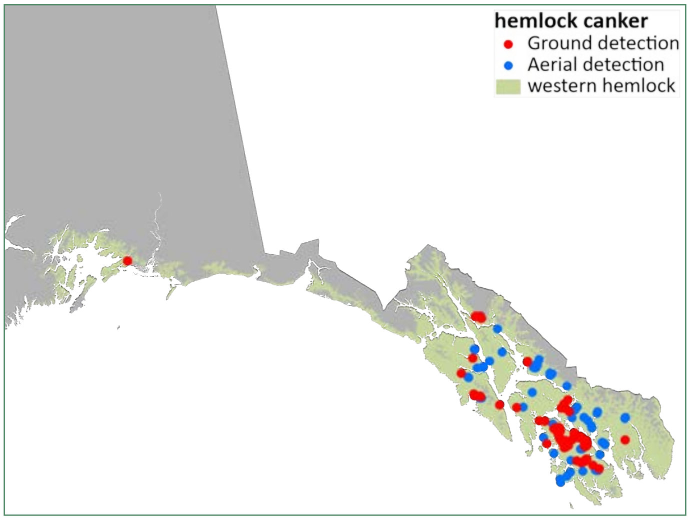
Diplodia tumefaciens (Shear) Zalasky

Diplodia gall (Figure 29) was recorded at 11 sites in 2019. Over the past few years we have documented its occurrence from the Kenai Peninsula, east to the Canadian border, and to the north of Fairbanks (Map 13). This disease is reportedly distributed throughout North America on trembling aspen, balsam poplar, and other *Populus* species, but to date we have only recorded it on aspen. The patches are generally small and discrete, less than 2 acres in size. When occurring on the trunk, it strongly resembles Chaga, also known as the cinder conk (*Inonotus obliquus*); however, Diplodia gall has only been found on aspen in Alaska, whereas the cinder conk is most common on birch. Diplodia galls can weaken stems and branches, but generally does not kill trees.

Figure 29. Diplodia gall on trembling aspen near Minto.



Map 13. Diplodia gall cumulative mapped locations and modeled host tree distribution(s).



Map 14. Hemlock canker cumulative mapped locations and modeled host tree distribution(s).

Figure 30. With the bark of western hemlock removed, the lesion around the inoculation hole can be measured. This lesion was caused by a species of *Pezicula*, which tended to cause the largest lesions to develop of all fungi used in the inoculation trial.

Hemlock Canker
Unknown fungus

There was negligible active hemlock canker damage in 2019. A significant hemlock canker outbreak occurred throughout Southeast Alaska from 2012-2017, with the most substantial damage mapped through roadside surveys on Prince of Wales Island (Map 14). Hemlock canker causes synchronized tree and lower branch mortality along forest edges and can only be aerially mapped when it occurs along coastlines. Recent outbreaks have persisted longer and been noted farther north (Juneau and Cordova) and farther from roads than past reported outbreaks.

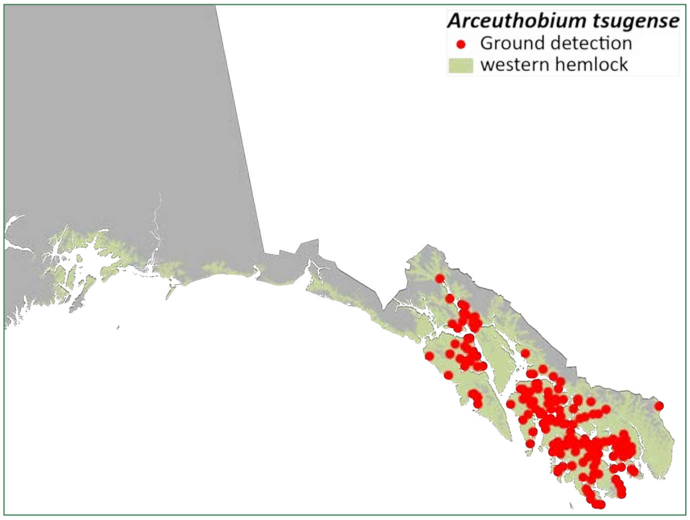
Over the last several years, live tree inoculation trials have been conducted in collaboration with Dr. Gerard Adams at the University of Nebraska to determine the causal fungus. In June 2018, more than 500 live hemlock saplings were inoculated with 12 fungal isolates and a control treatment near Juneau. Lesion development was measured in 2019 and several top pathogens caused consistently larger lesion development than the control treatment (Figure 30). The pathogen that caused the largest lesions was *Pezicula livida* (or a closely related species), followed by *Allantophomopsis tsugae*, *Discocainea treleasei, Chalara* sp., *Dermea* sp. and *Caliciopsis* sp. Identification of our *Pezicula* and *Dermea* isolates to species will require DNA sequencing of at least four different genes and may yet remain as unnamed species (not previously collected and molecularly identified).

Hemlock Dwarf Mistletoe

Arceuthobium tsugense (Rosendahl) G.N. Jones

Hemlock dwarf mistletoe, a parasitic plant, is the leading disease of western hemlock in unmanaged old-growth stands in Southeast Alaska (Figure 31). Hemlock dwarf mistletoe brooms (prolific branching) provide important wildlife habitat, contribute to canopy gap creation, and serve as infection courts for decay fungi. Clear-cutting reduces or eliminates dwarf mistletoe in second-growth timber stands. Managers can choose to retain some mistletoe-infected trees for wildlife benefits, since growth loss and mortality only occur at high infection levels. Hemlock dwarf mistletoe is uncommon above 500 feet in elevation and 59 °N latitude (Haines, AK) and is absent from Cross Sound to Prince William Sound despite the continued distribution of western hemlock (Map 15).

Figure 31. Hemlock dwarf mistletoe, caused by *Arceuthobium tsugense*, on western hemlock.

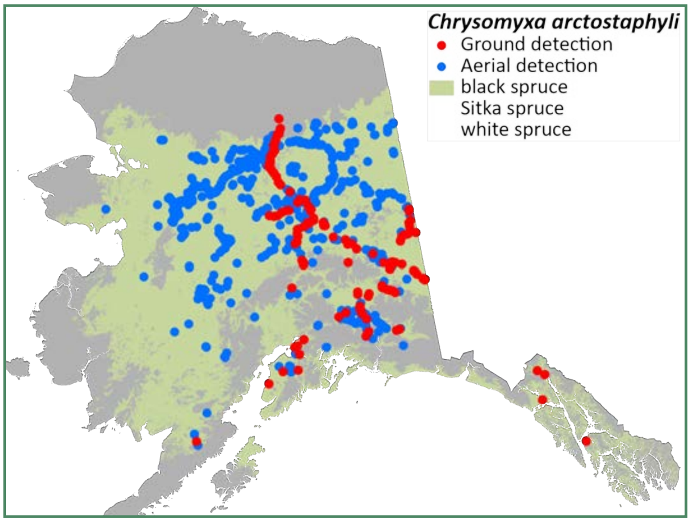


Map 15. Hemlock dwarf mistletoe cumulative mapped locations and modeled host tree distribution(s).

Spruce Broom Rust

Chrysomyxa arctostaphyli Diet.

In 2019 nearly 50 ground observations and 141 aerial observations were added to the map (Map 16). The incidence of perennial brooms in spruce crowns changes little over time, although aerial detection varies by surveyor, locations flown, and timing of color changes. In 2018, an observation was made on the Seward Peninsula, over 100 miles west of previous detections and west of the proposed range of *Arctostaphylos uva-ursi*, the alternate host plant (based on Hulten, 1968, Flora of Alaska). This part of the state was not flown in 2019 to confirm the record. Broom rust is common and widespread on white and black spruce branches and stems throughout Southcentral and Interior Alaska (Figure 32); it is absent from most of Southeast Alaska aside from Glacier Bay, northern Lynn Canal and Halleck Harbor on Kuiu Island.

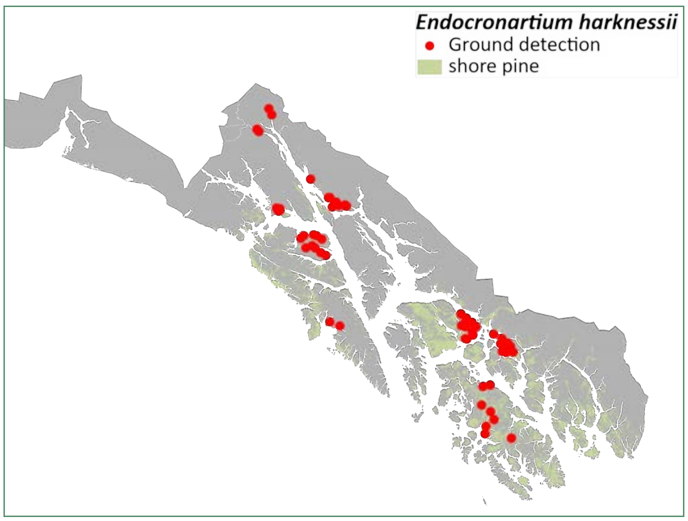


Map 16. Spruce broom rust cumulative mapped locations and modeled host tree distribution(s).

Figure 32. Spruce broom rust on black spruce near the Yukon River.

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

Western gall rust does not require an alternate host and is common throughout the range of shore pine in Southeast Alaska (Map 17). The incidence of western gall rust, which typically causes spherical swellings on branches and tree boles, does not vary significantly from year to year. In permanent plots established to evaluate shore pine health in Southeast Alaska, 85% of live pines were infected and infection was detected in all plots. Thirty-four percent of monitored trees had at least one gall on the main stem (bole galls) that could lead to top kill or whole tree mortality, and 25% had dead tops associated with bole galls (Figure 33). In June 2017, western gall rust was observed sporulating at the edge of a large, diamond-shaped canker on a shore pine tree bole, suggesting that it likely causes this common type of bole canker. Secondary insects and fungi frequently invade gall tissue, girdling infected boles and branches. Another stem rust, stalactiform blister rust caused by *Cronartium coleosporioides*, was detected on shore pine near Haines (molecularly confirmed) and Gustavus (suspected).



Map 17. Western gall rust cumulative mapped locations and modeled host tree distribution(s).

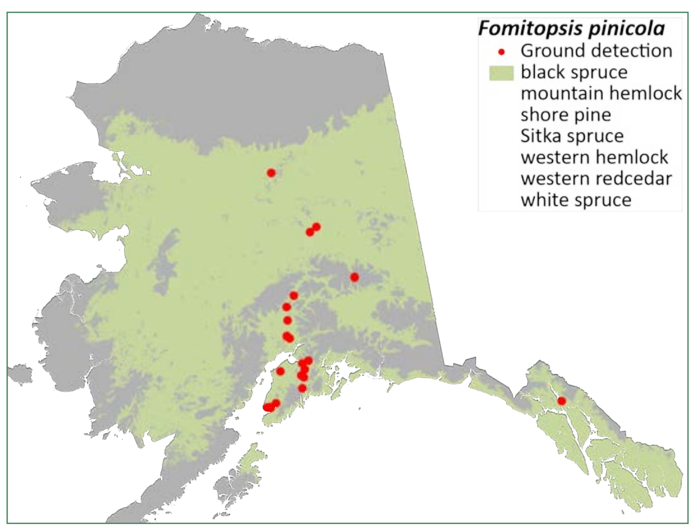
Figure 33. Fresh topkill and branch dieback of shore pine near Hoonah. This occurs when secondary insects and fungi invade the spherical swellings of western gall rust, girdling stems and branches.

Stem Decays

Brown Crumbly Rot
Fomitopsis pinicola (Swartz ex Fr.) Karst

Over 30 observations of *Fomitopsis pinicola* (red belt conk) were recorded in 2019. Many of these were associated with the substantial spruce beetle activity in the Matanuska-Susitna Valley on white spruce. In this area, many of the spruce beetle-killed trees snapped off in the lower bole to mid-bole. Almost all of them had red belt conks and brown, crumbly, decayed wood with mycelial mats in the cracks (Figure 34). Two popular Southcentral Alaska state campgrounds were closed in 2019 (Byers Lake Campground and South Rolly Lake Campground in the Nancy Lakes State Recreation Area) because of hazard trees. It is assumed that the trees had been infected long before they snapped because of the extensive advanced decay. *F. pinicola* is presumed to occur throughout the range of its hosts and has been recorded on all spruce and hemlock species in Alaska (Map 18).

Figure 34. Internal decay created hazardous white spruce trees north of Trapper Creek. Conks of *Fomitopsis pinicola* were visible at the bottom of the broken bole.

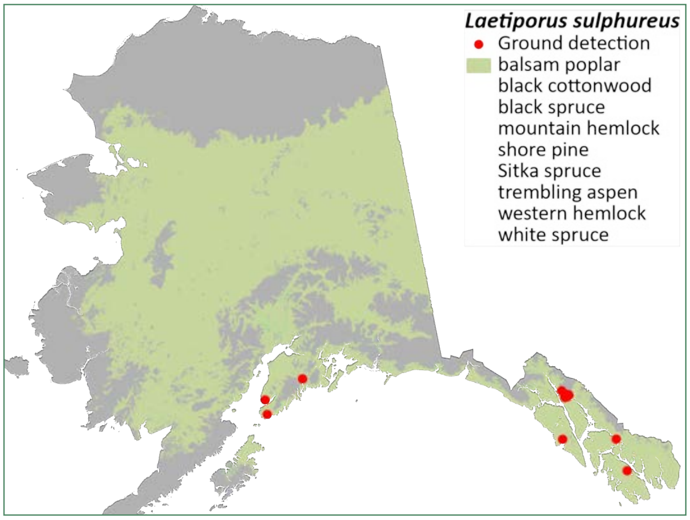


Map 18. Brown crumbly rot disease cumulative mapped locations and modeled host tree distribution(s).

Brown Cubical Rot

Laetiporus sulphureus (Bull. Ex Fr.) Bond. Et Sing.

Found mainly on host trees of the coastal forest, in 2019 we recorded this fungus on Sitka spruce on the southern Kenai Peninsula and on western hemlock near Juneau (Map 19). Occurring on both living and dead trees, its presence indicates significant internal decay (Figure 35), generally in the butt. Therefore, when found in recreation sites, trees should be considered hazardous. In Southeast, this fungus is mainly seen on broken snags.



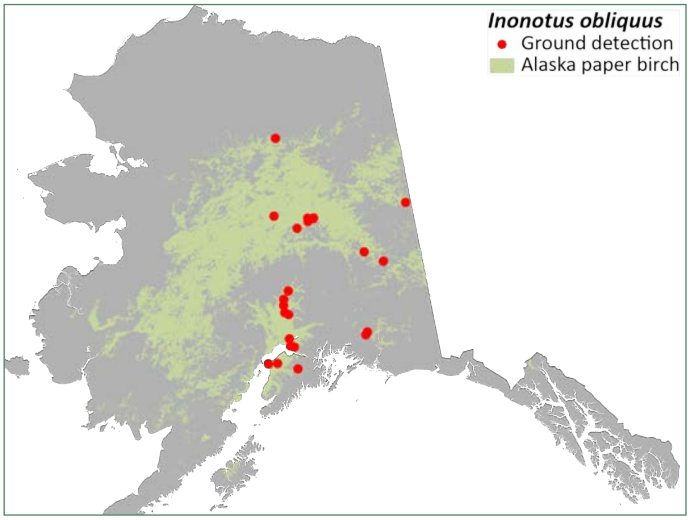
Map 19. Brown cubical rot disease cumulative mapped locations and modeled host tree distribution(s).

Figure 35. Ephemeral orange fruiting structures of *Laetiporus sulphureus* which causes brown cubical rot.

Canker-Rot of Birch

Inonotus obliquus (Pers.:Fr.) Pilat

Nine new locations of *I. obliquus* were recorded in 2019. We have documented it in numerous locations from the Kenai Peninsula, north to the Brooks Range, and east to Eagle (Map 20). Also known as Chaga, it is easy to identify on birch trees (Figure 36); a superficially similar symptom on aspen is the Diplodia gall. Unlike most stem decays, *I. obliquus* is a primary colonizer that kills and decays sapwood and the inner bark, killing it and the vascular cambium.



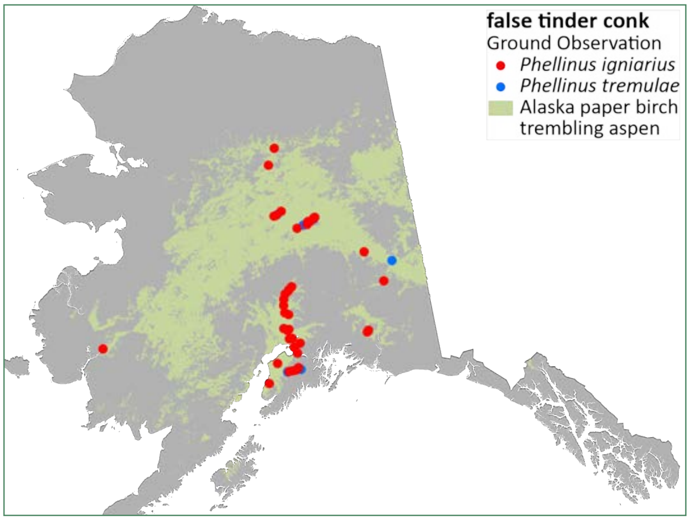
Map 20. Canker-rot of birch disease cumulative mapped locations and modeled host tree distribution(s).

Figure 36. *Inonotus obliquus* on birch near Fairbanks. This specimen has been chopped open to reveal the ochre interior.

Trunk Rot of Aspen and Birch

Phellinus igniarius (L.:Fr.) Quel.
Phellinus tremulae (Bord.) Bond et Boriss

We recorded 31 new locations of trunk rot on birch (caused by *P. igniarius*), including near the Arctic Circle on the Dalton Highway and north of Akiachak in the Yukon-Kuskokwim Delta. This disease is extremely widespread and common in Alaska on both live and dead birch trees (Map 21). Although reported on many hardwood species elsewhere, we have otherwise only recorded it on alder and willow species. This fungus is known as an important white rot of hardwoods in the cooler regions of northern temperate forests. Although it appears identical to *P. igniarius* (Figure 37), *Phellinus tremulae* only occurs on aspen and accounts for the majority of most aspen stem decay in Southcentral and Interior Alaska (Map 21). This fungus is considered the most important decay pathogen of aspen species in the Northern Hemisphere.



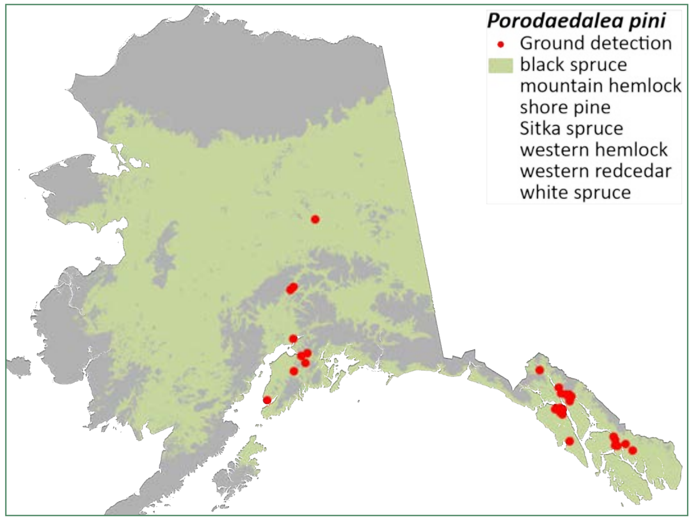
Map 21. False tinder conk cumulative mapped locations and modeled host tree distribution(s).

Figure 37. Conks of *Phellinus igniarius* (left) on birch, and *P. tremulae* (right) on aspen.

Red Ring Rot

Porodaedalea pini (Brot.) Murrill (=*Phellinus pini*)

P. pini was recorded on white spruce in Denali State Park, on mountain hemlock at two locations along Turnagain Arm, and on western hemlock near Juneau (Map 22). One of the Turnagain Arm locations was a large patch of more than 30 affected trees. Fruiting bodies (Figure 38) often occur near branch stubs on live trees and are an indicator of heart rot. Extensive internal decay is often indicated by multiple fruiting bodies along the length of the bole. Although primarily considered a heart rot, *P. pini* can progress into sapwood and kill trees.



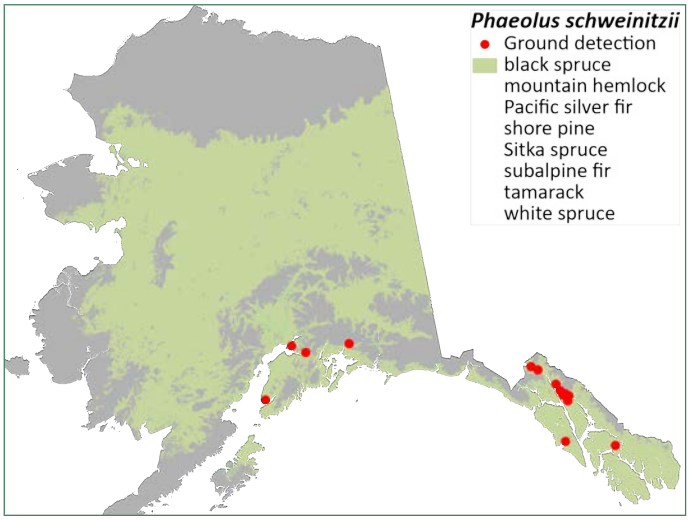
Map 22. Red ring rot disease cumulative mapped locations and modeled host tree distribution(s).

Figure 38. *Porodaedalea pini* on white spruce in Denali State Park.

Root and Butt Diseases

Brown Cubical Butt Rot
Phaeolus schweinitzii (Fr.:Fr.) Pat.

Phaeolus schweinitzii was recorded in six locations of Southcentral and Southeast Alaska on Sitka spruce, white spruce, and mountain hemlock in 2019. It is particularly common on Sitka spruce in Southeast Alaska (Map 23). The fruiting bodies are most noticeable in fall, emerging from decayed wood of broken tree boles or around the bases of the tree, connected to tree roots below ground (Figure 39). Damage can be most severe in areas with compacted or disturbed soils; for this reason, this fungus increases hazard tree issues at recreation sites, where infrastructure development or aggressive public use may inadvertently compromise tree roots and encourage infection. The brown cubical rot symptom of *P. schweinitzii* may easily be mistaken for that caused by the much more common *Fomitopsis pinicola*.



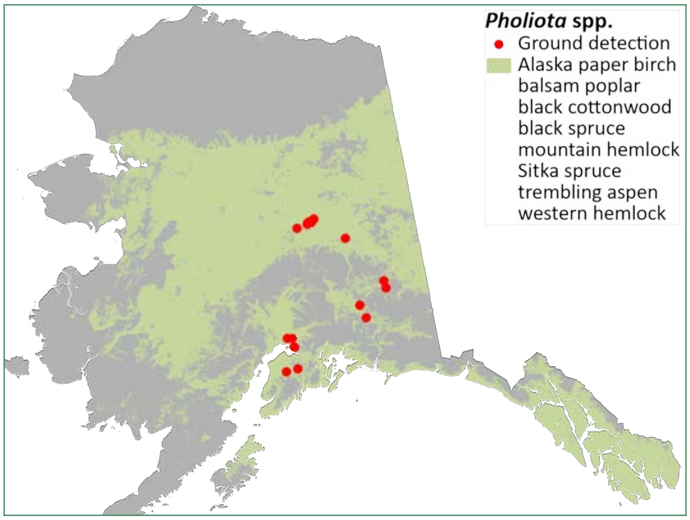
Map 23. Brown cubical butt rot disease cumulative mapped locations and modeled host tree distribution(s).

Figure 39. *Phaeolus schweinitzii* fruiting at the base of a Sitka spruce.

Pholiota Butt Rot
Pholiota spp.

In 2019, two records of *Pholiota* mushrooms were documented on aspen and birch (Figure 40) in the Tanana Valley, as well as one *Pholiota squarrosa* on willow. To date, many *Pholiota* occurrences have been mapped on aspen, birch, black spruce, and willow in Southcentral and Interior Alaska (Map 24) but most have not been identified to species. *Pholiota* mushrooms are most commonly found on the base of trembling aspen, but usually these trees have no symptoms until they uproot or snap near the root collar. Last year, mushrooms thought to be *Pholiota* were found on a live Sitka spruce and a western hemlock tree near Juneau during *Armillaria* collections; we hope to molecularly confirm the identification this year. *Pholiota* is less frequently encountered in Southeast Alaska than other parts of the state.

Figure 40. A species of Pholiota butt rot disease found on a wounded birch tree near Delta Junction.

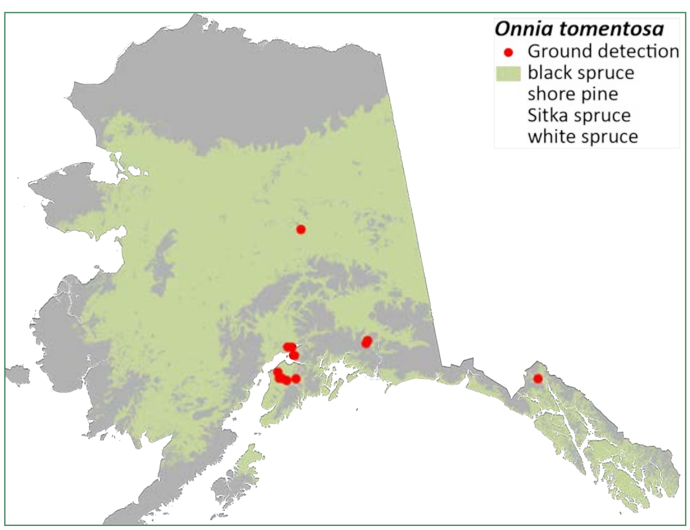


Map 24. Pholiota butt rot disease cumulative mapped locations and modeled host tree distribution(s).

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

We recorded two occurrences of *O. tomentosa* in 2019, both on the Kenai Peninsula. The pathogen is presumed to be widespread throughout spruce stands of Southcentral and Interior Alaska. However, because the fruiting structures are ephemeral (Figure 41) and it is difficult to confidently identify without them, it has only been confirmed and mapped in a few locations (Map 25). Post-harvest stump surveys in Interior Alaska have shown very high incidence of decay and stain symptoms consistent with Tomentosus; however, fruiting bodies of the fungus are usually not found at the time of survey. The lack of above-ground diagnostic features are obstacles to detection and comprehensive surveys. In Southeast Alaska, this pathogen has been reported on Sitka spruce and shore pine near Skagway, Haines, and Hoonah.

Figure 41. *Onnia tomentosa* on the ground near the base of white spruce in the Kenai National Wildlife Refuge.



Map 25. Tomentosus root disease cumulative mapped locations and modeled host tree distribution(s).

STATUS OF NONINFECTIOUS DISEASES AND DISORDERS

Topkill of western redcedar was common on Prince of Wales Island in 2019 and thought to be attributed to recent severe drought.

2019 NONINFECTIOUS DISEASES & DISORDERS UPDATES

Abiotic Damage

Windthrow, flooding, drought, winter injury, and wildfires are common forms of abiotic damage in Alaska and affect forest health and structure to varying degrees. Wildfire is not mapped during our aerial forest health surveys, but causes extensive tree mortality in Alaskan boreal forests, and may be especially severe after bark beetle outbreaks or in times of drought. The Alaska Interagency Coordination Center (https://fire.ak.blm.gov/) reported that 719 fires burned across over 2.6 million acres in 2019. Yellow-cedar decline is one of the best examples of climate-induced forest decline in the world and the decline mechanism is well-understood.

Drought

It is normal for conifers to lose older foliage (discoloration followed by needle loss) in fall as they approach winter dormancy. Excessively warm, dry conditions can increase needle shed as trees partition limited resources to more productive, younger foliage. Dry conditions in the Interior and Southcentral in 2019 likely caused the observed orange-brown discoloration damage to older foliage of many black and white spruce this year (Figure 42). Winter damage, or the interaction between drought and winter damage, may have contributed to crown discoloration symptoms, which became more apparent as summer progressed. In 2019, just over 2500 acres of drought damage were mapped, nearly all in Southeast Alaska. Extreme drought in the far southern panhandle is thought to have caused brown foliage discoloration of salal on Revillagigedo and Prince of Wales Islands in 2019, as well as topkill and mortality of western redcedar concentrated on Prince of Wales from 2017-2019 (see page 33). Recently, salal foliar damage has also been observed in British Columbia and may be caused by a combination of summer drought and winter freezing injury; no insects or diseases are consistently associated with the damage. Drought damage is difficult to confirm or refute; other biotic or abiotic factors may interact with drought to cause damage.

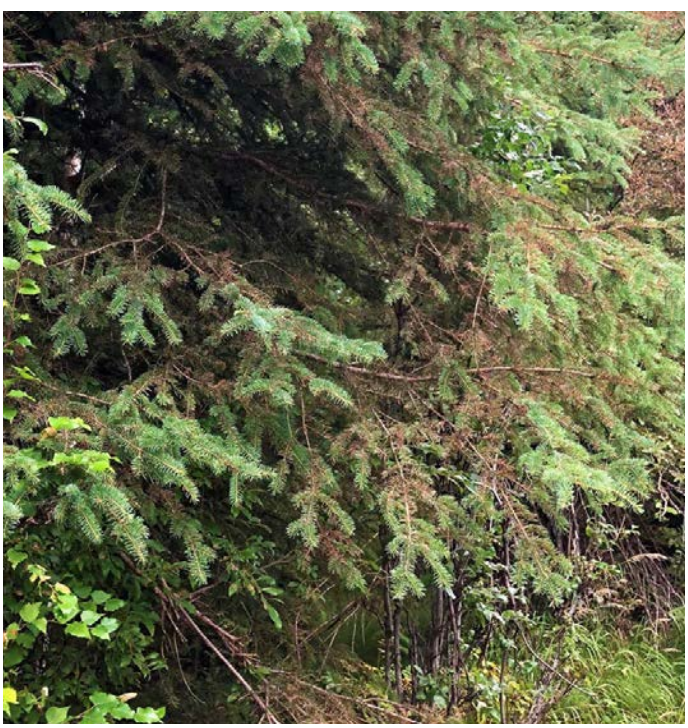


Figure 42. Discolored older needles on white spruce in Interior Alaska possibly caused by drought or winter damage.

In addition to the mapped acres of drought damage, unknown damage to alder and possibly willow was mapped across 6,800 acres between Farwell and Kantishna on the flats below the northern slopes of the Alaska Range (Figure 43).The damage was not ground-truthed, but it appeared that alder and or willow along drainages and damp areas had turned gray/brown and orange. We will resurvey the area in 2020 to verify the species affected and assess the cause.

Figure 43. Discolored foliage on alder or willow of unknown origin, possibly due to drought.

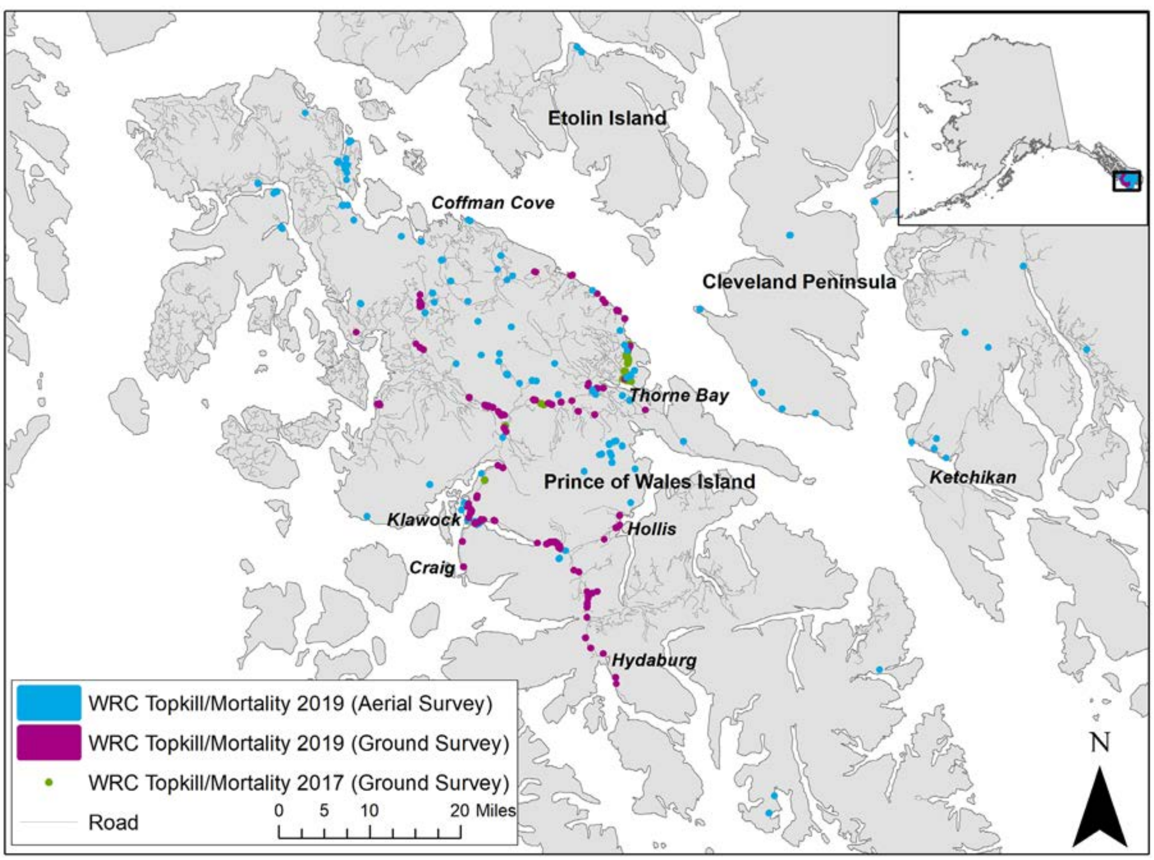
Figure 44. Western redcedar topkill on Prince of Wales Island. Photo by Molly Simonson, Thorne Bay Ranger District.

Western Redcedar Topkill

Western redcedar is susceptible to topkill and mortality associated with drought. Areas affected by this type of damage in Southeast Alaska were subject to moderate to severe drought conditions in 2018 and 2019. Widespread topkill of small and medium western redcedar trees (Figure 44) and some full tree mortality was reported in the southern Panhandle, with the most concentrated damage on central Prince of Wales Island (Map 26). Of 260 damage observations made in 2019, half were made from the air and half from the ground, almost always reflecting damage to one or a few trees. Damage occurred in both unmanaged forests and managed young-growth stands, and associated tree species were not affected.

This year, aerial observations confirmed that damage is most concentrated close to roads. Old dead tops, often with multiple dead forks, are common in old-growth western redcedar in Southeast Alaska, but the now-prevalent red, actively dying tops are not. In addition to drought, we are investigating other biotic and abiotic factors that may also be involved. Bole wounds and loose, peeling bark have been observed on some affected trees; however, wounds seldom encircled the full stem, were not consistently associated with topkill, and may have occurred after topkill. Although black bears are common on Prince of Wales Island and can create bole wounds, porcupines, and Douglas squirrels are absent. Other factors that may contribute to western redcedar topkill include: site hydrology that predisposes western redcedar to more intense effects from drought; secondary pests attracted to drought-stressed trees; or winter injury interacting with drought to cause more damage.

NONINFECTIOUS DISORDERS



Map 26. Western redcedar topkill observations from 2017-2019.

Windthrow

In 2019 there was a wind event or possible winter damage that occurred about 15 miles south of the Yukon River along the Dalton Highway. Numerous black and white spruce (Figure 45), as well as some birch, had broken tops and boles. This damage was recorded through ground observations and although aerial detection survey was flown over this area in 2019, due to severely smoky conditions during the over-fly, the amount and extent of the damage could not be assessed. This area will be flown in 2020 in an attempt to assess the extent of the damage.

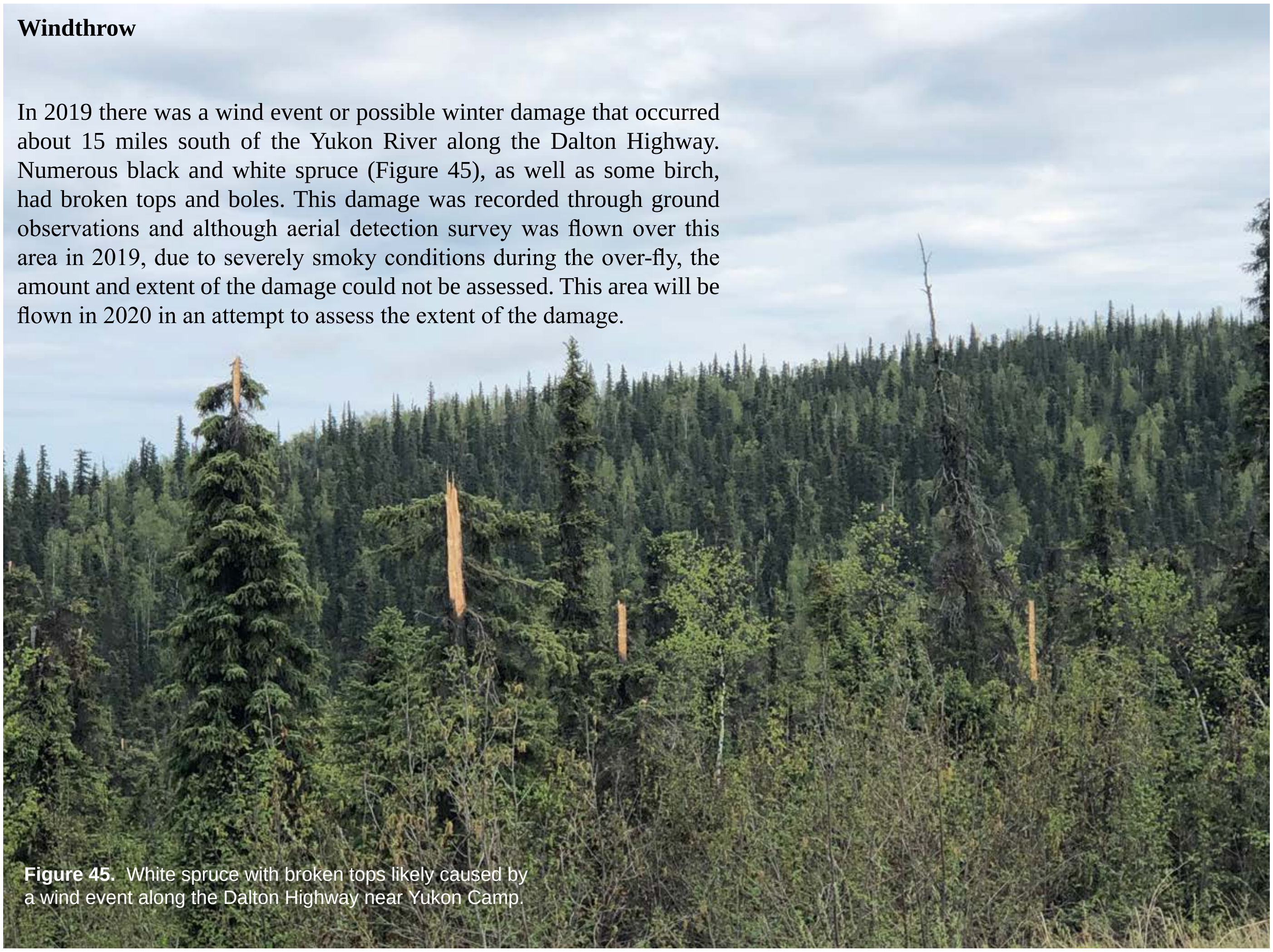


Figure 45. White spruce with broken tops likely caused by a wind event along the Dalton Highway near Yukon Camp.

Unknown Conifer Damage

Over 8,600 acres of unknown conifer crown damage to Sitka spruce was mapped in Southeast during aerial detection survey. Damage was located in Glacier Bay National Park, with 6,700 acres of damage along the outer coast and 1,800 acres in Glacier Bay and Muir Inlet. Ground checks are planned for 2020 to confirm the cause of damage. Winter damage or another form of abiotic damage likely contributed to the observed symptoms (Figure 46 & Figure 47).

Figure 46. Unknown conifer damage along the coast in Glacier Bay National Park.

Figure 47. Damaged spruce trees, likely due to frost or other abiotic factors.

Animal Damage

Throughout the state, several animal species cause damage to forest trees; porcupines, beavers, moose, black bears and brown bears can be particularly destructive. Porcupines and beavers kill trees by girdling tree boles, and beavers also cause flooding which can lead to tree mortality. In Southeast Alaska, brown bears selectively feed on the inner-bark of yellow-cedar trees in the spring, and approximately half of the yellow-cedar trees on islands with high brown bear populations have feeding scars.

Porcupine
Erethizon dorsatum L.

In 2019, almost 2,000 acres of porcupine damage was recorded in Southeast Alaska during aerial detection surveys. About two-thirds of the damage was mapped in the vicinity of Hobart Bay on the mainland along Stephen's Passage, where significant porcupine damage has been noted in recent years. Moderate damage was noted on Wrangell, Kupreanof, Mitkof and Etolin Islands. Farther north, damage was also noted northwest of Skagway and Excursion Inlet. Porcupines can be major pests in managed young-growth stands where they girdle Sitka spruce and western hemlock (Figure 48) managed for timber. They often wound the largest and fastest growing trees. Historic porcupine migration patterns from mainland river valleys to offshore islands has influenced their current distribution in the Alexander Archipelago. Porcupines are absent from Admiralty, Baranof, Chichagof, Kupreanof, Zarembo and Prince of Wales Islands (and others) near to the Gulf of Alaska but are abundant closer to or on the mainland.

Figure 48. Fresh porcupine teeth marks on western hemlock.

Snowshoe Hare
Lepus americanus Erxleben

Pronounced winter browse damage was recorded in the Interior in 2018 and 2019, especially along the Dalton Highway between Coldfoot and Atigun Pass (Figure 49). The damage consisted of pruned twigs and partial to complete girdling of the bark 2 to 3 feet above the snow line. Willow mortality from heavy browsing that occurred in 2018 was also evident. A greater incidence of browsing damage has coincided with a dramatic increase in hare populations. Hare damage also occurred sporadically along the road system throughout Interior and Southcentral Alaska (Figure 50).

Figure 49. Hare damage on willow along the Dalton Highway north of Coldfoot.

Figure 50. Hare damage along the Parks Highway near Healy.

Yellow-Cedar Decline

Active Yellow-Cedar Decline in 2019

Yellow-cedar decline, caused by root-freezing injury to yellow-cedar in the absence of insulating snowpack, is the most significant threat to yellow-cedar populations in Alaska. We continue to monitor yellow-cedar decline in old-growth forests (Figure 51) and, more recently, in previously harvested stands that continue to be managed for timber (young-growth stands). About 20,000 acres of actively dying yellow-cedar forests were mapped in 2019. The current northern margin of decline on the outer coast of Chichagof and Yakobi Islands, was sparsely surveyed in 2019. Nearby, about 4,000 acres of decline were mapped from Salisbury Sound to the Duffield Peninsula and Peril Strait (northern Baranof and southern Chichagof Islands). Decline was active at Cape Fanshaw (700 acres), and 2,500 acres were mapped on eastern Kuiu, Mitkof, and Kupreanof Islands. Widely scattered damage was mapped across 2,800 acres on Zarembo, Wrangell, and Etolin Islands and the adjacent mainland coast. Prince of Wales was heavily surveyed in 2019, where 7,500 acres of decline were mapped. Lastly, 2,500 acres were mapped on the Cleveland Peninsula, Misty Fiords, and Revillagigedo Island, especially from the head of Carroll Inlet across to Shrimp Bay.

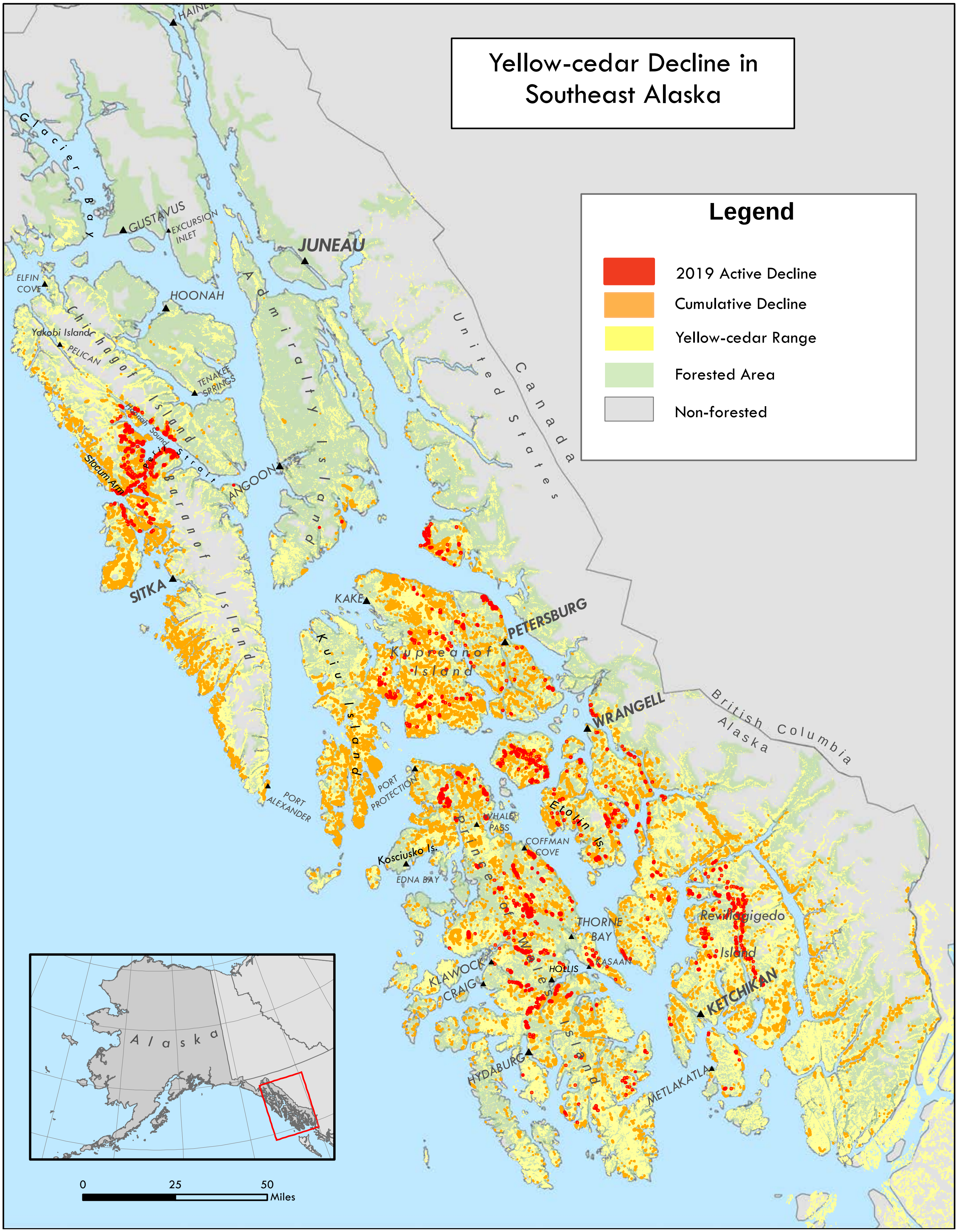
In total, more than 600,000 acres of yellow-cedar decline have been mapped across Southeast Alaska (Map 27) (Table 3). At lower latitudes, active decline occurs at relatively higher elevations compared to declining forests farther north. Over the last several years we have used GIS tools to improve this cumulative estimate by restricting decline to upland forest and forested wetlands (two land cover classes in the NLCDmodified dataset, Frances Biles, USFS PNW Research Station). The use of this forest mask reduces the total cumulative acreage of yellow-cedar decline by 58,277 acres compared to the unfiltered total.

Figure 51. Long-dead and dying yellow-cedar trees near Deep Bay, between Chichagof and Baranof Islands. In heavily affected forests, 10-20% of yellow-cedar trees survive.

Young-Growth Yellow-Cedar Decline

Young-growth yellow-cedar decline (Figure 52) is an emerging issue, particularly where soils are wet or shallow. The problem was first observed in young-growth forests on Zarembo Island in 2012 and confirmed in 2013; previously, decline was thought to be a problem of old-growth forests. We subsequently created a database of managed stands on the Tongass National Forest known to contain yellow-cedar (now 338 stands). Low-altitude aerial imagery and aerial detection surveys are used alongside the database to identify stands with discolored tree crowns and suspected decline, which are then inspected on the ground. Decline has now been ground-verified in 33 young-growth stands on Zarembo, Kupreanof, Wrangell, Mitkof and Prince of Wales Islands. Affected stands are typically 27- to 45-years-old, were thinned between 2004 and 2012, and occur on south to southwest aspects. Of the 33 stands with decline, five stands have relatively high concentrations of affected trees. Last year, we installed

Figure 52. Crown discoloration and thinning symptoms in a young-growth stand.



Map 27. Current (2019) and cumulative yellow-cedar decline mapped by aerial detection surveys in Southeast Alaska.

Table 3. Cumulative acreage affected by yellow-cedar decline as of 2019 in Southeast Alaska by ownership.

Ownership	*Cumulative Acres*
National Forest	**616,651**
Admiralty NM	**5,300**
Admirality Is.	5,300
Craig RD	**40,929**
Dall Is. & Long Is.	1,590
Prince of Wales Is.	39,339
Hoonah RD	**782**
Chichagof Is.	782
Juneau RD	**1,238**
Mainland	1,238
Ketchikan Misty Fjords RD	**85,831**
Duke Is.	15
Gravina Is.	2,080
Mainland	46,936
Revillagigedo Is.	36,801
Petersburg RD	**193,666**
Kuiu Is.	79,494
Kupreanof Is.	91,823
Mainland	10,636
Mitkof Is.	8,782
Woewodski Is.	2,932
Sitka RD	**129,781**
Baranof Is.	59,032
Chichagof Is.	45,431
Kruzof Is.	25,318
Thornebay RD	**79,410**
Heceta Is.	1,536
Kosciusko Is.	14,780
Prince of Wales Is.	63,094
Wrangell RD	**79,713**
Etolin Is.	28,272
Mainland	22,268
Woronkofski Is.	1,448
Wrangell Is.	12,536
Zarembo Is.	15,189

Ownership	*Cumulative Acres*
Native	**34,442**
Admiralty Is.	55
Annette Is.	2,367
Baranof Is.	381
Chichagof Is.	1,077
Dall Is. & Long Is.	1,285
Heceta Is.	6
Kosciusko Is.	543
Kruzof Is.	135
Kuiu Is.	657
Kupreanof Is.	5,454
Mainland	1,783
Prince of Wales Is.	18,592
Revillagigedo Is.	2,107
State & Private	**35,704**
Admirality Is.	21
Baranof Is.	4,313
Chichagof Is.	1,107
Dall and Long Is.	51
Etolin Is.	20
Gravina Is.	1,933
Heceta Is.	63
Kosciusko Is.	290
Kruzof Is.	397
Kuiu Is.	1,915
Kupreanof Is.	3,026
Mainland	4,160
Mitkof Is.	2,530
Prince of Wales Is.	8,651
Revillagigedo Is.	4,946
Woewodski Is.	9
Wrangell Is.	2,082
Zarembo Is.	189
Grand Total	**686,797**

41 random permanent plots to assess damage severity in the parts of these stands with yellow-cedar (Figure 53). Although only two percent of yellow-cedar trees were dead, eight times more yellow-cedar trees were dead than all other tree species combined. Up to 26 percent of yellow-cedar trees were dead per plot and eight percent per stand. Overall, one-third of yellow-cedar trees in our plots had crown discoloration symptoms. The condition of symptomatic trees is expected to worsen based on the progressive nature of individual yellow-cedar death in declining old-growth forests. The highest rates of mortality occurred where secondary bark beetles were attacking the stressed trees, causing more rapid tree death than occurs with freezing injury alone. Young-growth yellow-cedar decline has now been detected in 18 percent of stands in our database that fall within the highest-risk

Figure 53. Paula Rak and Tom Roland (Wrangell Ranger District) install monitoring plots with Forest Health Protection in a young-growth stand affected by yellow-cedar decline on Wrangell Island.

age bracket (27-45 years old). Half of the stands in our database are in this age range and one-third are younger. Applying modified thinning prescriptions to younger stands that have not been thinned yet could reduce or prevent damage. One hypothesis is that opening tree crowns through thinning may trigger decline onset by exposing the soil around trees to greater temperature fluctuation; if true, tighter spacing around yellow-cedar trees or foregoing thinning treatment in wet, lower productivity parts of stands could be beneficial. Our recommendation is to maintain tight spacing between cedars (6-8 ft.) during pre-commercial thinning, which could also compensate for potential future mortality. In wet portions of stands, thinning provides little or no payoff because tree growth is limited by soil hydrology and nutrients rather than competition. Improving our ability to predict where young-growth decline is likely to occur could allow for the prioritization of other conifers during thinning in the areas expected to be most vulnerable to decline (southerly aspects and elevations where snowpack is reduced), or the implementation of alternative thinning regimes.

Endangered Species Act Decision

In October 2019, federal protection for yellow-cedar under the Endangered Species Act (ESA) was deemed unwarranted. The U.S. Fish and Wildlife Service's listing decision is available in the Federal Register. The petition to list yellow-cedar as endangered or threatened under the ESA was received in June 2014. The initial finding was that a review of the science and status of yellow-cedar was warranted. As part of the scientific review of yellow-cedar, the Yellow-Cedar Biology, Ecology, and Emerging Knowledge Summit was held at the University of Alaska Southeast in October 2017. The meeting was attended by experts across many disciplines from the United States and Canada and covered the best available science and information needs regarding yellow-cedar. The Yellow-Cedar Species Status Assessment was completed in December 2018.

> *We found that yellow-cedar is experiencing a decline primarily caused by a changing climate in the core of its range; therefore, it has somewhat reduced resiliency. However, the area affected represents less than 6 percent of the species' range, and there are still high levels of representation and redundancy as demonstrated by its high levels of genetic diversity and wide distribution on the landscape, respectively. Despite impacts from effects of climate change, timber harvest, fire, and other stressors, the species is expected to persist in thousands of stands across its range, in a variety of ecological niches, with no predicted decrease in overall genetic diversity into the foreseeable future.*
> - USFWS Listing Decision, Federal Register Vol. 84, No. 194

STATUS OF INVASIVE PLANTS

Downhill mountain bike trails through orange hawkweed infestation at Alyeska Resort in Girdwood, AK.

2019 INVASIVE PLANTS UPDATES

Figure 55. KP CWMA partners rake up Elodea strands rafted up along the shoreline near the public boat launch at Sports Lake in May 2017, shortly after ice-out. This was an unusual opportunity to significantly reduce biomass before applying herbicide. Photo by John Morton.

Status of Elodea on the Kenai Peninsula

Elodea was first discovered on the Kenai Peninsula in Stormy Lake in September, 2012, and then again in Daniels Lake in October, 2012. Based on these discoveries the Kenai Peninsula Cooperative Weed Management Area (KP CWMA) partners worked together to address this issue. They immediately started obtaining permits for herbicide applications, surveying additional lakes, completing an Environmental Assessment and completing the first draft of an Integrated Pest Management Plan. They also gave a presentation to the Kenai Peninsula Borough Assembly which resulted in the first dedicated funds.

Through surveys or accidental findings, Elodea has also been found in Beck Lake (2013), Sports Lake (2017), and two connected waterbodies, Seppu and Hilda Lakes (2017). The latest infestation of Elodea was found in 2019 in Sandpiper Lake.

The big story here is the huge success of an aggressive Early Detection and Rapid Response model demonstrated by the KP CWMA partners. Immediate action led to herbicide treatments in the original three lakes by the summer of 2014 (Figure 54). The last time Elodea was detected in these lakes was September, 2015. Infestations found in 2017 were treated that same year and by the end of 2019 Elodea was also considered eradicated from these lakes (Figure 55). The latest infestation has just been discovered in September, 2019, but there are already plans underway to start treating this infestation early in the spring, 2020, shortly after ice-out. In short, Elodea has been eradicated in five of the six Kenai Peninsula lakes with known infestations.

Figure 54. Liquid herbicide being applied into Beck Lake from two trailing hoses on either side of the stern. Note the pump system hanging from the aft side of the center console; the mixing tank is immediately below. Containers of undiluted herbicide are stored in the bow. Photo by John Morton.

This Early Detection and Rapid Response model is one that will continue to be used on the Kenai Peninsula but can be used by others in Alaska. The approach integrates herbicides for eradication (fluridone) and risk reduction (diquat bromide); monitoring for treatment efficacy and early detection; regular public outreach; and continued organizational and agency engagement. The latest version of the Integrated Pest Management Plan (v. 5.0) has been completed in 2019. It is a plan the KP CWMA and others can continue to use to eradicate infestations of Elodea.

Status of Elodea in Interior Alaska

The Fairbanks Soil and Water Conservation District (FSWCD) conducted surveys on 33 water bodies, both local and remote (Figure 56). No new infestations were detected! They hope to expand the scope of their surveys in 2020 to include the middle Yukon and more remote lakes. In addition, they would like to improve their survey methods to ensure higher detection probability and fewer recording errors. Herbicide treatments were also successful across the Interior. This was the third year of treatment on the Chena Slough, and the

Figure 56. Vegetation survey on Big Minto Lake. Photo by Colin McKenzie.

overall infestation appears to be eliminated with native vegetation widely present (Figure 57). On the Tochaket Slough, this was the second year of treatment and already there was a huge difference from the year before. Chena Lake and Bathing Beauty Pond were treated with herbicide for the first time this year (Figure 58 & Figure 59). Next year there are plans to do initial herbicide treatments on Birch Lake and secure a permit for herbicide use on Manley Hot Springs Slough. Finally, a mechanical treatment in 2017 on a small 5-acre pond attached to the lower Chena appears to have been successful as no Elodea was found during surveys this year.

The FSWCD continued their outreach efforts by ramping up their sign installations, which will continue in 2020. The FSWCD also participated in events to educate targeted user groups and communities such as float plane users, village councils, and lakeside communities.

Figure 57. Chena Slough discharge measurements being taken after treatments. Photo by Colin McKenzie.

Figure 58. Elodea in Bathing Beauty Pond. Photo by Colin McKenzie.

Figure 59. Chena Lake pellet treatment. Photo by Colin McKenzie.

2019 Alyeska Ski Resort Orange Hawkweed Control

Girdwood's Alyeska Ski Resort has had a long simmering infestation of orange hawkweed (*Hieracium aurantiacum*) that had grown to over an estimated 30 acres by 2018 (Figure 60). Thanks to funding from a Copper River Watershed Project Invasive Plant Mini-Grant and years of community outreach and effort by local

Figure 60. Large infestation of orange hawkweed at Alyeska Resort in Girdwood, AK. Photo by Heather Thamm.

partners, this infestation was treated over several visits during 2019. The Community of Girdwood is surrounded by natural areas comprised of Chugach State Park, Chugach National Forest, and Turnagain Arm. There have been local community efforts dating back more than ten years to hand pull invasive weeds in the community. The Chugach National Forest, Glacier Ranger District has been a key partner in this from the beginning. Tim Stallard of Alien Species Control joined this effort in 2015 with a contract to manage invasive weeds on behalf of the community. To secure local permission to use herbicides as part of an integrated vegetation management effort to control invasive plants, during the past five years Stallard has given over ten community presentations to the Girdwood Land Use Committee and Girdwood Board of Supervisors.

Over the years, significant progress has been made in controlling and dramatically reducing the abundance of priority invasive weeds on local government public lands. Following these years of community effort and targeted outreach to Alyeska Resort, the resort agreed to allow and facilitate treatment of the orange hawkweed on their property this summer (see page 41). The availability of Invasive Plant Mini-Grant funds was a key factor in making this project happen, with a $5,000 match provided by local Girdwood government funds to control invasive plants in the community.

First treatments were started on May 30, 2019 with additional treatments in mid-June. Follow up visits later in the summer indicated successful control of treated hawkweed and relatively few plants were missed. Overall, this project achieved an estimated 90% or better reduction in this large hawkweed infestation. Future efforts will be needed to find and control additional plants, especially those populations that are isolated.

European Bird Cherry in Alaska

European bird cherries (*Prunus padus*) are highly ornamental; however, as Alaskans have discovered, this species is also highly invasive. The Alaska Center for Conservation Science has given the European bird cherry an invasiveness ranking of 74 based on its invasive plant ranking system. Generally, a ranking of 70 or greater is considered highly invasive in Alaska. This highly ornamental species has been planted widely in Alaska from Juneau to Fairbanks. It is spreading into natural forests and in some places has become a monoculture. Across the state, invasive species experts and local citizens have been working hard to better understand the extent of this problem and how to address it. The following are some highlights from this past year.

An unfortunate discovery was made in Juneau last year. John Hudson with the Southeast Watershed Coalition completed a survey near Eagle River State Park in Juneau and was surprised to discover approximately 3,000 bird cherry trees covering several acres. The infestation had been there for a while as some of the trees were up to 9" DBH. Future planning efforts may need to be made to address this infestation.

On the Kenai Peninsula, Chugach National Forest staff revisited the site of an old cabin on Grant Lake near Moose Pass, AK where they had previously treated a single bird cherry tree. The treated tree was dead, but the crew found several hundred seedlings nearby, which were subsequently treated. They also found several small trees along the railroad tracks near Moose Pass and initiated discussion with the Alaska Railroad staff on eradication. These findings highlight a potential need to survey for this species.

Farther north on the Kenai in Hope, AK, there has been a bird cherry success as nearly all of the ornamentally planted mother trees have been controlled with the exception of one or two private landowner holdouts. Much of the success here is due to local champion Frank Gwartney who convinced local residents to remove ornamental bird cherries from their properties (Figure 61). Although small seedlings are still found in the surrounding forest, these numbers are decreasing with control efforts by local residents and volunteer groups such as the American Hiking Society. Chemical control of the European bird cherry continues in Anchorage. The work is mainly conducted by Anchorage group Citizens Against Noxious Weeds Invading the North (CANWIN) along with contractor, Alien Species Control. In one project they treated about 20 acres of riparian forest along Chester Creek that was thickly infested with bird cherry using several techniques, including frilling, basal bark, and foliar applications (Figure 62). Different techniques were used in order to monitor the effectiveness of each type of treatment, which in turn can help improve future management of the species (Figure 63).

In addition to monitoring of different treatment methods, the University of Alaska Fairbanks Cooperative Extension Service (UAF CES) is nearing the completion of a three-year Special Technology Development Program project that is studying the effectiveness of basal bark treatments, and the potential for impact to surrounding vegetation. They also have a proposal under final review by the National Institute of Food and Agriculture to expand this research question to determine the full impacts to native vegetation and identify what factors necessitate revegetation after control. Public outreach efforts continue with the 9th annual Anchorage Weed Smackdown in Valley of the Moon Park. Dense thickets of seedling and sapling sized bird cherry trees were targeted. Volunteers pulled bird cherries by hand or with weed wrenches. This year nearly 80 volunteers showed up to the Smackdown! This event is largely organized by CANWIN and the Anchorage CWMA.

Figure 61. Hope, AK local Frank Gwartney and volunteers pull a bird cherry root from the Hope Library grounds.

Figure 62. Damage to bird cherry trees showing approximately 4-5 weeks after treatment. Photo by Tim Stallard.

Figure 63. Site visit in mid-May to Valley of the Moon Park, where treatments occurred the previous fall, shows the boundary with private property that was left untreated. The understory had been nearly 100% bird cherry. Another site visit later in the summer showed that the upper canopy of native trees survived the treatments, but the understory of bird cherry did not survive. Photo by Tim Stallard.

Farther north in Alaska, the community of Talkeetna is becoming more concerned about and interested in managing European bird cherry. In 2019, Brian Okonek from the Talkeetna Community Council reached out to Gino Graziano from UAF CES, Tim Stallard from Alien Species Control, and Jim Renkert from the Alaska Division of Forestry. Graziano was able to do a site visit in the spring of 2019 to see infested areas in the community. Reports from local rafters indicate that bird cherry trees have moved onto islands along the Susitna River. The shorefront of the Susitna River in Talkeetna that was infested with bird cherry trees washed away last winter taking many trees with it. Currently, Mr. Okonek is working with the Upper Susitna Soil and Water Conservation to send a letter to community residents to encourage them to remove ornamentally planted trees. They are interested in developing plans to survey and control feral trees in natural areas and control trees on private properties.

In 2017 the Municipality of Anchorage enacted an ordinance to ban the sale of European bird cherry in the municipality. Since then, the Alaska Community Forest Council has sent a resolution to the Alaska Division of Agriculture requesting they add *Prunus padus* and *Prunus virginiana* to their noxious weed list, which has prompted them to consider taking action. If successful, this will be a significant contribution to the statewide fight against these species.

Alaska Invasive Species Workshop 2019

The Alaska Invasive Species Workshop, the annual meeting of the Alaska Invasive Species Partnership, took place in Fairbanks from October 22-24. The workshop started off with a talk from the Great Lakes Region by Katherine Wyman-Grothem of the US Fish and Wildlife Service on aquatic invasive species prevention and early detection. The focus remained on aquatic invasive species with numerous talks on Elodea and invasive fish. Steven McCaughey from the Seaplane Pilots Association gave an inspiring talk on engaging seaplane pilots in the invasive species dialogue and introducing tools to assist in communicating vital resource information to protect waterways. Other interesting talks included education and outreach projects, *Prunus* control in Alaska, native and non-native ticks and statewide all-taxa strategic planning. State Representative Geran Tarr presented invasive species legislation for Alaska that she hopes to introduce in early 2020.

Awards were presented during the session. Trish Wurtz received the Lifetime Achievement Award. Phil Kaspari and Tim Stallard (Figure 64) were both awarded the Outstanding Contributor to Invasive Species Management in the Leadership category. Finally, each year there is a fun award given to a person with great knowledge of invasive species. This award originally started out as the "Biggest Weed Geek" but to reflect the all taxa aspect of the workshop, it has been renamed the "Biggest Invasive Species Geek." To win this award, attendees of the workshop participate in a quiz that tests their knowledge pertaining to invasive species. The top three or four scoring participants face each other off in a gameshow-style contest. This year the winner of the "Biggest Invasive Species Geek" award is Delia Vargas-Kretsinger who is a wildlife biologist at the Yukon Flats National Wildlife Refuge.

Figure 64. Tim Stallard was presented with the Leadership in Invasive Plan Control award under the Outstanding Contributor to Invasive Species Management in the Leadership category at the Alaska Invasive Species Workshop 2019.

Alaska's Invasive Plant Mini-Grant Program

This is the second year that R10 FHP and the Copper River Watershed Project have managed Alaska's Invasive Plant Mini-Grant program. This program supplies funds to non-federal organizations targeting invasive terrestrial plants that are ranked 60 or higher in the Alaska invasive plant ranking system. With funding from the mini-grant program, organizations are able to conduct outreach on invasive plants in their local communities, survey new areas, and manually or chemically treat infestations. Eight projects were funded in 2019. The Anchorage group CANWIN along with contractor Tim Stallard used mini-grant funds to treat spotted knapweed (*Centaurea stoebe*) using the herbicide Milestone. The infested sites occur on the right-of-way of both the Alaska Railroad and the Seward Highway along Turnagain Arm between Anchorage and Girdwood.

The Copper River Watershed Project used their mini-grant funding to control over 14 acres of invasive species within the Copper River watershed. Targeted species include reed canarygrass (*Phalaris arundinacea*), orange hawkweed (*Hieracium aurantiacum*), white sweetclover (*Melilotus alba*), bird vetch (*Vicia cracca*), and a single infestation of bohemian knotweed (*Fallopia* X *bohemica*). Treatments included both manual and chemical control methods. In addition, the group also used mini-grant funds for outreach and education materials and events.

Homer SWCD used mini-grant funding to conduct manual and chemical control across the Kenai Peninsula over nearly 100 acres. Target species include orange hawkweed, bird vetch, white sweetclover, reed canarygrass, common tansy (*Tanacetum vulgare*) and European bird cherry (*Prunus padus*).

The Fairbanks SWCD used mini-grant funds to survey, map and control approximately 40 acres across three sites (Fairbanks Dog Park, Chena River State Recreation Area, and private property). Targeted species include bird vetch, white sweetclover, perennial sowthistle (*Sonchus arvensis*), and foxtail barley (*Hordeum jubatum*). They also used funds to create outreach materials and signage to increase public awareness about invasive plants.

Kodiak SWCD is using mini-grant funds to help support their Invasive Plant Program in completing surveys, education and outreach, and control of terrestrial invasive plants throughout Kodiak. They have successfully created and distributed outreach materials throughout Kodiak and neighboring remote communities, conducted field surveys and chemically controlled reed canarygrass and bohemian knotweed.

The Metlakatla Indian Community Invasive Species Program used their funding to continue chemical and manual control on less than ¼ acre of tansy ragwort (*Senecio jacobaea*) and less than one acre of orange hawkweed at the Annette Bay Camp. Due to warming climates, treatments will start earlier in the season and extend through October. The Southeast Alaska Watershed Coalition used mini-grant funds to build upon knotweed control projects initiated last year. There were 59 knotweed infestations totaling 1.6 acres that were chemically treated.

The Tyonek Tribal Conservation District used mini-grant funds to chemically treat 24 acres in and around Beluga and Tyonek. Targeted species include orange hawkweed, white sweetclover, oxeye daisy (*Leucanthemum vulgare*) and butter and eggs (*Linaria vulgaris*). Their ultimate goal is to eradicate these species from the road system that connects the two communities.

STATUS OF INSECTS

Hemlock sawfly larvae feeding on hemlock in Southeast Alaska.

2019 INSECT UPDATES

Hardwood Defoliators- External Leaf Feeding

Alder Defoliation
Acronicta dactylina Grote
Eriocampa ovata (L.)
Hemichroa crocea (Geoffroy)
Lophocampa maculata Harris
Monsoma pulveratum (Retzius)
Orthosia hibisci (Gueneé)

Alder defoliation was observed on 2,600 acres during the 2019 aerial detection survey. The highest concentration of damage (1,100 acres) was between the McArthur and Susitna Flats. There were also several patches of damage along the Tanana River between Fort Wainwright and Healy Lake (700 acres in total). Small patches of damage were observed spread over several locations throughout Southeast. Several species of sawflies and caterpillars feed on alders throughout the state, and their abundance levels often vary year to year. Caterpillars of the fingered dagger moth (*Acronicta dactylina*) were observed feeding on Sitka and red alder in Ketchikan, Petersburg and Wrangell (Figure 65). Native to North America, their range was thought to end in southern British Columbia. First reported in Southeast Alaska in 2015, this caterpillar became increasingly common by 2019. This may be an example of range expansion. Green alder sawfly (*Monsoma pulveratum*) was observed feeding on thin-leaf alder near the Deshka River and was the most commonly encountered sawfly on alder in Southeast (Figure 66). Spotted tussock moth caterpillars (*Lophocampa maculata*) continue to be abundant in Southeast, their feeding occurs late in the season causing minimal damage.

Figure 65. Fingered dagger moth caterpillar found feeding on red alder on Wrangell Island.

Figure 66. Green alder sawfly larvae consuming thinleaf alder near the Deshka River.

Aspen Defoliation
Choristoneura conflictana (Walker)

In 2019, aspen defoliation was mapped on only 364 acres during aerial detection surveys, considerably less acreage than has been mapped in recent years. The damage was scattered throughout Interior and Western Alaska, as well as in the Copper River Valley. Historically during aerial survey, the more general code "aspen defoliation" was used when it was not clear if the damage was caused by large aspen tortrix or aspen running canker. As the large aspen tortrix and aspen running canker aerial signatures have become clearer, aspen defoliation has been mapped less often. In 2019 aspen defoliation was frequently used in areas with atypical aspen leafminer damage warranting use of the more generic aerial signature code.

Birch Leafroller
Caloptilia alnivorella (Chambers)
Caloptilia strictella (Walker)
Epinotia solandriana (Linnaeus)

Birch leafroller was not mapped during aerial survey in 2019. This is down from highs of 330,000 and 121,000 acres mapped in 2013 and 2014, respectively. Based on ground observations, the frequency (number of trees infested) of birch leafroller infestations in the Interior and Southcentral has remained relatively constant, however the intensity (number of leaves per tree) is low. Low intensity infestations are difficult to detect during aerial surveys. Leafroller activity on alder in Southeast was also low.

Miscellaneous Hardwood Defoliation
Chrysomela spp. F.
Epirrita undulata (Harrison)
Eulithis spp. Hübner
Eurois astricta Morrison
Hemichroa crocea (Geoffroy)
Hydriomena furcata (Thunb.)
Monsoma pulveratum (Retzius)
Nematus currani Ross
Operophtera bruceata (Hulst)
Orgyia antiqua (L.)
Orthosia hibisci (Gueneé)
Rheumaptera hastata (L.)
Sunira verberata (Smith)

Almost 4,000 acres of general hardwood defoliation was mapped in 2019, and 75% of this damage was in the Southeast around Muir Inlet and along the Chilkat River. No specific causal agent was identified for the damage observed in Southeast or Southwest Alaska. The remaining hardwood defoliation mapped in the state was in the northern portion of the Susitna River valley. Birch and willow defoliation was also observed in small pockets during aerial detection surveys. Reports of the rusty tussock moth (*Orgyia antiqua*) causing heavy hardwood defoliation on the Seward Peninsula near Nome were received through multiple sources and confirmed through photo ID. Common throughout Alaska, this may be the first report of it causing damage so far northwest.

Scattered pockets of cottonwood defoliation were observed in several parts of the state in 2019 (approximately 1,500 acres statewide), though most could not be ground checked to confirm the cause. Cottonwood leaf beetle (*Chrysomela spp.*) was noted as the damage agent on about 500 acres along Turnagain Arm in Southcentral Alaska this year. Cottonwood leaf beetle may be the causal agent in the remaining cases, though there are several species of defoliators that feed on cottonwood throughout the state.

Biologists from Glacier Bay National Park contacted FHP staff in May about a defoliation event in a primary succession forest of the Muir Inlet (Figure 67). Nearly every tree was infested with caterpillars (family Noctuidae) or had been previously infested, with remains of caterpillars visible in treetops and shrubs. The caterpillars were infected with a baculovirus (Figure 68), which is an insect-specific virus that alters the behavior of their caterpillar host: caterpillars exhibit increased locomotion and move to tops of trees and shrubs before dying. This increased the area over which the virus is able to spread to a new host. The caterpillars were identified using LifeScanner® DNA kits as *Eurois astricta*, a generalist that feeds on many species of hardwoods. Interestingly the disease cycle was completed before June; typically this is something that builds up throughout the season. Upon a revisit to the area in August 2019, the biologists found most trees had re-foliated and recovered from the early season feeding damage.

Figure 67. Heavily defoliated cottonwood, willow and alder seedlings in the Muir Inlet of Glacier Bay National Park. Defoliation occurred in May 2019, the trees were able to re-foliate and during a revisit in August seemed to have recovered.

Figure 68. Commonly referred to as 'zombie virus', baculoviruses liquefy a caterpillar's internal organs as it drives them to move to tops of trees enabling the virus to spread further.

INSECTS

Hardwood Defoliators- Internal Leaf Feeding

Aspen Leafminer
Phyllocnistis populiella Chambers

Aspen leafminer (Figure 69) damage was nearly continuous across the Interior, though this insect does not typically cause tree mortality. Over 130,000 acres of damage were mapped in 2019. This is a decrease of roughly 110,000 acres from what was mapped in 2018. The decrease in acres mapped in 2019 could be due in part to reduced visibility during aerial detection surveys. Wildfires were present throughout much of Interior Alaska and as a result, smoke and temporary flight restrictions impacted routes and visibility to the north, south and east of Fairbanks on a daily basis. Regardless, the majority of aspen leafminer damage was still mapped in the Interior, but 7,500 acres were recorded in the Copper River Valley, and little more than five acres were recorded on the Kenai Peninsula. While aspen leafminer has been in outbreak with the damage easily visible from the air for nearly 20 years in the Interior; activity on the Kenai Peninsula is only sporadically dense enough to be viewed during aerial survey but is regularly observed on the ground.

Figure 69. An aspen leafminer emerging from its egg and initiating a mine (left), and full extent of aspen leafminer gallery on an aspen leaf (right).

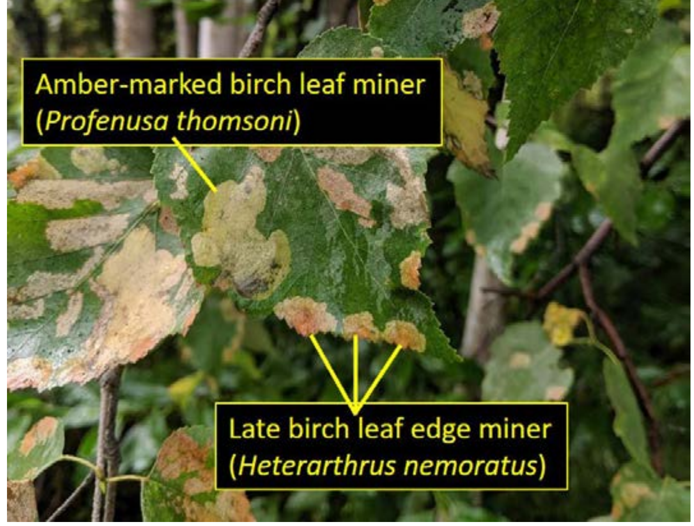


Figure 70. Birch leaf presenting with both *P. thomsoni* and *H. nemoratus*.

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

All birch leafminer damage mapped in 2019 was presumed to be either amber-marked birch leafminer (*P. thomsoni*) or late birch leaf edgeminer (*H. nemoratus*) (Figure 70). Prior to 2018, these invasive birch leafminers were believed to predominantly infest stands in major population centers and along roadways. Late season survey flights in the Matanuska-Susitna Valley in 2018 found birch leafminer activity extending well beyond these locations. In 2019, special late season aerial surveys were scheduled in both Southcentral and Interior Alaska to better assess the impacts of these invasive insects. Over 280,000 acres of impacted forests were mapped in 2019. In the Interior 17,000 acres of damage were recorded with > 9,000 acres observed between Fairbanks and Eielson Air Force Base. In Southcentral, over 170,000 acres of birch leafminer damage were recorded in the Matanuska-Susitna Borough and over 80,000 acres were mapped on the northern Kenai Peninsula. Additionally, a small area of activity was noted on the west side of Cook Inlet in the Big River Lakes area, approximately 45 miles west of the nearest known birch leafminer infestation on the Kenai Peninsula. Based on the extent of the damage in this area and its geographic isolation and separation from other known infestations of birch leafminers in the region, this appears to be a more recent introduction. It is unknown exactly how these leafminers were introduced or how long they have been present at this location, but the area is a popular recreation site amongst residents of Southcentral Alaska. Amber-marked birch leafminer and late birch leaf edgeminer were commonly observed during ground surveys in the Interior and Southcentral. Damage in the Interior was predominately from amber-marked birch leafminer, whereas the late birch leaf edgeminer was predominately in Southcentral, and both species were observed at relatively equal levels on the Kenai Peninsula. Birch leafminers are often found infesting alder leaves in Southeast, however very little damage was observed in 2019. This may be due in part to drier than normal conditions throughout the area.

Willow Leafblotch Miner
Micurapteryx salicifoliella (Chambers)

Willow leafblotch miner damage was recorded on 31,000 acres in 2019, down from 35,000 acres in 2018 (Figure 71). Willow leafblotch miner damage was mapped almost exclusively in the Interior, with high concentrations recorded in the Yukon Flats (13,500 acres), an area of historically heavy activity for this insect. Over 100 acres were mapped in the Copper River Valley in 2019, compared to no damage mapped south of the Alaska Range in

Figure 71. Willow leafblotch miner damage.

2018. Ground observations indicate willow leafblotch miner is present throughout the Interior and may be more widespread than aerial surveys indicate. Visibility and temporary flight restrictions associated with wildfires may have contributed to some of the decrease in mapped acres as it may have with aspen leafminer.

Softwood Defoliators

Spruce Aphid
Elatobium abietinum (Walker)

Spruce aphid damage remains low with less than 100 acres recorded during aerial survey. Damage continues to persist between Craig and Klawock on Prince of Wales Island, in Sitka, as well as near Thomas Bay and on Douglas and Shelter Islands near Juneau. Additionally, three small pockets of spruce aphid activity were observed in the Kodiak Archipelago (26 acres), two on the Kupreanof Peninsula of Kodiak Island and one near Onion Bay on Raspberry Island. Spruce aphid damage was not recorded on the Kenai Peninsula in 2019; October ground surveys found very light spruce aphid activity in six locations around Homer (up from only two locations in May) and heavy spruce aphid damage in a small area near the Homer library. An area of spruce defoliation was observed on Annette Island in Southeast (57 acres), however the damage agent could not be determined. It may have been spruce aphid, however hemlock sawfly, which is currently in outbreak, was also found feeding on spruce in some areas.

Spruce Budworm
Choristoneura fumiferana (Clemens)
Choristoneura orae Freeman

No spruce budworm damage was mapped during aerial detection surveys in 2019. Spruce budworm population monitoring was conducted in 2019 using pheromone traps targeting both species of spruce budworm at 46 sites along major roadways in Southcentral and Interior Alaska (Figure 72), an increase of 22 sites from previous years. On average 93 budworm moths were collected per site in 2019, a substantial decrease from the average 208 collected per site in 2018. Traps baited with *C. fumiferana* lures primarily captured moths north of the Alaska Range, but *C. fumiferana* were also recorded in two of the traps located just south of the Alaska Range. Traps baited with *C. orae* captured fewer moths compared to *C. fumiferana* traps but over a larger area.

Figure 72. Spruce budworm trap captures.

Western blackheaded budworm
Acleris gloverana (Walsingham)

No damage from western blackheaded budworm was observed during the aerial detection survey in 2019. The last time damage was recorded in Southeast was 2009. During ground surveys, western blackheaded budworm larvae were found in 50% of the plots (n=76) however within those plots the proportion of trees with larvae were low (<20%). Western blackheaded budworm larvae feed in the buds and on the new foliage of western hemlock (Figure 73). An outbreak in combination with the hemlock sawfly outbreak could result in tree mortality.

Figure 73. Western blackheaded budworm feed on the new growth of western hemlock often tying needles together to create a shelter. Inset is a western blackheaded budworm larvae.

INSECTS

Figure 74. Western hemlock defoliated by hemlock sawfly.

Figure 75. Hemlock sawfly only partially consume the needles; the part that is left behind turns colors before falling from the tree, this contributes to the dramatic color change of western hemlock that occurs during an outbreak.

Hemlock Sawfly
Neodiprion tsugae Middleton

Southeast Alaska is currently experiencing the second year of a hemlock sawfly outbreak, which has increased in intensity and extent since 2018 (Figure 74 and Figure 75). The outbreak was mapped on >380,000 acres of western hemlock forest. Defoliation is heavy in some areas, especially Prince of Wales, Mitkof and Kupreanof Islands, and extends as far north as the Borough of Juneau. Activity was notably lower on Baranof Island. A ground survey was conducted during mid-summer to assess defoliator activity and defoliation rating: 76 plots were established in hemlock stands off the road system in Southeast Alaska. Hemlock branches were hit with a stick and the defoliating insects were collected onto a sheet below. The larvae were identified and counted and the level of defoliation was recorded for each tree. Similar to aerial survey findings, the amount of defoliation and number of sawflies was greatest on Mitkof and Kupreanof islands and lowest on Baranof (Figure 76). Larvae infected with entomopathogenic fungal disease were recorded in high numbers in areas experiencing the second year of outbreak, such as Mitkof and Kupreanof. This indicates that the hemlock sawfly population in those areas is declining. Population levels are indirectly linked to environmental conditions; entomopathogenic fungi are more abundant during cool/wet summers. Southeast Alaska exhibited warmer and drier than average summer conditions, which limited this fungal growth, allowing larval populations to build to outbreak status. In ground surveys, hemlock sawfly was the most common defoliator detected on beating sheets, with low numbers of western blackheaded budworm. The low incidence of western blackheaded budworm activity indicates that most trees should be able to survive the outbreak. However, in some areas defoliation was so extensive trees may not recover. Populations of hemlock sawfly were so great in some areas that frass could be heard raining down from the trees and they could be found feeding on Sitka spruce as well as western hemlock (Figure 77). Hemlock sawflies feeding on non-hemlock hosts often occurs during outbreaks when their preferred host material becomes scarce. They could have been the cause of the unknown defoliation on spruce recorded on Annette Island.

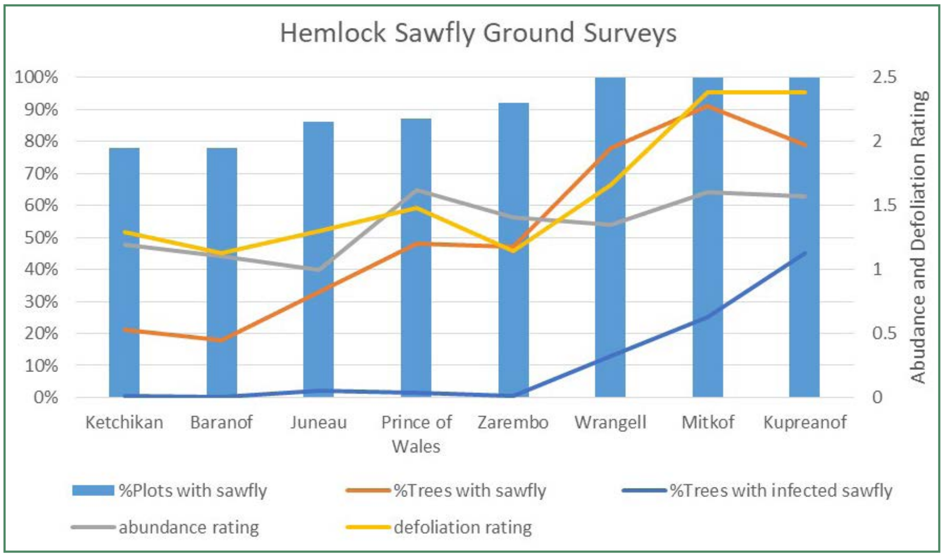


Figure 76. Results from hemlock sawfly ground surveys by island: proportion of plots with hemlock sawfly, proportion of trees within those plots with healthy and infected hemlock sawfly, average abundance rating for sawflies (1= <10 sawflies per branch, 2=10-20 sawflies per branch, 3= >20 sawflies per branch), and the average defoliation rating (1= 0-20% defoliation, 2= 21-50% defoliation, 3= >50% defoliation).

Figure 77. Populations of hemlock sawfly were so great on Killisnoo Island that they were feeding on Sitka spruce as well as the hemlock trees.

Bark Beetles

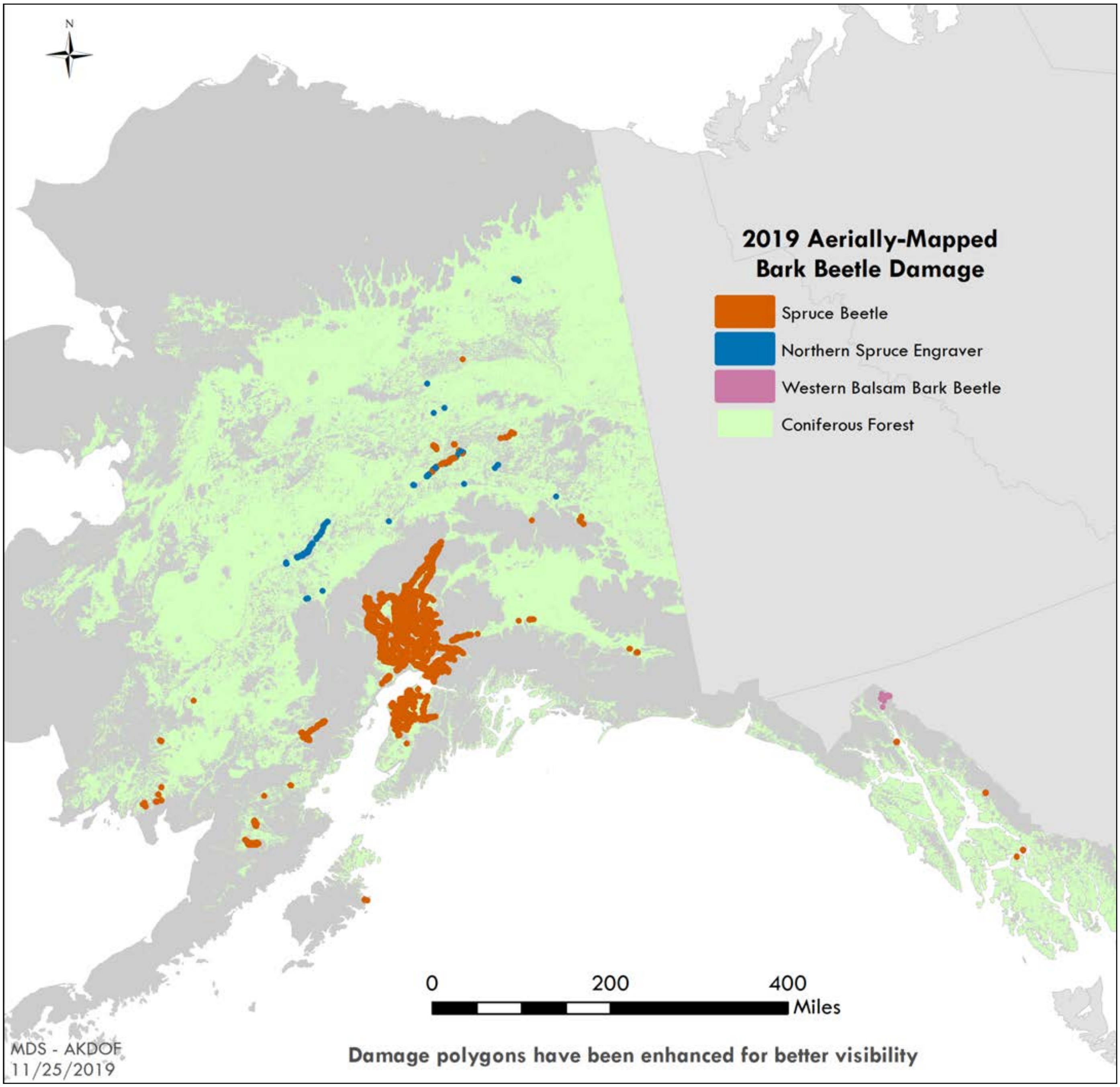
Bark beetles are an ever present risk to forest health in Alaska (Map 28), although the severity of the damage they cause fluctuates from year to year. Three species are repeatedly observed through aerial detection survey and ground observations; spruce beetle, northern spruce engraver and western balsam bark beetle. The following are details of each.

Spruce Beetle

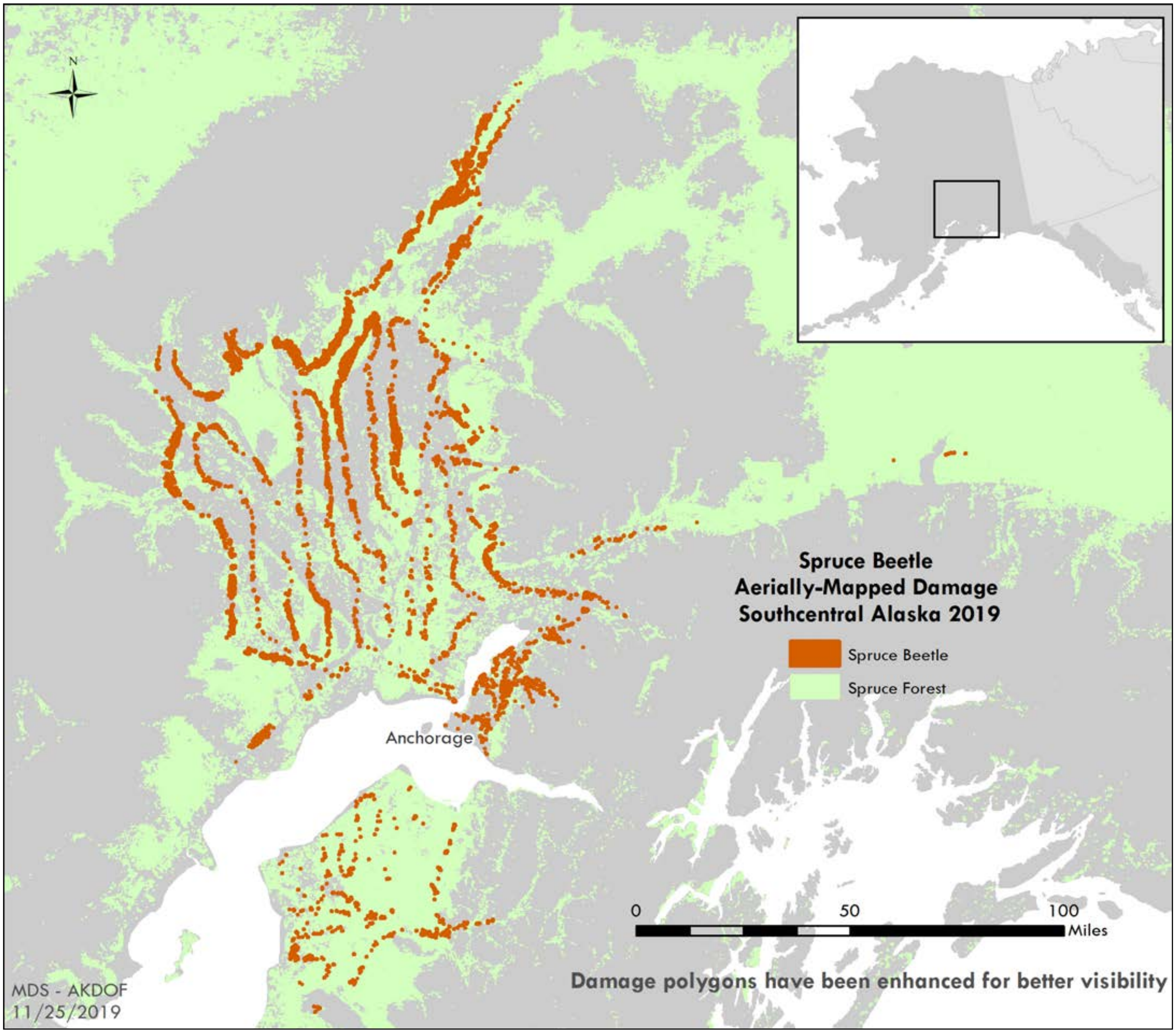
Dendroctonus rufipennis (Kirby)

Spruce beetle activity was observed on 139,500 acres statewide during aerial detection surveys in 2019, down considerably from the 593,000 acres mapped in 2018 (Map 29). Despite this substantial decrease, Southcentral Alaska is still experiencing a spruce beetle outbreak, estimated to be in its fourth year (Figure 78). White spruce host material is near exhaustion in some areas where the outbreak has been most severe. In these areas, an increase in spruce beetle activity in black spruce has been observed. Spruce beetle activity continues to expand in nearly all directions along the periphery of the outbreak area.

Spruce beetle-related public outreach continued to be a priority in 2019. The website www.alaskasprucebeetle.org (which launched in 2018 as a result of a cooperative effort between the Alaska Division of Forestry, the University of Alaska Fairbanks Cooperative Extension Service, and Region 10 FHP) was updated with relevant content as the outbreak progressed. Numerous public events were conducted to provide updates on the status of the outbreak, ongoing management and research efforts, and mitigation options for landowners.



Map 28. All bark beetle damage mapped during aerial detection surveys in 2019.



Map 29. Spruce beetle damage mapped in Southcentral Alaska during aerial detection surveys in 2019.

Figure 78. Spruce beetle-killed trees at the Denali South Overlook along the Parks Highway.

Two tree protection research efforts were undertaken in 2019: a systemic pesticide trial and an anti-aggregation pheromone trial using SPLAT-MCH. Both projects are being conducted collaboratively with the USDA Forest Service Pacific Southwest Research Station, Region 10 FHP, and the Alaska Division of Forestry. The systemic insecticide trial began in 2018. The study trees were initially challenged by beetles in 2019 and the success of the treatments will be assessed in the spring of 2020. The SPLAT-MCH trial is a one-year project that was initiated in 2019 and the results will be determined in the spring of 2020. The results from a separate MCH-based tree protection research project completed in 2018 by the Alaska Division of Forestry, in partnership with the USDA Forest Service Rocky Mountain Research Station, were published in 2019 and are available here: https://academic.oup.com/jee/article/112/5/2253/5523060; the MCH-based treatments tested in this study were not found to effectively protect white spruce from spruce beetle attack in Alaska.

Additionally, an effort was undertaken by the Alaska Division of Forestry to assess whether spruce beetle was the unknown bark beetle mass attacking several ornamental pines, presumed to be jack pines, in a Houston, Alaska park, and if so, were the beetles successful in the trees (Figure 79). Emergence traps were placed on one of the attacked trees in the spring and dozens of beetles were collected from the traps through the summer. Taxonomists at the Oregon Department of Agriculture confirmed the beetles were spruce beetle. The collection of these beetles in the emergence traps suggest that they were successful in completing their life cycle in these trees, but further assessment is needed for confirmation.

Surveyed areas experiencing notable spruce beetle activity in 2019 are listed below, along with the damage acreage in those areas in 2018, where applicable. Areas without 2018 acreages listed either weren't flown or lacked notable damage in 2018.

Southcentral – Matanuska-Susitna, Kenai, and Municipality of Anchorage Boroughs:

Active spruce beetle damage was observed on about 126,000 acres in the outbreak area in 2019 (557,000 acres in 2018). The outbreak has affected roughly 1.1 million cumulative acres of mixed spruce and birch forests since it was initially documented in 2016. A mix of univoltine (one generation per year) and semivoltine (one generation every two years) beetles were observed within the outbreak area. While semivoltine beetles are typical in Southcentral Alaska, the presence and proportion of univoltine beetles in the population can affect how quickly beetle populations build in an area. Spruce beetle life cycle timing is closely tied to temperature.

Many of the affected forests are composed of a mix of birch and white, Lutz, and black spruce. In 2019, spruce beetle activity in black spruce increased notably, primarily in areas within the Susitna River valley where the damage to white spruce has been severe. In addition to white, Lutz, black, and ornamental spruces, spruce beetle attacks on Scots pine, jack pine, and Siberian larch have also been confirmed. With the exception of the attacks on jack pine mentioned previously, spruce beetle attacks on non-spruce hosts observed to date do not appear to negatively impact the trees. At present, the spruce beetle outbreak does not appear to be impacting the Sitka spruce forests of Southcentral Alaska.

Figure 79. Spruce beetle attacks on a non-spruce host are common during large outbreaks when preferred host material becomes scarce. Photo by Jason Moan.

Matanuska-Susitna Borough (*113,300 acres*)
All areas surveyed in this region showed some level of spruce beetle activity. Substantial active damage was noted in the areas listed below. Note that heavily impacted areas where the susceptible spruce host has been exhausted and no current activity was detected are not included in the following list. Due to the overlap in the areas of damage in this region, summarized acreage values for the individual areas below were not calculated.

- Mount Susitna area
- Central Susitna River valley between the Yentna River and the Susitna River
- Western edge of the Susitna River Valley from Beluga Lake north along the front range of the Tordrillo Mountains to the Alaska Range
- Chelatna Lake Area
- Kroto and Peters Creek drainages and surrounding Peters Hills area
- Northern Susitna River drainage along the south side of Curry and Kesugi Ridges
- Chulitna River at Ruth Glacier to Broad Pass
- North and east of the Parks Highway in the foothills of the Talkeetna Mountains up to tree line from central Wasilla to Talkeetna
- Along the Glenn Highway corridor from Sutton to Chickaloon
- Surrounding the Butte community
- Northern edge of the Chugach Mountains between the Old Glenn Highway and tree line below Twin and Pioneer Peaks

Spruce beetle activity was mapped approximately 25 miles farther north along the Parks Highway in 2019 than in 2018, scattered damage was observed close to the lower end of Summit Lake. Spruce beetle activity continues to persist in the urban and suburban portions of the Palmer-Wasilla area.

Municipality of Anchorage (*5,200 acres*)
The annual aerial surveys typically cover much of the northern and southern portions of the municipality, but often have limited coverage of the Anchorage Bowl due to airspace issues. In 2019, surveyors partnered with Joint Base Elmendorf-Richardson to survey spruce beetle on the forested portions of the base; notable current and old spruce beetle activity was observed. This additional survey resulted in increased survey coverage within the Municipality and contributed to the increased affected area in the Municipality of Anchorage, up from 1,500 acres in 2018.

Additional areas experiencing increased spruce beetle activity included the drainages of Ship Creek, Eagle River, South Fork Eagle River, Eklutna River, and Campbell Creek, as well as scattered throughout the Anchorage Bowl.

Kenai Peninsula Borough (*7,500 acres*)
Spruce beetle activity continued on the northwestern portion of the Kenai Peninsula, though mapped acreage has substantially declined from 2018 (52,000 acres). Overall, all areas of notable activity decreased from 2018. Impacted areas include the following:

- Northwestern corner of Kenai Peninsula, north and east of Nikiski, west of the Moose and Chickaloon Rivers, and north of Sterling **(1,535 acres; 32,549 acres in 2018)**
- Nikiski area **(80 acres; 1,282 acres in 2018)**
- Skilak Lake North to Chickaloon Bay along Sterling Highway and western edge of Chugach Mountains **(2,248 acres; 9,064 acres in 2018)** *
- Tustumena Lake and Skilak Lake areas **(1,737 acres; 2,308 acres in 2018)**
- West side of Cook Inlet within the Kenai Peninsula Borough **(1,363 acres; 1,831 acres in 2018)**

* The Swan Lake fire impacted much of this area in 2019. As a result, surveys in this area were delayed and/or shortened and it is possible the fire may have burned beetle-infested spruce that would have otherwise been documented during the aerial surveys.

Southcentral – Eastern: Copper River Valley (*57 acres*):
This area includes the Glenn Highway corridor, parts of Copper River Valley, and the Valdez area. The total mapped acreage has decreased notably from 458 acres in 2018, and this area in general has had relatively low beetle pressure in recent years.

- South of the Chitna River near its confluence with the Tana River **(10 acres)**
- South of Glenn Highway near Tazlina Lake **(47 acres; 21 acres in 2018)**

West (*11,300 acres*):
Spruce beetle damage mapped in western Alaska decreased substantially from 2018 (24,300 acres). Spruce beetle damage has been persistent in Lake Clark National Park and Katmai National Park for several years and the acreage affected has fluctuated. Katmai National Park saw a substantial decrease in affected area from 2018. Within the park, comparable areas were affected this year as were in 2018, including Lake Brooks, the Iliuk Arm of Naknek Lake, and Lake Coville. Damage decreased in Lake Clark National Park as well and the areas affected that were consistent with those observed in 2018. Most damage was mapped in pockets along the south shore of Lake Clark from Kontrashibuna Lake northeast into the Chokotonk River drainage. Little active spruce beetle was observed in Wood-Tikchik State Park in 2019, though scattered spruce beetle damage was observed there in 2018.

- Katmai National Park **(9,507 acres; 18,999 acres in 2018)**
- Lake Clark National Park **(1,542 acres; 2,352 acres in 2018)**
- From the mouth of the Wood River north to the Chikuminuk Lake, east of Wood River Mountains **(212 acres; 1,774 acres in 2018)**
- Holitna River near Taylor Mountain **(4 acres; 767 acres in 2018)**

The forested portion of the Kodiak Archipelago was also surveyed in 2019, though no notable damage was found (<10 acres of spruce beetle damage). The archipelago was last surveyed in 2016.

Interior (*1,800 acres*):
After a bump in activity in 2018 (7,000 acres), spruce beetle damage substantially decreased in 2019. Small pockets of spruce beetle damage observed were dispersed across a large area. Activity was documented along the Tanana River and Chena River.

- Along the Tanana River upstream of the confluence with the Gerstle River to the confluence with the Robertson River **(90 acres; 3,372 acres in 2018)**
- Along the Tanana River drainage from the town of Nenana northward to Fairbanks **(1,180 acres; 99 acres in 2018)**
- Along the Tanana River near the Minto Flats **(390 acres)**
- Along Chena Hot Springs Road from Colorado Creek to Angel Creek **(126 acres)**

Southeast (*235 acres*):
Mapped spruce beetle damage decreased drastically in Southeast Alaska from 2018, when 3,200 acres were mapped. The majority of the damage from 2018 occurred in the Excursion River valley and did not continue into 2019 (Figure 80). Spruce beetle activity in Southeast regularly fluctuates from year to year, though outbreaks have been known to occur in the past (Figure 81).

- Endicott River, near Lynn Canal **(187 acres; 373 acres in 2018)**
- Endicott Arm of Stephens Passage, near North Dawes Glacier **(36 acres; 87 acres in 2018)**
- Sokolof Island and Zarembo Island, just west of Wrangell **(12 acres)**

Figure 80. Previously killed Sitka spruce on the east side of Excursion Inlet; no active damage was observed in 2019.

Figure 81. Sitka spruce killed by spruce beetle on Sokolof Island in Southeast Alaska.

Northern Spruce Engraver
Ips perturbatus (Eichhoff)

Northern spruce engraver damage was observed on about 1,100 acres in small pockets throughout Interior and Western Alaska. This represents a slight decrease from the 1,600 acres mapped in 2018 and marks the lowest observed damage from northern spruce engraver since 2003. Damage from northern spruce engraver was typically mapped along streams and rivers and in areas of natural disturbances such as fire and wind.

All acreages should be considered the total of several scattered small areas of damage unless otherwise noted. Areas without 2018 acreages listed either weren't flown or lacked notable damage in 2018.

- Tanana River near Nenana and upstream to Fairbanks **(533 acres; 10 acres in 2018)**
- Tanana River upstream of Fairbanks to Gerstle River **(22 acres)**
- Kuskokwim River drainage **(506 acres; 1,142 acres in 2018)**

Western Balsam Bark Beetle
Dryocoetes confusus (Swain)

Western balsam bark beetle damage was observed on 106 acres, remaining steady with the 110 acres observed in 2018. Activity occurred in the Skagway area, along the Taiya and Skagway River drainages, from their mouths up to Mt. Cleveland and White Pass, respectively. Western balsam bark beetle attacks subalpine fir, which has a limited distribution in Alaska. As such, even small amounts of affected acreage are notable. The non-native and invasive species, balsam woolly adelgid, was recently discovered on urban subalpine fir in Juneau, prompting concern for the subalpine fir in nearby Skagway. See Urban Tree Pests for further information.

Urban Tree Pests
Adelges cooleyi (Gillette)
Adelges piceae (Ratzeburg)
Gracillaria syringella (Fabricius)
Dendroctonus rufipennis (Kirby)
Heterarthrus nemoratus (Fallén)
Oligonychus ununguis (Jacobi)
Profenusa thomsoni (Konow)

This year has been an interesting one for landscape and ornamental trees throughout the state. Depending on the region, our urban trees have experienced record high temperatures, record drought conditions, and high levels of rainfall. These conditions impact overall tree health and pest presence and populations.

Spruce beetle continues to be the most frequently observed pest in ornamental and landscape trees in the urban and community forests of Southcentral Alaska. Ground observations and homeowner/landowner calls from around the region are up from 2018. An increasing number of calls regarding spruce beetle were received from the northernmost areas of the Matanuska-Susitna Borough and from the Denali Borough. Additionally, observations and reports of activity within the Anchorage Municipality continue to increase.

In addition to spruce beetles, ornamental spruce were observed with very high populations of spruce spider mites throughout Southcentral Alaska. Spider mites are not uncommon on spruce, however their damage is rarely severe and their presence usually goes unnoticed. Damage from spruce spider mites was very evident in some trees, with entire branches being completely web-covered (Figure 82). Another spruce pest that was more evident in 2019 than in previous years was woolly adelgids, primarily in Anchorage and the Matanuska-Susitna Valley. Woolly adelgids were observed on planted and naturally occurring spruce and on ornamental Douglas-fir trees. Woolly adelgids were also reported from one ornamental Siberian larch tree in Palmer; however, samples could not confirm the identification. In Southeast, Cooley spruce gall adelgids (*Adelges cooleyi*) were commonly found on Sitka spruce in urban settings.

Outside of spruce pests, 2019 was a banner year for leafmining pests. Lilac leafminer has been on the rise for the last several years and continues to plague ornamental plantings throughout Southcentral Alaska (Figure 83). Lilac leafminer damage was first observed in late June and continued to be reported into September. The lifecycle of this pest in Alaska has not been confirmed, but it is suspected to complete one and a partial generation each year. Birch leafminer activity has seen similar increases in ornamental and landscape trees as has been reported in forest settings from the Matanuska-Susitna Valley to Interior Alaska.

Figure 82. High populations of spruce spider mites were found on ornamental spruce throughout Southcentral Alaska in 2019. Photo by Mike Post.

Figure 83. Lilac leafminer larvae exposed from within the damaged leaf. The lower surface was removed to expose lilac leafminer larvae feeding inside. Photo by Landon Smith.

Figure 84. Ornamental subalpine fir infested with the invasive balsam woolly adelgid planted along Dimond Park in Juneau, Alaska.

Figure 85. A multi-agency team collaborated to conduct road surveys to delineate the extent of the non-native balsam woolly adelgid in Juneau. From left to right: Mia Kirk (AK Division of Agriculture), Jason Moan and Martin Schoofs (AK Division of Forestry), Karen Hutten (USFS FHP).

In June 2019, balsam woolly adelgid (*Adelges piceae*) was discovered infesting ornamental subalpine fir trees near Dimond Park in Juneau, Alaska (Figure 84). This is the first known detection of this invasive species in Alaska. Balsam woolly adelgids are native to Europe and are known to occur in several other parts of the United States. They are small sap-sucking insects that feed on true fir trees (*Abies*) and can kill a tree within a few years. Fir trees do not occur naturally in the Juneau area but are a popular ornamental tree. Subalpine fir and Pacific silver fir are native in nearby parts of Southeast Alaska, and balsam woolly adelgids can easily be spread over great distances by wind or wildlife.

A road survey was conducted in Juneau November 13-14, 2019 by USFS and AKDNR (Division of Agriculture and Division of Forestry) staff (Figure 85) to determine the extent of the BWA infestation and note where ornamental fir trees occur across the city. The majority of the infested trees found during the survey are on City and Borough of Juneau property and will be removed and destroyed. Workshops are planned for winter 2020 to inform property owners with fir trees how to best protect their tree's health and prevent this invasive species from spreading into Alaska's natural fir forests.

APPENDICES

Surveys out of Ketchikan in Southeast Alaska were flown in a de Havilland Beaver on floats owned by Misty Fjords Air.

Appendix I: Aerial Detection Survey

Introduction

Aerial surveys are conducted each year to monitor and map insect, disease and other forest disturbance. In Alaska, Forest Health Protection (FHP) and the Alaska DNR Division of Forestry, monitor about 25 million acres of forest annually. Much of the damage acreage referenced in this report was generated by aerial detection surveys, so it is important to understand how these data are collected and the data's inherent strengths and weaknesses. While there are limitations, no other method is currently available to effectively and economically detect subtle differences in vegetation damage signatures within a narrow temporal window.

Each year approximately 15-20 percent of Alaska's 126 million forested acres are surveyed, which equates to approximately 3 percent of all forested land in the United States. Unlike some regions of the United States, surveys in Alaska do not cover 100 percent of the forested lands. Preparations for the survey season begin in early spring with the training of personnel, data-collection software updates, equipment and safety inspections, securing and authorizing planes, pilots, and fuel sources, planning flight routes, finding accommodations for remote flights, and submitting flight requests to ensure communication with dispatch and flight following. Even with excessive planning, surveyors must remain adaptable. Atmospheric conditions change on a daily, sometimes hourly basis. Low clouds, wind, precipitation, smoke from nearby wildfires (Figure 86), and poor light conditions all have the potential to inhibit damage signature visibility. As a result, flight routes are often rerouted and some areas cannot be surveyed due to safety concerns. Add to this a short summer season, vast land areas, challenging terrain, limited time and personnel, and the forested areas that are surveyed become quite large.

One advantage to aerial surveying is that trained observers witness the forest conditions first hand. The aircraft fly at about 100 knots (115 mph) and 1,000-1,500 feet above ground level. The use of floats allows aircraft to land in remote locations when practical. The possibility of landing in areas off the road system allows for closer inspection of damage areas as needed. From the vantage of the aircraft, surveyors are able to see foliar damage with their own eyes. While in flight, surveyors work with pilots to adjust their perspective by observing damage areas from multiple angles and altitudes (Figure 87). Surveyors recognize damage patterns, discoloration, tree species, and other clues that allow them to distinguish specific types of forest damage from surrounding undamaged forest. Damage attributable to a known agent is called a "damage signature" and is often pest-specific; for example, silver foliage seen in aspen is almost unmistakably aspen leafminer. Knowledge of these common damage signatures allows trained surveyors to identify the causal pest, and also, to be alerted to new or unusual signatures, such as those that may be caused by uncommon or invasive species.

Aerial surveyors employ a method known as aerial sketch-mapping to document forest damage observed from the aircraft. When an observer identifies an area of forest damage, a polygon or point is drawn with a stylus on a computer touch screen (Figure 88).

Figure 86. Wildfire smoke and temporary flight restrictions can cause aerial survey missions to be rerouted or canceled.

Figure 87. Dave Oberg and Garret Dubois working together to identify alternate routes to maximize damage mapping and safety.

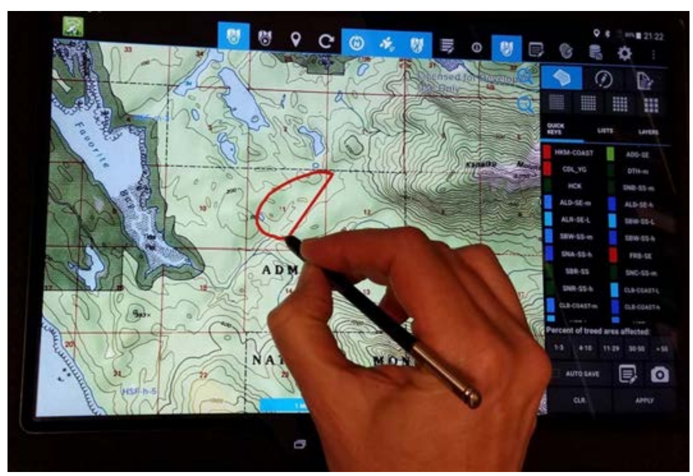


Figure 88. The current sketch-mapping tablet and DMSM software aid aerial survey data collection.

Prior to 1999, sketch-mapping was done by hand with pencil or pen on 1:250,000 (1 inch = 4 miles) paper USGS quadrangle maps (Figure 89). Today, forest damage information is sketched on 1:63,000 scale (1 inch = 1 mile) digital USGS quadrangle maps or imagery. Data are collected using a modern lightweight tablet known as a digital mobile sketch-mapping system (DMSM). This system displays the plane's location via GPS and has many advantages over paper maps including greater accuracy and resolution in polygon placement and shorter turnaround time for processing and reporting data. The sketch-map information is then entered into a computerized Geographic Information System (GIS) for more permanent storage and retrieval by users. Over 40 years of aerial survey data has been collected in Alaska, giving a unique perspective of Alaska's dynamic and changing forests.

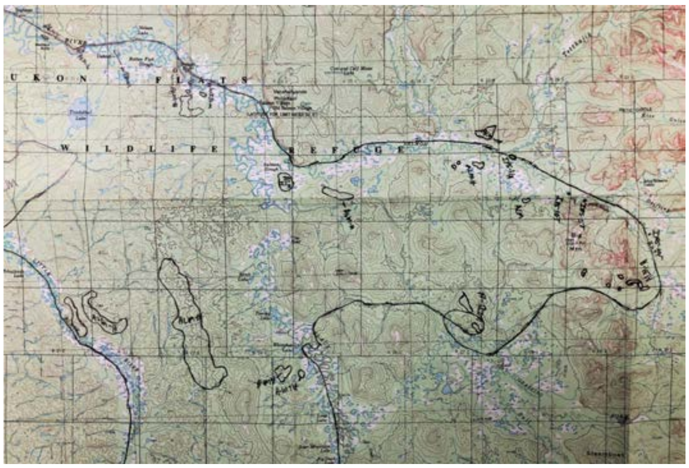


Figure 89. In the past, flightlines and damage polygons were drawn by hand on paper maps with pen and pencil.

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

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

For the most part, surveys provide a non-systematic sampling via flight transects. Due to survey priorities, client requests, known outbreaks, and a number of logistical considerations, some areas are rarely or never surveyed, while other areas are surveyed annually. The reported data should only be used as a partial indicator of insect and disease activity for a given year. When viewing the maps in this document, keep in mind the survey flightlines that indicate where data was collected (Map 2 on page 6). Although general trends in non-surveyed areas could be similar to those in surveyed areas, this is not always the case. 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. Repeatable sampling methods require significant time and effort to be statistically robust.

We are currently working to develop satellite-based remote sensing methods for Alaska (page 11). As of 2019, processed and cloud-free Landsat imagery is available for all of Alaska for each summer going back to 1999. Combining aerial survey with satellite-based change detection may allow us to monitor more of Alaska's forest each year, and even improve our understanding of historic damage.

Ground-Truthing

Ground-based verification improves the quality of present and future aerial survey data. The objective is to gather more specific information about interesting or potentially significant forest damage, improve the final mapping products, and hone observer skills. From the ground, a surveyor can look closely for signs and symptoms to identify or confirm the causal agent and host species, and corrections can be made directly on the sketch-mapping tablet. Surveyors can also verify the size and geographic position of a damage polygon sketched quickly from the plane. As an added benefit, feedback from ground observations calibrates the observer and improves their understanding and ability to map subtle patterns from the air that are unique to an agent and host.

Ground checks must be accomplished after the first survey of the season and prior to final reporting. Timing is critical because physical evidence of the insect or disease often begins to disappear as damaged leaves or needles drop or larvae descend from trees to pupate. Ideally, one week is scheduled for ground truthing immediately following the survey (two weeks for new observers). Additional ground checks may be conducted outside of this time frame for some agents or opportunistically incorporated into other fieldwork that is being conducted. Ground-truthing strategies vary from region to region and year to year based on needs, limitations, and professional judgement of experienced surveyors.

Polygons are prioritized for ground visits based on several criteria including size or severity of the damage, extension of range, uncertainty of the agent or host, and ease of access. Access is perhaps the biggest challenge. Alaska has few roads, vast acreages of forest, and the most remote country in the United States. Even forests that are close to roads can be difficult to access due to rugged terrain or impassable waterways. Remote areas off the road system are rarely visited unless an on-the-spot visit can be made safely during the survey. A closer view can sometimes be achieved from a roadside overlook with the aid of binoculars; but surveyors usually hike to the damage site. Therefore, the first polygons to be visited are often adjacent to roads. The more important the event or polygon, the more effort will be made to travel to the site, including by plane (Figure 90) or boat. Well-known and established damage patterns are lowest priority, but may still provide insight and are worth visiting when easily accessible. Identifying polygons of interest at the end of each aerial survey day is excellent preparation for ground-truthing. Whereas ground-truthing is generally considered to be conducted by aerial surveyors at the completion of their aerial surveys, valuable ground checks are also made during the survey at refueling or lunch stops or when damaged areas are safely accessible (Figure 91). Furthermore, ground-to-surveyor communication with entomologists, pathologists, other specialists, and importantly the public informs surveyors about damage area locations and agents that are active on the landscape. We value communication with all observers on the ground.

Figure 90. Garret Dubois and Steve Swenson iInspecting willow defoliation on Chakachamna Lake on a special mission after identifying locations to revisit during aerial survey.

Figure 91. Ground truthing spruce needle aphid on Raspberry Island during aerial survey.

2019 Ground-Truth Observations by Region

Interior Alaska

Two days of Interior ground truthing were completed during aerial surveys in 2019. One day was completed when smoke and weather prevented surveyors from attaining minimum conditions to fly while the other was conducted after the completion of the last survey flight. Additional ground truthing was informally conducted during other field work and while traveling Interior roads. Major damage agents in the Interior included aspen leafminer, birch leafminer and willow leafblotch miner. The signs and symptoms of all these agents are quite distinctive and easily recognizable. Those stands that had enough access to ground truth were identified correctly, with the size and placement of some areas being slightly adjusted.

Southcentral Alaska

Surveyors completed three days of ground-truthing in Southcentral this year. In the Anchorage area, an increased amount of spruce beetle was mapped during aerial surveys this year. The aerial signature for spruce beetle is clear, so spruce beetle damage is almost always correctly mapped. Our sketch-mapping base maps are 20- to 30-year-old topographic maps, and roads, development, and forested areas in Anchorage have often drastically changed over this time period. This temporal disconnect between the current municipal infrastructure configuration and that shown on our current base maps has led to occasional polygon placement errors for correctly mapped damage agent/host combinations. Imagery-based base maps are in development to provide more current and detailed views of populated areas.

Southeast Alaska

Ground surveys conducted prior to aerial surveys in SE Alaska have served as an opportunistic reverse ground-truthing when agent activity documented on the ground is observed and mapped from the air. Spruce beetle activity was noted while boating adjacent to Sokolof Island and could therefore be confidently mapped during aerial survey. Ground surveys of western redcedar topkill, yellow-cedar decline, spruce aphid and hemlock sawfly on Prince of Wales Island aided aerial surveyors in location and signature calibration for these agents. Post-aerial-survey ground checks were conducted to confirm hemlock sawfly activity in the Auke Lake/Goat Hill area of Juneau, on North Douglas Island, and near Eagle Crest on Douglas Island. We are grateful to the Wrangell Ranger District for ground checking yellow-cedar decline polygons in question on Zarembo Island.

How to request surveys and survey data

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

FHP Mapping and Reporting Portal, Insect and Disease Survey (IDS) Explorer (https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/gis-spatial-analysis/detection-surveys.shtml#idsdownloads). Other applications available on the Portal include Forest Pest Conditions, Data Summaries, Alien Forest Pest Database, National Insect and Disease Risk Maps, and more. All available information within the FHP Mapping and Reporting Portal is on a national scale and often lists data by US Forest Service Region; Alaska is Region 10. Some available products may not include Alaska. For aerial survey requests or data prior to 2013, contact Karen Hutten at karen.hutten@usda.gov or Garret Dubois at garret.d.dubois@usda.gov. Alaska Region Forest Health Protection also has the ability, as time allows, to produce customized pest maps and analyses tailored to projects conducted by partners.

Aerial Detection Survey Data Disclaimer:

Forest Health Protection and its partners strive to maintain an accurate Aerial Detection Survey (ADS) dataset, but due to the conditions under which the data are collected, FHP and its partners shall not be held responsible for missing or inaccurate data. ADS data 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.

Flying over forested landscape in Southeast Alaska.

Appendix II: Damage Type by Category

Abiotic
Drought
Flooding
Landslide/avalanche
Windthrow
Winter damage

Alder Defoliation
Alder defoliation
Alder leafroller
Alder sawfly

Alder Dieback
Alder dieback

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

Aspen Mortality
Aspen running canker

Birch Defoliation
Birch aphid
Birch defoliation
Birch leafminer
Birch leafroller
Dwarf birch defoliation
Spear-marked black moth

Cottonwood Defoliation
Cottonwood defoliation
Cottonwood leaf beetle
Cottonwood leafminer
Cottonwood leafroller

Fir Mortality
Western balsam bark beetle

Hardwood Defoliation
Hardwood defoliation
Speckled green fruitworm

Hemlock Defoliation
Hemlock looper
Hemlock sawfly

Hemlock Mortality
Hemlock canker
Hemlock mortality

Larch Defoliation
Larch budmoth
Larch sawfly

Larch Mortality
Larch beetle

Shore Pine Damage
Dothistroma needle blight
Shore pine dieback
Western gall rust

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

Spruce Mortality
Northern spruce engraver
Spruce beetle

Spruce/Hemlock Defoliation
Conifer defoliation
Western black-headed budworm

Willow Defoliation
Willow defoliation
Willow leafblotch miner
Willow rust

Willow Dieback
Willow dieback

Yellow-Cedar Decline
Yellow-cedar decline

Other damage (agent not identified)
Birch crown thinning
Hemlock flagging
Larch discoloration
Unknown agent

Appendix III. Information Delivery

Internet and Social Media

Alaska Region Forest Health Protection: https://www.fs.usda.gov/main/r10/forest-grasslandhealth

Alaska Forest Health Conditions Reports, ADS Damage Maps and Story Maps: https://www.fs.usda.gov/detailfull/r10/forest-grasslandhealth/?cid=fsbdev2_038884&width=full

Forest Health Highlights 2019 Story Map: https://storymaps.arcgis.com/stories/150e94edf7ce4e84808b55a487cde528

Ground Survey Map Dashboard: https://usfs.maps.arcgis.com/apps/opsdashboard/index.html#/5305f2b62f8f4ced92d85b6766fee10f

Hemlock Sawfly in Alaska Video: https://www.youtube.com/watch?time_continue=1&v=Hhfz2_a39sQ

Spruce Beetle in Alaska's Forest (Interagency Site): https://www.alaskasprucebeetle.org/

Facebook: ChugachNF and TongassNF

Twitter: @AKForestService, #alaskaforesthealth

Biological Evaluations

Dubois, G., S. Swenson, A. Wenninger, J. Moan and M. Schoofs. Russian River Campground spruce beetle bioevaluation. Provided to Chugach National Forest, Seward Ranger District. Seward, AK. November 2019.

Graham, E.E. and I.J. Davis. Hemlock sawfly bioevaluation and ground survey summary. Southeast, AK. November 2019.

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Burr, S. J. 2019. Forest health protection key insect pests. Society of American Foresters. February 20. Fairbanks, AK.

Burr, S. J. 2019. Insects and firewood. Firewood Workshop, Society of American Foresters. February 23. Fairbanks, AK.

Burr, S. J. 2019. Assessing forest health in Alaska. Western Forest Insect Work Conference. April 23. Anchorage, AK.

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Graham, E. E. 2019. Working with limitations; how to use social media and improve websites as a federal employee Western Forest Insect Work Conference. April 25. Anchorage, AK.

Graham, E. E. 2019. Southeast Drought: Forest Health Impacts. Southeast Alaska Drought Workshop. May 7. Juneau, AK.

Graham, E. E. 2019. Forest health issues in Alaska brown bag lunch. May 20. Wrangell, AK.

Graham, E. E. 2019. It's raining frass: insect activity in 2019. R10 Silvilculture Meeting. September 11. Wrangell, AK.

Graham, E. E. 2019. Hemlock sawfly outbreak in Southeast Alaska. Oct 24. San Diego, CA.

Graham, E. E. 2019. Balsam woolly adelgid infestation in Juneau. Oct 24. San Diego, CA.

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Winton, L. M. 2019. The more interesting forest diseases of Interior Alaska. Cooperative Extension Service seminars. March 19-20. Fairbanks, AK.

Winton, L. M. 2019. Spruce bud blight in Alaska. Western International Forest Insect Work Conference. April 23. Anchorage, AK.

Winton, L. M. 2019. Using commercial services for molecular disease diagnosis; from field to preliminary identification. Western International Forest Disease Work Conference. June 4. Estes Park, CO.

Winton, L. M. 2019. Aspen running canker in Alaska. Bonanza Creek Long Term Ecological Research Site Review. June 21. Fairbanks, AK.

Winton, L. M. 2019. Forest decays and diseases in boreal Alaska. Fairbanks Folk School Week in the Woods, June 23. Fairbanks, AK.

Publications

Bowser, M. L., S. J. Burr, I. Davis, G. D. Dubois, E. E. Graham, J. E. Moan, S. W. Swenson. 2019. A test of metabarcoding for Early Detection and Rapid Response monitoring for non-native forest pest beetles (Coleoptera). Research Ideas and Outcomes 5: e48536. https://doi.org/10.3897/rio.5.e48536

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Winton, L. M., S. Burr, R. Mulvey, E. Graham and G. Dubois. 2019. Pocket guide for the identification of common forest diseases and insects in Alaska. USDA Forest Service. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd539703.pdf

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Wenninger, A. Southcentral Spruce Beetle Season Trap Report. R10 S&PF-FHP-Trip Report October 2019.

Wenninger, A. Southcentral Birch Leafminer Assessments 2019. R10 S&PF-FHP-Trip Report October 2019.

Wenninger, A. Expired and Damaged Bear Spray Performance. R10 S&PF-FHP-Trip Report October 2019.