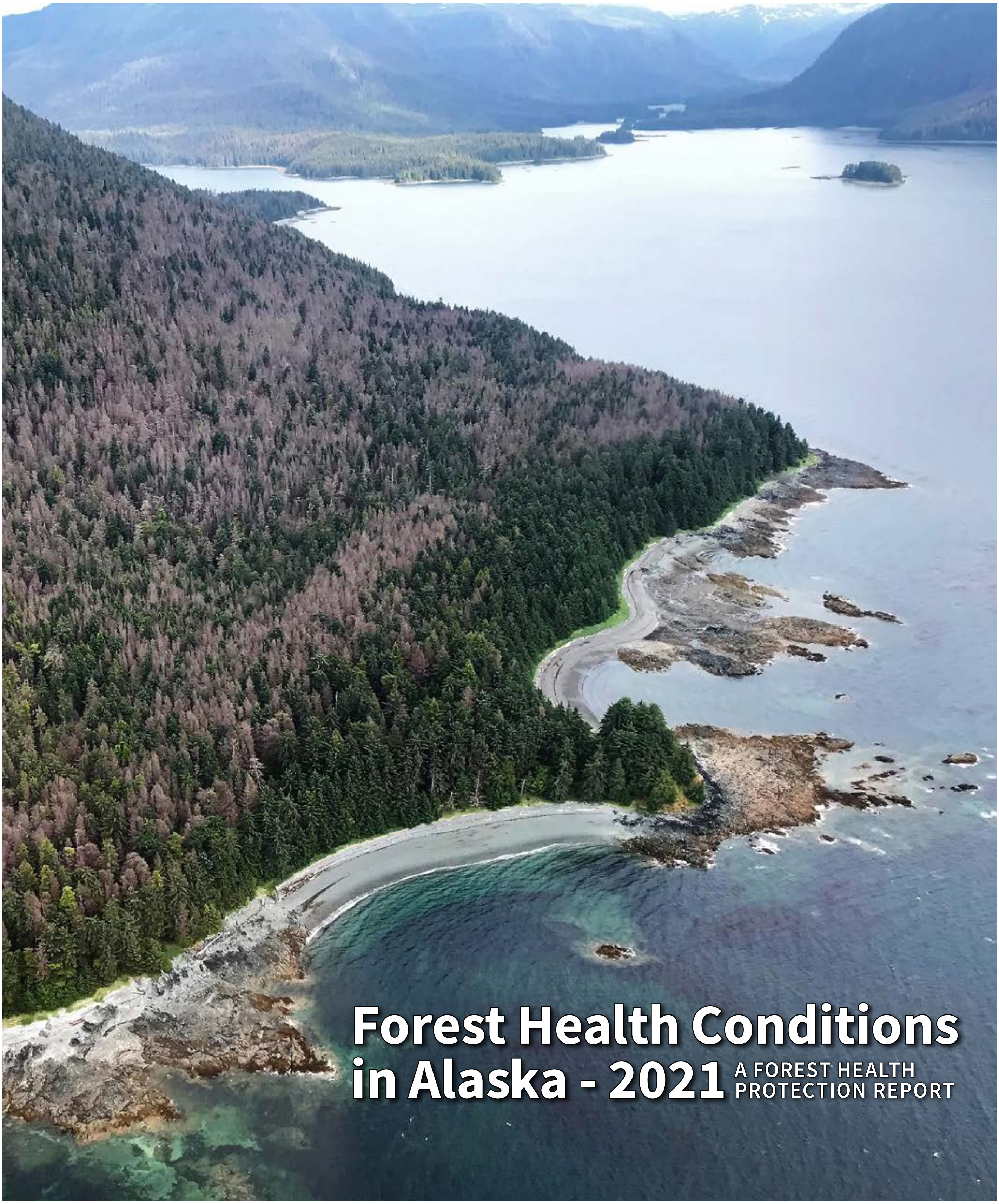
Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Alaska Region | R10-PR-047 | May 2022



Forest Health Conditions in Alaska - 2021

A FOREST HEALTH PROTECTION REPORT

STATE & PRIVATE FORESTRY, ALASKA REGION

CHAD DAVIS
Director for State & Private Forestry
1220 SW Third Avenue, Portland, OR 97204
chad.davis2@usda.gov

KARL DALLA ROSA
Assistant Director for State & Private Forestry
1220 SW Third Avenue, Portland, OR 97204
karl.dallarosa@usda.gov

MICHAEL SHEPHARD
Deputy Director for State & Private Forestry
161 East 1st Avenue, Door 8, Anchorage, AK 99501
michael.shephard@usda.gov

Cover Photo | Western hemlock mortality associated with hemlock sawfly along Chaik Bay on Admiralty Island in Southeast Alaska. USDA Forest Service photo by Robin Mulvey.

ALASKA FOREST HEALTH SPECIALISTS

U.S. FOREST SERVICE, FOREST HEALTH PROTECTION

http://www.fs.fed.us/r10/spf/fhp/

ANCHORAGE, SOUTHCENTRAL FIELD OFFICE

161 East 1st Avenue, Door 8, Anchorage, AK 99501

Phone: (907) 743-9451 Fax: (907) 743-9479

Betty Charnon | betty.charnon@usda.gov
Invasive Plants, Forest Health Monitoring, Pesticides

Jessie Moan | mary.moan@usda.gov
Entomologist

Steve Swenson | steven.swenson@usda.gov
Biological Science Technician

FAIRBANKS, INTERIOR FIELD OFFICE

3700 Airport Way, Fairbanks, AK 99709

Phone: (907) 451-2799, Fax: (907) 451-2690

Sydney Brannoch | sydney.brannoch@usda.gov
Entomologist

Garret Dubois | garret.d.dubois@usda.gov
Biological Science Technician

Lori Winton | loretta.winton@usda.gov
Plant Pathologist

JUNEAU, SOUTHEAST FIELD OFFICE

11175 Auke Lake Way, Juneau, AK 99801

Phone: (907) 586-8811; Fax: (907) 586-7848

Isaac Dell | isaac.dell@usda.gov
Biological Scientist

Elizabeth Graham | elizabeth.e.graham@usda.gov
Entomologist

Karen Hutten | karen.hutten@usda.gov
Aerial Survey Program Manager

Robin Mulvey | robin.mulvey@usda.gov
Plant Pathologist

STATE OF ALASKA, DEPARTMENT OF NATURAL RESOURCES, DIVISION OF FORESTRY

550 W 7th Avenue, Suite 1450, Anchorage, AK 99501

Phone: (907) 269-8460; Fax: (907) 269-8931

Jason Moan | jason.moan@alaska.gov
Forest Health Program Coordinator

UNIVERSITY OF ALASKA FAIRBANKS COOPERATIVE EXTENSION SERVICE

219 E. International Airport Road, Anchorage, AK 99518

Phone: (907) 786-6300; Fax: (907) 786-6312

Gino Graziano | gagraziano@alaska.edu
Invasive Plants Instructor

Alexandria Wenninger | akwenninger@alaska.edu
Integrated Pest Management Program Assistant

AERIAL SURVEY REQUEST

You can request for our aerial survey team to examine specific forest health concerns in your area. Simply email the following information or fill out this form and send it to:

MAIL: Karen Hutten, USDA Forest Service S&PF/FHP, 11175 Auke Lake Way, Juneau, AK 99801

EMAIL: karen.hutten@usda.gov

Name: ______________________ **Organization:** ______________________

Contact Information: ______________________

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

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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 including references to a specific island, river drainage, lake system, nearest locale/town/village.

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Do you need additional forest pest information? (e.g., GIS data, extra copies of the 2021 Forest Health Conditions in Alaska Report, etc.)? Please be as specific as possible. If hardcopies are desired, provide a mailing address.

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WE NEED YOUR FEEDBACK

MAILING LIST UPDATE

Would you like to remain on our mailing list for the annual Forest Health Conditions in Alaska Report? Simply email the following information or fill out this form and send it to:

MAIL: Garret Dubois, USDA Forest Service S&PF/FHP, 3700 Airport Way, Fairbanks, AK 99709

PHONE: (907)-374-3758 | **FAX**: (907)-451-2690

EMAIL: garret.d.dubois@usda.gov

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▶ Do you have changes to your address, contact person or organization? Please update details here:

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FEEDBACK

▶ 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? https://www.fs.usda.gov/main/r10/forest-grasslandhealth

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Forest Health Conditions in Alaska - 2021

FHP REPORT R10-PR-47

EDITED BY: Garret Dubois, Isaac Dell, and Sydney Brannoch

CONTRIBUTORS: Sydney Brannoch, Betty Charnon, Isaac Davis, Isaac Dell, Garret Dubois, Ali Gilchrist, Elizabeth Graham, Tom Heutte, Karen Hutten, Jason Moan, Jessie Moan, Robin Mulvey, Michael Shephard, Martin Schoofs, Steve Swenson, Lori Winton, and Alexandria Wenninger

DESIGN: Jennifer Angelo

CITATION:
FS-R10-FHP. 2021. Forest Health Conditions in Alaska 2021.
Anchorage, Alaska. U.S. Department of Agriculture, Forest Service, Alaska Region.
Publication R10-PR-47. 67 PAGES

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Introduction

We are excited to present the *Forest Health Conditions in Alaska—2021* 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 and is summarized and synthesized by our forest health team. Please feel free to contact us if you have any questions or comments. In addition to this report, current forest health information and resources are available on our newly redesigned and mobile-friendly Forest Health Protection website https://www.fs.usda.gov/main/r10/forest-grasslandhealth. Check out our new look with the most up-to-date information.

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

NEW ARRIVALS: Forest Health Protection is excited to introduce our new Director of State and Private Forestry (S&PF) for Regions 6 and 10, **Chad Davis.** Chad came to the Forest Service following eight years at the Oregon Department of Forestry where he oversaw the state's implementation and administration of S&PF programs. Chad has a broad background working with private industry, academia, and non-governmental organizations. He leads with his values of adventure, creativity, authenticity, and passion into the role as Director. Based out of Portland, Chad is very active and loves to spend time outdoors. He has biked on four continents and been to 43 states, checking Alaska off the list in 2021 with his bicycle in tow! Welcome Chad, we look forward to working with you and sharing our amazing Alaskan forests with you!

Forest Health Protection would also like to welcome **Jennifer Angelo** to Region 10. Jennifer joined the Public Affairs Office in December of 2021 as a Visual Information Specialist, replacing Carol Teitzel. Jennifer brings a wealth of experience in the communications field and served more than 16 years as a civilian in the Army Special Operations community working in graphic design, marketing, and media relations. She also served in the Army National Guard for 14 years, initially enlisting as a photojournalist, then transitioning to be a Public Affairs Officer. One of Jennifer's first assignments was this report, the *Forest Health Conditions in Alaska—2021.* We look forward to working with her on many more projects to come!

RECENT DEPARTURES: Forest Health Protection would love to congratulate **Carol Teitzel,** Visual Information Specialist, on her retirement. Carol joined the Public Affairs Office in August 2009 and became a liaison to the State and Private Forestry Team. A self-proclaimed science geek, she quickly became a part of our team appreciating not only our work but our mutual respect for the Public Affairs Team. She has designed the layout of this report for the last 12 years, streamlining the process to get the design-to-print time down from five months to 45 days! Carol has also played a crucial role in fulfilling our communication and outreach goals by providing guidance and support as well as bringing creativity and humor to our work. She looks forward to seeing what the future holds for Forest Health Protection and will be following us as she works at "being her best self" and adding many more miles to the treads of her boots during retirement. We wish you well Carol, thank you for all your help!

SEASONAL TECHNICIAN: Ali Gilchrist joined us for the 2021 field season in our Anchorage field office. Ali has a bachelor's degree in Forestry from Purdue University and previously worked as a timber buyer in Indiana. Ali enjoyed getting to know our Alaska forests and forest health issues and was a great asset in the field and the lab! Thank you Ali!

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

Chad Davis, new Director of State and Private Forestry R6 &10. USDA Forest Service photo by Robin Mulvey.

Jennifer Angelo, new Visual Information Specialist. Photo courtesy of Jennifer Angelo.

Carol Teitzel, retired Visual Information Specialist with her husband Dennis. Photo courtesy of Carol Teitzel.

Ali Gilchrist, returning biological technician. USDA Forest Service photo by Jessie Moan.

This report is available online at http://www.fs.usda.gov/goto/ForestHealthReports or in print by contacting Biological Science Technician, Garret Dubois garret.d.dubois@usda.gov

2021 Highlights

Forest health issues, like insect and disease outbreaks and invasive plant infestations, do not adhere to management boundaries. Alaska's expansive forests encompass diverse ecoregions and ownership. Nested within the State & Private Forestry branch of the U.S. Forest Service, Forest Health Protection monitors across all lands to meet the needs of federal, state, tribal, and private stakeholders.

Of the 126 million acres of forestland in Alaska, nearly 11 million acres are contained within the United States' two largest National Forests: the Chugach (1.1 million acres) and the Tongass (9.8 million acres). One-quarter of all federal forestland and 43 percent of all state-owned forestland in the country can be found here. Completely outside National Forest boundaries, there are 115 million acres of boreal forest. Another unique aspect of Alaska's forest management is that more than 200 Alaska Native Corporations own 35 million acres of non-industrial private forestland.

In 2021, Alaska's aerial detection surveys resumed after a one-year hiatus due to the COVID-19 pandemic. Approximately 1.2 million acres of damage (Table 1) were mapped across the 15.7 million acres aerially surveyed (Table 2). In addition, our forest health team made more than 800 ground observations of forest damage from diseases (430 records), insects (359 records), and noninfectious agents (21 records), which can be accessed through the interactive data dashboard at https://arcg.is/1SH58a. Ground survey observations are summarized in Table 3, alongside research grade observations from iNaturalist. For the second year, Forest Health Protection solicited observations for the Alaska Forest Health Observations iNaturalist project, receiving 1,255 research grade observations and 2,000 total observations in 2021. Genera that commonly damage trees and plants in Alaska are automatically filtered into the project. Learn more at: https://www.inaturalist.org/projects/alaska-forest-health-observations.

Pathology Highlights

Significant progress on the aspen running canker disease has been made in the past year with the publication of three peer-reviewed journal articles. We completed and published results of pathogenicity tests on both live trees and cut logs to determine that the causal agent was an undescribed fungus (Figure 1). Dr. Pedro Crous at the Westerdijk Fungal biodiversity Institute (Netherlands) led the effort to name this new fungus *Neodothiora populina* Crous, G.C. Adams & Winton. In a third study, we measured over 16,000 trees within 88 sites distributed over six ecoregions and found canker at 82% of the sites. Modeling climate, regional, and site characteristics suggests that the disease is exacerbated by drought and a long-standing aspen leafminer outbreak.

Noninfectous Highlights

Yellow-cedar decline was mapped on about 8,150 acres during aerial detection surveys, about half the typical acreage. Widespread defoliation from the western blackheaded budworm outbreak likely masked decline detection. The northern margin of decline on the outer coast of Chichagof and Yakobi Islands was monitored for the first time in several years. Three small patches of dying yellow-cedar were observed along the outer coast of Glacier Bay National Park during the aerial detection survey. The cause of this damage will be ground verified and carefully tracked moving forward, as yellow-cedar has been healthy in those forests. Monitoring of managed young-growth stands with yellow-cedar decline continues.

Figure 1 | Forest Pathologist Lori Winton pointing to a lesion of aspen running canker. The bark has been scraped away at the margin between healthy and infected tissue. USDA Forest Service photo.

Figure 2 | A western redcedar tree with fresh topkill. USDA Forest Service photo by Molly Simonson.

Figure 3 | A group of western redcedar trees on Prince of Wales Island with dieback and topkill symptoms associated with severe drought. USDA Forest Service photo by Molly Simonson.

Figure 4 | Western blackheaded budworms feed on the new foliage of western hemlock and other conifers leaving the trees with a reddish appearance. USDA Forest Service photo by Elizabeth Graham.

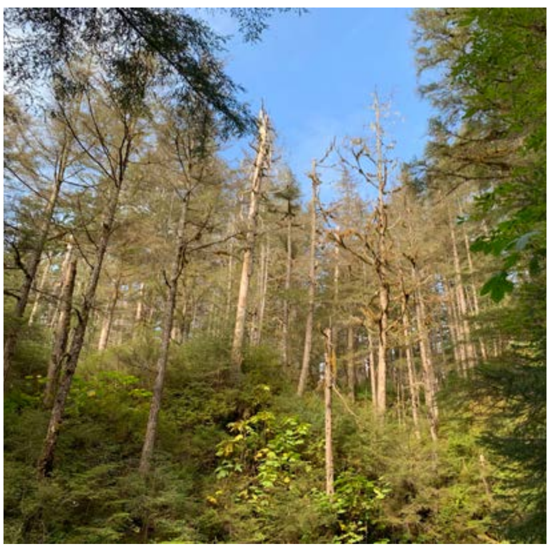


Figure 5 | Topkill and mortality as a result of the hemlock sawfly outbreak from 2018-2020. USDA Forest Service photo by Elizabeth Graham.

Figure 6 | Spruce beetle damage along the Denali Highway near Cantwell. USDA Forest Service photo by Sydney Brannoch.

Observations over the past several years suggest that there are two distinct causes of western redcedar damage, which is concentrated on Prince of Wales Island in Southeast Alaska. The first cause is topkill associated with bole injury of unknown cause (Figure 2). The second cause is direct impacts of the drought of 2018 and 2019 (Figure 3). In Southeast, the return of adequate precipitation over the past two years will limit drought damage in the near-term, though impacts have continued elsewhere in the Pacific Northwest. There is a range-wide effort to track forest health issues of western redcedar.

Insect Highlights

Western blackheaded budworm populations, which began to rise in 2020, increased into an outbreak that has extended across much of Southeast Alaska. Defoliation was recorded on 520,000 acres and was heaviest in the central Tongass area, including Kuiu, Kupreanof, Mitkof, and Zarembo Islands, as well as Chichagof and Admiralty Islands and several drainages on the mainland (Figure 4). Large numbers of moths were observed, indicating that this outbreak will continue in 2022.

Impacts of the hemlock sawfly outbreak that started in 2018, peaked in 2019, and crashed in 2020 are still being observed. Topkill associated with hemlock sawfly feeding was recorded on >186,000 acres in Southeast Alaska during aerial detection surveys, mostly in the central part of the Tongass National Forest (Figure 5). Mortality from severe defoliation was observed on another 21,000 acres, half of which was on Admiralty Island.

The ongoing spruce beetle outbreak has impacted over 1.6 million acres in Southcentral Alaska since it was first detected in 2016. In 2021, damage was most prevalent along the northern portions of the Matanuska-Susitna Borough, the southern portions of the Denali Borough, and around Cooper Landing, Kenai, and Soldotna on the Kenai Peninsula. Activity near Cantwell (Figure 6) will be monitored closely in 2022 as the outbreak is nearing more Interior-like forests and conditions. The activity within the Chugach National Forest has prompted a large-scale response to manage spruce beetle impacts across the landscape. Nearly 194,000 acres of spruce beetle activity were mapped statewide in 2021, with more than 98% observed within the outbreak area.

Invasive Plant Highlights

In early-August 2021, a dense infestation of white sweetclover extending along eight miles of the Seward Highway was hand pulled by dedicated weed warriors from six agencies and organizations. Weed warriors have worked diligently for over a decade to keep this invasive plant off the Kenai Peninsula. In just two days, six dumpsters were filled with bagged white sweetclover and the flowering plants were nowhere in sight between the Placer River and the "Welcome to the Kenai Peninsula" sign.

As part of a larger effort to control the spread of invasive chokecherries, Alaska DOF developed the *Prunus* Remove and Replace program for the Municipality of Anchorage. This program provides a $100 voucher to homeowners who choose to remove their invasive chokecherry and replace it with a non-invasive tree. The intent of this program is to raise awareness about the issues associated with the invasive chokecherries. Public response has been overwhelming with over 120 applications received for 80 available vouchers.

The Fairbanks Soil and Water Conservation District were busy again this year with Elodea control and surveys. Although their control work has been successful, surveys unfortunately identified 10 new infestations in lakes and ponds; nine located on Eielson Air Force Base and one located on Fort Wainwright military lands.

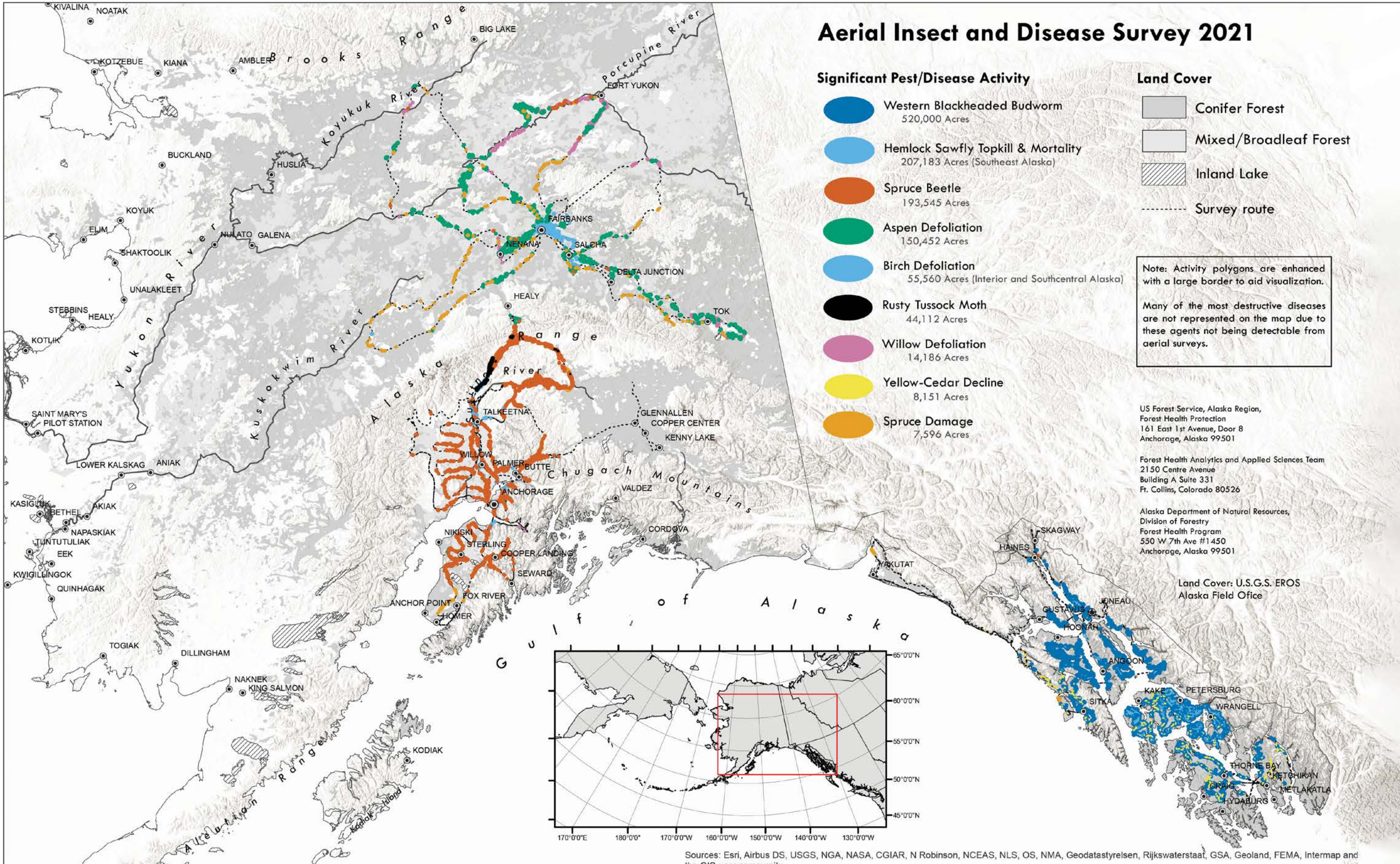
Table 1 | Forest insect and disease activity detected during aerial surveys in Alaska in 2021 by land ownership and agent. All values are in acres*.

Category	Agent	Total Acres	National Forest	Native	Other Federal	State & Private
Disease	Alder dieback	138	52	2	40	44
Disease	Aspen running canker	56	0	0	0	56
Disease	Dothistroma needle blight	428	0	0	86	342
Disease	Spruce broom rust	123	0	20	32	72
Disease	Spruce needle rust	6,619	0	6	3,457	3,155
Disease	Western gall rust dieback	73	59	0	5	10
Noninfectious	Drought	104	0	0	23	81
Noninfectious	Flooding/high-water damage	13,962	236	1,591	1,493	10,641
Noninfectious	Hemlock flagging	29	8	0	16	5
Noninfectious	Landslide/avalanche	1,044	264	368	234	178
Noninfectious	Porcupine damage	209	97	24	79	9
Noninfectious	Windthrow/blowdown	1,619	1,531	38	0	50
Noninfectious	Yellow-cedar decline	8,151	7,520	236	43	352
Insect	Aspen leafminer	146,189	0	41,249	26,712	78,228
Insect	Birch aphid	79	0	0	0	79
Insect	Birch leafminer	47,708	0	693	4,112	42,903
Insect	Cottonwood leaf beetle	5	0	0	0	5
Insect	Hemlock sawfly mortality	21,030	20,012	137	0	881
Insect	Hemlock sawfly topkill	186,153	170,908	4,699		10,545
Insect	Northern spruce engraver	5	0	0	4	1
Insect	Rusty tussock moth	44,112	0	115	2,690	41,307
Insect	Spruce beetle	193,545	6,974	31,630	44,064	110,877
Insect	Western balsam bark beetle	90	33	0	9	47
Insect	Western blackheaded budworm	520,000	460,845	20,733	3,947	34,476
Insect	Willow leafblotch miner	14,178	0	9,760	3,000	1,418
General Damage	Alder defoliation	3,052	129	208	427	2,289
General Damage	Aspen defoliation	4,263	0	2,511	990	762
General Damage	Birch defoliation	7,773	0	418	723	6,633
General Damage	Cottonwood defoliation	676	30	0	415	231
General Damage	Hardwood defoliation	443	0	0	3	440
General Damage	Spruce defoliation	854	796	13	0	45
General Damage	Willow dieback	12	6	0	0	6
	TOTAL	**1,222,722**	**669,501**	**114,452**	**92,605**	**346,166**

*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.

**General Damage is tree damage that cannot be attributed to a particular agent because more than one agent is known to similarly damage the same host. Either or both insects and pathogens may cause the damage. Damage caused by a currently unidentified agent is also included in this category.

Map 1 | 2021 Aerial Insect and Disease Survey. The light-blue color used twice in the legend to represent two different agents; these are separated by region, one active only in Southeast Alaska and the other in the Interior and Southcentral Alaska. For more information on changes to the survey methods in 2021, please see Appendix 1, page 58.



Map 2 | 2021 Aerial Detection Survey Flight Paths. For more information on changes to the survey methods in 2021, please see Appendix 1, page 58.

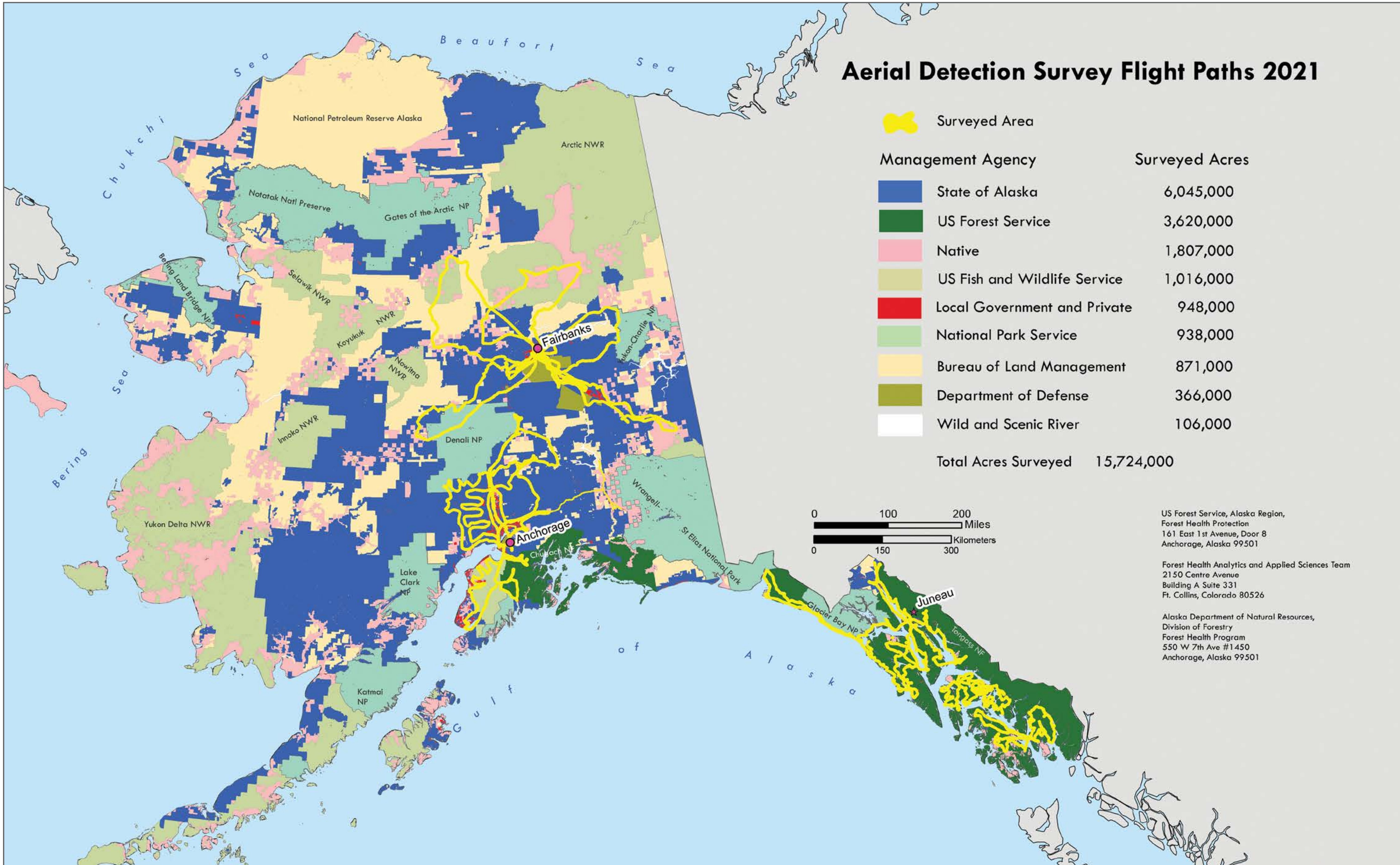


Table 2 | Mapped affected area (in thousands of acres) from 2017 to 2021 from aerial detection survey.

Damage Type	2017	2018	2019	2020	2021
Abiotic damage	5.6	5.0	10.8	0.2	16.7
Alder defoliation	3.4	0.9	2.6	1.0	3.1
Alder dieback	1.0	3.2	1.2	0.0	0.1
Aspen defoliation	168.5	259.7	132.4	38.8	150.5
Aspen mortality	0.0	5.7	0.1	0.0	0.1
Birch defoliation	7.2	132.8	283.4	3.9	55.6
Cottonwood defoliation	1.0	3.6	1.7	0.7	0.7
Fir mortality	0.04	0.1	0.1	0.0	0.1
Hardwood defoliation	38.7	15	3.9	0.1	0.4
Hemlock defoliation	0.0	48.6	381	124.4	520.0
Hemlock mortality	2.7	0.1	0.0	80.0	21.0
Larch mortality	*	0.01	0.0	0.0	0.0
Porcupine damage	1.5	2.5	1.9	0.1	0.2
Shore pine damage	0.3	3.7	0.4	0.0	0.5
Spruce damage	36.1	2.5	117.8	0.7	7.6
Spruce mortality	411.4	594.3	140.6	145.3	193.7
Spruce/hemlock defoliation	1.1	4.2	0.0	0.0	0.0
Willow defoliation	113.2	39.9	32.7	0.5	58.3
Willow dieback	1.0	0.0	0.6	0.0	0.0
Yellow-cedar decline	47.4	17.7	20.0	10.4	8.2
Other damage	*	0.7	9.5	0.0	0.0
Total damage acres	**840.3**	**1139.9**	**1140.8**	**342.0**	**1036.7**
Total acres surveyed	**27,540**	**27,954**	**24,421**	**7,322**	**15,724**
Percent of acres surveyed showing damage	**3.05%**	**4.08%**	**4.67%**	**5.4%**	**6.59%**

* Not documented in previous reports.

Table 3 | Ground observations of forest insects and pathogens in Alaska in 2021. Cumulative ground observations by forest health professionals are displayed in our interactive Ground Survey Dashboard at https://arcg.is/1SH58a. Ground survey protocols are described in Appendix 2 on page 62. Ground observations by citizen scientists can be found in The Alaska Forest Health Observations project on iNaturalist, accessed at https://www.inaturalist.org/projects/alaska-forest-health-observations. Observations of unidentified or noninfectious agents from our ground surveys and species not closely tied to forest health are excluded.

Damage Agent Category	Damage Causing Agent	Scientific Names	Ground Observations*	iNaturalist Research Grade Observations**	Total
Insects	Adelgidae	*Adelgidae* spp.	6	0	6
Insects	Alder woolly sawfly	*Eriocampa ovata*	1	6	7
Insects	Amber-marked birch leafminer	*Profenusa thomsoni*	20	0	20
Insects	Aspen leafminer	*Phyllocnistis populiella*	28	10	38
Insects	Balsam woolly adelgid	*Adelges piceae*	0	0	0
Insects	Battered sallow	*Sunira verberata*	0	2	2
Insects	Birch aphid	*Euceraphis betulae*	5	0	5
Insects	Birch leafminer/roller	*Caloptilia* spp.	18	0	18
Insects	Birch leafroller	*Epinotia solandriana*	10	0	10
Insects	Cooley spruce gall adelgid	*Adelges cooleyi*	0	0	0
Insects	Cottonwood leaf beetle	*Chrysomela scripta*	8	0	8
Insects	Eriophyid mite	*Eriophyidae* spp.	20	5	25
Insects	Engraver beetles	*Ips* spp.	0	0	0
Insects	Gall midge	*Cecidomyiidae* spp.	0	15	15
Insects	Giant conifer aphid	*Cinara* spp.	0	0	0
Insects	Green alder sawfly	*Monsoma pulveratum*	20	8	28
Insects	Hemlock sawfly	*Neodiprion tsugae*	9	1	10
Insects	Hemlock woolly adelgid	*Adelges tsugae*	0	0	0
Insects	Larch sawfly	*Pristiphora erichsonii*	1	0	1
Insects	Late birch leaf edgeminer	*Heterarthrus nemoratus*	22	0	22
Insects	Leaf beetles spp.	*Leaf beetles* spp.	1	13	14
Insects	Rusty tussock moth	*Orgyia antiqua*	5	32	37
Insects	Spotted tussock moth	*Lophocampa maculata*	0	41	41
Insects	Spruce aphid	*Elatobium abietinum*	0	0	0
Insects	Spruce beetle	*Dendroctonus rufipennis*	2	10	12
Insects	Spruce bud moth	*Zeiraphera canadensis*	6	0	6
Insects	Spruce budworm	*Choristoneura* spp.	1	0	1
Insects	Striped alder sawfly	*Hemichroa crocea*	2	1	3
Insects	Western blackheaded budworm	*Acleris gloverana*	32	19	51
Insects	Western tent caterpillar	*Malacosoma californicum*	4	1	5
Insects	Willow leafblotch miner	*Micrurapteryx salicifoliella*	27	2	29

*"Ground Observations" are observations made by Forest Health Protection professionals in the field via direct observation, these include 20-minute timed meanders along the road system as well as opportunistic surveys. A single ground observation in this table can represent damage detected on 1 tree, 2-5 trees, 6-15 trees, 16-30 trees, or more than 30 trees.

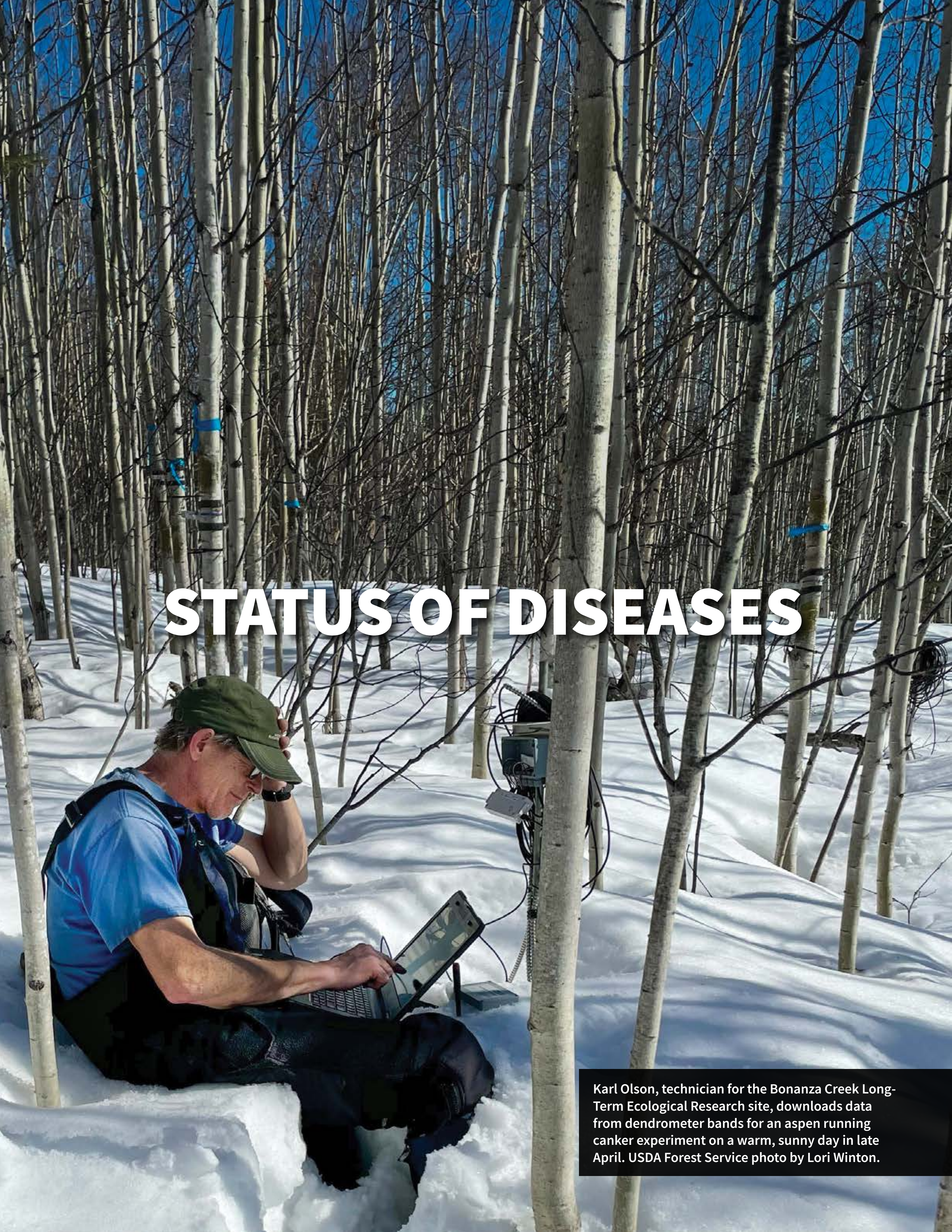
** "iNaturalist Research Grade Observations" are observations reported by citizen scientists on iNaturalist that are identified to species and have 2/3rds community agreement in the taxonomic identification. While species-level IDs are typically needed to establish an observation as "research grade," observations can be deemed "research grade" at any taxonomic level below family, as long as the iNaturalist community votes that the observation does not need more specific IDs.

*** FHP staff recorded brown crumbly rot as *Fomitopsis pinicola sensu lato* (a species complex), whereas iNaturalist users further identified to the species level. There are two species that occur within Alaska: *F. mounceae* and *F. ochracae*.

Table 3 | continued

Damage Agent Category	Damage Causing Agent	Scientific Names	Ground Observations*	iNaturalist Research Grade Observations**	Total
Pathogens	Artist's conk	*Ganoderma applanatum*	6	14	20
Pathogens	Aspen running canker	*Neodothiora populina*	11	0	11
Pathogens	Aspen shoot blight	*Venturia mucularis*	5	0	5
Pathogens	Aspen target canker	*Cytospora notastroma*	2	0	2
Pathogens	Bear's tooth fungus	*Hercicium abietis*	1	6	7
Pathogens	Birch polypore	*Fomitopsis betulina*	3	38	41
Pathogens	Brown crumbly rot	*Fomitopsis mounceae****	—	30	30
Pathogens	Brown crumbly rot	*Fomitopsis ochracae****	—	84	84
Pathogens	Brown crumbly rot	*Fomitopsis pinicola sensu lato****	10	—	10
Pathogens	Brown cubical butt rot	*Phaeolus schweinitzii*	15	23	38
Pathogens	Canker-rot of birch	*Inonotus obliquus*	2	14	16
Pathogens	Coral tooth fungus	*Hericium coralloides*	0	18	18
Pathogens	Cottonwood/Polar shoot blight	*Venturia populina*	1	0	1
Pathogens	Diplodia gall	*Diplodia tumefaciens*	1	3	4
Pathogens	Dothistroma needle blight	*Dothistroma septosporum*	1	0	1
Pathogens	Hardwood leaf rusts	*Melamspora* spp.	12	11	23
Pathogens	Hartig's conk	*Phellinus hartigii*	3	0	3
Pathogens	Hemlock dwarf mistletoe	*Arceuthobium tsugense*	6	6	12
Pathogens	Hemlock-blueberry rust	*Naohidemyces vaccinii*	16	0	16
Pathogens	Lacquer/varnish conk	*Ganoderma oregonense*	2	8	10
Pathogens	Lirula needle cast	*Lirula macrospora*	13	1	14
Pathogens	Paint fungus	*Echinodontium tinctorium*	0	1	1
Pathogens	Quinine conk	*Laricifomes officinalis*	0	2	2
Pathogens	Red ring rot	*Porodaedalea pini*	18	9	27
Pathogens	Sirococcus shoot blight	*Sirococcus tsugae*	9	0	9
Pathogens	Spruce broom rust	*Chrysomyxa arctostaphyli*	10	11	21
Pathogens	Spruce bud blights	*Spruce bud blights* spp.	156	0	156
Pathogens	Spruce bud rust	*Chrysomyxa woroninii*	4	8	12
Pathogens	Spruce needle rust	*Chrysomyxa ledicola*	23	11	34
Pathogens	Sulfur fungus	*Laetiporus conifericola*	7	98	105
Pathogens	Tinder conk/hoof fungus	*Fomes fomentarius*	7	27	34
Pathogens	Tomentosus root rot	*Onnia tomentosa*	0	6	6
Pathogens	Trunk rot of aspen	*Phellinus tremulae*	11	5	16
Pathogens	Trunk rot of birch	*Phellinus igniarius*	7	19	26
Pathogens	Viburnum leaf and stem rust	*Puccinia linkii*	0	20	20
Pathogens	Weir's cushion rust	*Chrysomyxa weirii*	2	0	2
Pathogens	Western gall rust	*Endocronartium harknessii*	3	2	5
Pathogens	Yellow cap fungus	*Pholiota* spp.	0	9	9

STATUS OF DISEASES

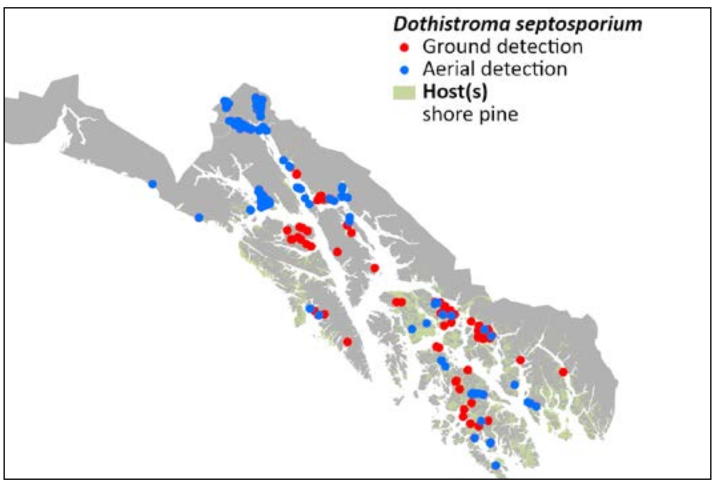


Karl Olson, technician for the Bonanza Creek Long-Term Ecological Research site, downloads data from dendrometer bands for an aspen running canker experiment on a warm, sunny day in late April. USDA Forest Service photo by Lori Winton.

DOTHISTROMA NEEDLE BLIGHT

Dothistroma septosporum (Dorog.) M. Morelet

Dothistroma needle blight occurs throughout the range of shore pine in Alaska (Map 3) and in 2021 there was a slight uptick in disease detection (Figure 7). During the aerial detection survey, discolored shore pine crowns were observed near Skagway by the Dewey Lakes trail system and on the western shore of Taiya Inlet below Face Mountain. The damage will be ground checked in 2022. Consecutive rainy days and temperatures greater than 62°F are linked to outbreaks. The dry weather in 2018 and 2019 inhibited disease spread, resulting in negligible disease in 2020. Abundant precipitation and slightly elevated temperatures in 2021 may facilitate worsening damage next year. Notable tree mortality has occurred in Alaska during localized, prolonged outbreaks. Dr. Renate Heinzelmann at University of British Columbia continues to evaluate genetic differences between *Dothistroma* isolates collected across western North America, including Southeast Alaska, and has partnered with PhD student Barbara Wong from Université Laval to assess how temperature and moisture regimes influence isolate growth on nutritional media.



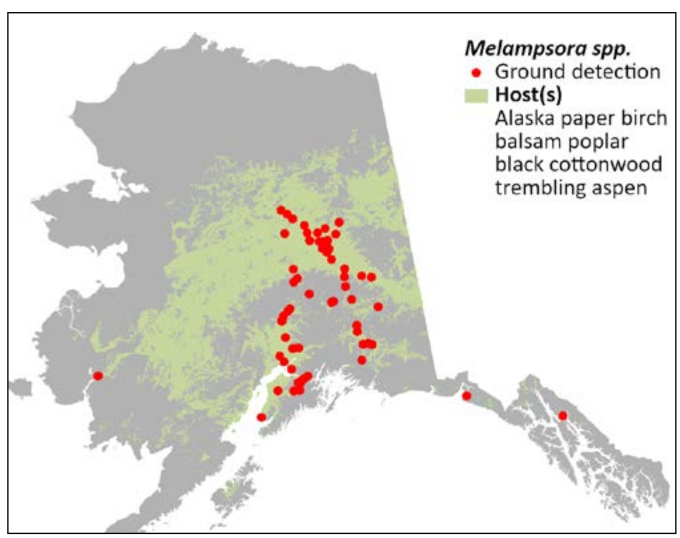
Map 3 | Dothistroma needle blight cumulative mapped locations and modeled host tree distribution(s).

Figure 7 | Discoloration and needle cast symptoms of Dothistroma needle blight caused by *Dothistroma septosporum* on shore pine from Douglas Island near Juneau. USDA Forest Service photo by Robin Mulvey.

HARDWOOD LEAF RUSTS

Melampsora epitea Thuem.
Melampsora medusae Thuem.
Melampsoridium betulinum Kleb

In Southcentral and the Interior, hardwood leaf rusts were recorded at two locations on aspen, seven on paper birch, and one on dwarf birch. Near Bethel, single observations were found on both paper birch and willow. There were five research grade observations of willow leaf rust *Melampsora epitea* recorded through iNaturalist near Seward, Cantwell, Denali National Park, and Fairbanks. Distinguishing among the species that cause hardwood leaf rusts is dependent on the host plant; *M. epitea* mainly occurs on willow, *M. medusae* on poplars, including aspen, and *M. betulinum* on birch. Most observations of hardwood leaf rusts (Map 4) have been recorded on willow species (69%); however, it is also common on Alaska paper birch, trembling aspen, alder, rose, and species of dwarf birch.



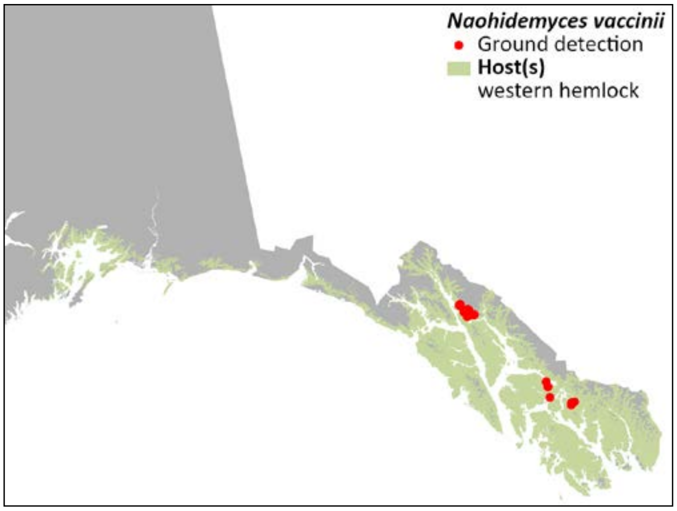
Map 4 | Hardwood leaf rusts cumulative mapped locations. Host tree and shrub distributions are not shown, but include willow, birch, aspen, and cottonwood.

HEMLOCK-BLUEBERRY RUST

Naohidemyces vaccinii (Wint.) Sato, Katsuy et Hiratsuka

Figure 8 | Hemlock needle rust on western hemlock on Wrangell Island. Diptera larvae from the genus *Mycodiplosis* commonly feed on the spores of rust fungi. USDA Forest Service photo by Elizabeth Graham.

Hemlock-blueberry rust is usually a disease of minor importance that can be difficult to find on both blueberry leaves and hemlock needles. However, this disease was widespread on western hemlock needles in Southeast Alaska from 2019 to 2021 (Map 5). The damage to blueberry leaves has been observed but is easily masked by other foliar damage. Infected hemlock needles (Figure 8) were collected in 2020 and 2021 to allow for molecular verification of the causal fungus. We sequenced DNA from three samples near Juneau, as well as Wrangell and Mitkof Islands. The closest match (97%) to our sequences came from an *N. vaccinii* specimen from the United Kingdom, the only *N. vaccinii* voucher sequence available for species determination. Our sequences all showed consistent base pair differences with that of the voucher specimen. Moving forward, we hope to compare our *N. vaccinii* sequences to other samples from western North America.

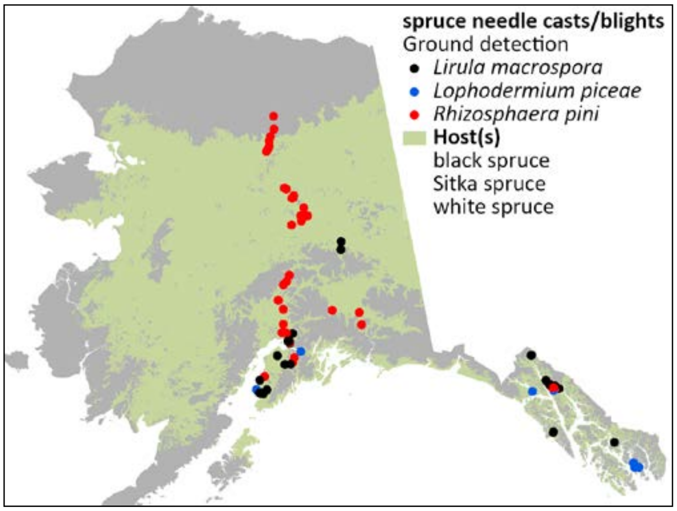


Map 5 | Hemlock-blueberry rust cumulative mapped locations and modeled host tree distribution(s).

SPRUCE NEEDLE CASTS/BLIGHTS

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

Three fungi cause needle casts and blights of spruce throughout much of Alaska (Map 6) although they are rarely noticeable. Lirula needle blight, more common in coastal forests, was found on Sitka spruce at nine sites in northern Southeast Alaska and near Wrangell in 2021, where unusually severe discoloration symptoms were observed on one-year-old Sitka spruce needles (Figures 9, 10). DNA sequencing of samples from Juneau and Gustavus verified that the causal fungus is *L. macrospora*. Similar damage was also reported from Chilkoot State Park near Haines. In coastal Southcentral Alaska, it was found on both white and black spruce. In the Interior, *L. macrospora* was found on many white spruce near Delta Junction. A sample of *Rhizosphaera* was collected near Juneau. We hope to refine our taxonomic identification of *Rhizosphaera* by obtaining samples with mature fruiting structures prior to spore dispersal in spring. Lophodermium needle cast was not detected this year.



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

Figure 9 | Needle discoloration symptoms of Lirula needle blight were common on Sitka spruce in northern Southeast Alaska in 2021. USDA Forest Service photo by Robin Mulvey.

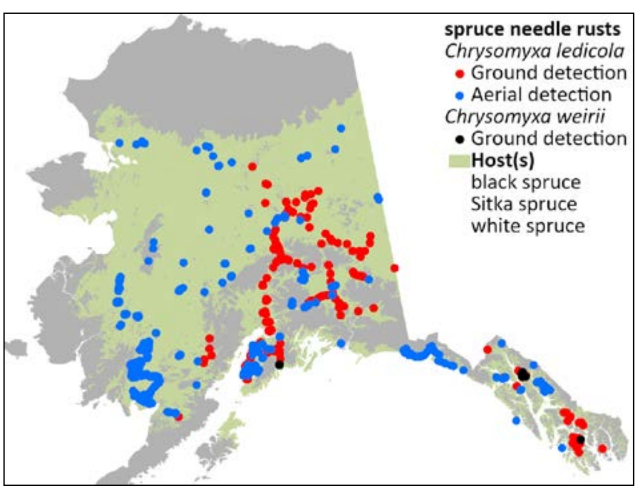
Figure 10 | Pronounced needle discoloration and immature fruiting structures on Sitka spruce needles infected with *Lirula macrospora*. USDA Forest Service photo by Robin Mulvey.

SPRUCE NEEDLE RUSTS

Chrysomyxa ledicola Lagerh. | *C. weirii* Jacks.

Chrysomyxa ledicola, the spruce needle rust fungus found in summer, was far less prevalent as compared to the widespread outbreaks of 2019 and 2020. Ground surveys in Interior found the fungus on both white and black spruce at nine locations from Denali National Park to just north of Fairbanks. From the air, about 6600 acres were found from Denali National Park south to the Kenai Peninsula in Southcentral. Typical disease levels were found on Sitka spruce in Southeast Alaska, where it was reported at 13 locations, mainly near Juneau and on Mitkof Island (Figure 11). Of eleven research grade observations submitted through iNaturalist, there were six near Fairbanks, one each near Glacier View and Healy, and three in Southeast on Wrangell, Chichagof, and Baranof Islands. *Chrysomyxa weirii*, which occurs in the spring, was recorded on Sitka spruce at two locations near Juneau in 2021. The affected trees showed uncommonly high levels of infection. Spruce needle rust is common throughout the range of hosts in Alaska (Map 7).

Figure 11 | Pronounced needle discoloration and immature fruiting structures on Sitka spruce needles infected with *Lirula macrospora*. USDA



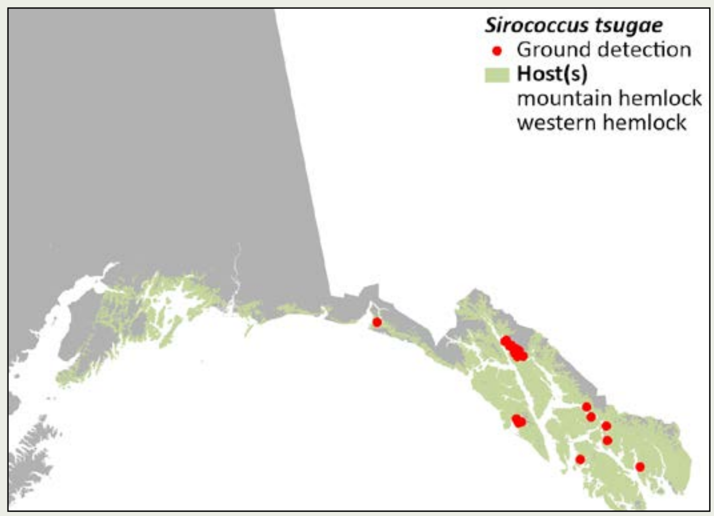
Map 7 | Spruce Needle Rust cumulative mapped locations and modeled host tree distribution(s).

Pathology Updates > Shoot, Twig, and Bud Diseases

SIROCOCCUS SHOOT BLIGHT

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

Sirococcus shoot blight, which affects western and mountain hemlock (occasionally spruce) across Southeast Alaska (Map 8), was active again in 2021. Seven ground observations were made near Juneau and another two were made on Mitkof and Revillagigedo Islands. Due to the outbreak of western blackheaded budworm, which also primarily damages western hemlock shoots, Sirococcus shoot blight was more difficult to confirm and detect. *Sirococcus tsugae* benefited from the wet conditions common in 2020 and 2021. Symptom severity and compromised tree form worsen with repeated years of shoot dieback. Conditions that favor chronic infection are most often found along creeks and in mountain bowls. Severe shoot disease observed in landscape plantings suggests greater susceptibility among non-native planted hemlock varieties.



Map 8 | Sirococcus shoot blight cumulative mapped locations and modeled host tree distribution(s).

VIBURNUM LEAF AND STEM RUST

Puccinia linkii Klotzsch

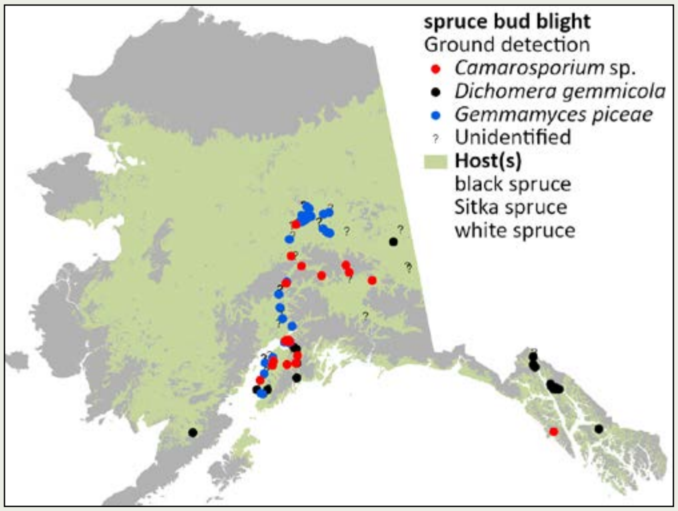
Leaf rust of highbush cranberry (*Viburnum edule*) occurs in Alaska and elsewhere in North America. Elevated damage from this disease was observed in 2020 and 2021. Increased disease incidence and severity is likely related to cool, wet conditions during the growing season. Infections begin as smooth magenta spots on leaves, petioles, fruits, and stems that darken as spores (teliospores) develop. Foliar infections tend to be most severe close to perennial stem infections. In 2014, this disease was observed causing stem rust near Juneau, marking the first-time stem damage had been attributed to this fungus. Since then, the disease has been recorded scattered throughout Alaska (Fairbanks, Anchorage, Soldotna, Willow, Susitna North, Skagway, and Juneau). iNaturalist has been a helpful way to track this disease in Alaska; twenty iNaturalist reports poured in from Southcentral Alaska in July and August 2021, including observations of stem infections near Seward, Whittier, and Anchorage.

SPRUCE BUD BLIGHTS

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

Spruce bud blight is found throughout the state, but damage has been minor and limited to the buds (Map 9). Identical symptoms are caused by three fungal species but distinguishing among them requires specialized equipment, thus the specific cause of many observations is not identified. Sergio Peralta, a graduate student from University of Nebraska-Lincoln, with help from FHP, collected 133 samples from Interior and Southcentral ranging from the Chatanika River north of Fairbanks to Homer. By microscopic examination, he found that 90 (68%) of the samples were *Gemmamyces piceae*, which causes widespread mortality of plantation spruce in Central Europe. Eighty-eight of the *G. piceae* samples were on white spruce and two were on ornamental spruce species on the Kenai Peninsula. Sixteen of his samples were solely *Dichomera gemmicola* on white and Sitka spruce on the Kenai Peninsula and seven were a *Camarosporium* species on white spruce south of the Alaska Range. Notably, he found one sample had both *G. piceae* and *D. gemmicola* on the same bud (Figure 12), while another had both *G. piceae* and *Camarosporium*. Sergio has sequenced the total genome of *G. piceae* and is using it to design a population genetics study to determine how long the fungus has been present in Alaska. FHP staff collected additional spruce bud blight samples in Southcentral and Interior Alaska: six were *G. piceae* and 41 were unidentified. In Southeast, *D. gemmicola* was found on Sitka spruce at two locations near Juneau, where *G. piceae* has never been detected.

Figure 12 | White spruce buds near Homer with fruiting bodies of both *Gemmamyces picea* and *Dichomera gemmicola* on the same bud. The black, spherical fruiting bodies are indistinguishable with the naked eye. USDA Forest Service photo by Steve Swenson.

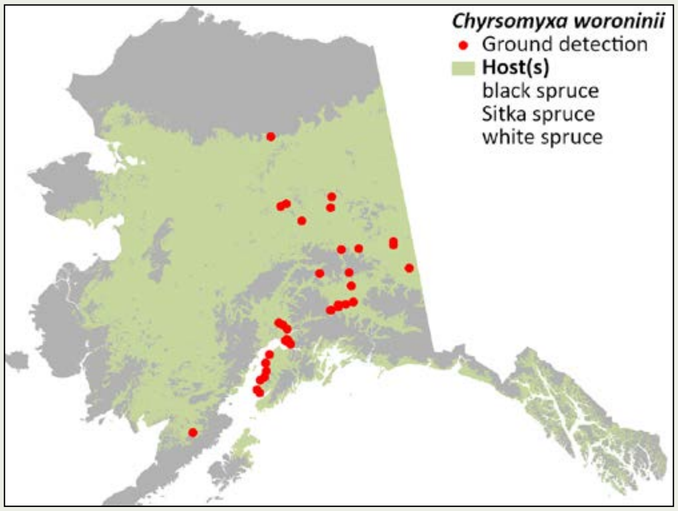


Map 9 | Spruce bud blight cumulative mapped locations and modeled host tree distribution(s).

SPRUCE BUD RUST

Chrysomyxa woroninii Tranz.

Two observations of spruce bud rust were recorded on black spruce in the Interior at the Chena River Recreation Area and in Southcentral in the Anchorage bowl. On white spruce, two observations were made just north of the Alaska Range. Spruce bud rust has been recorded on white, black, Lutz, and Sitka spruce throughout Southcentral and Interior Alaska (Map 10) but does not usually occur on more than five trees at a site. Six research grade observations in the Interior and Southcentral were submitted through iNaturalist near Anchorage, Delta Junction, Denali National Park and Preserve, and Fairbanks.



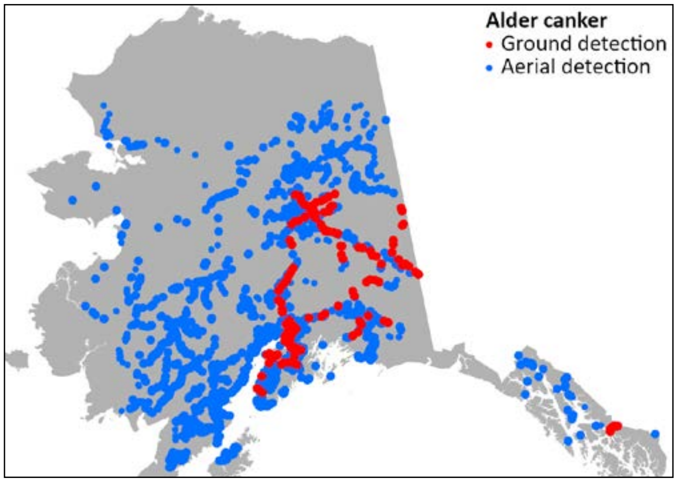
Map 10 | Spruce bud rust cumulative mapped locations and modeled host tree distribution(s).

Pathology Updates > Stem and Branch Diseases

ALDER CANKER

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

During ground surveys in Southcentral and the Interior, minor alder canker was recorded in 2021 at four locations near Anchorage and Delta Junction. From the air, almost 140 acres of alder dieback were observed in Southcentral between Denali State Park and the Caribou Hills on the Kenai Peninsula. Diagnostic fungal structures cannot be seen from the air, but dieback symptoms on thin-leaf alder are usually caused by *Valsa melanodiscus* and can culminate in mortality. Other canker causing fungi, including a species of *Valsalnicola*, are more prevalent on Sitka and Siberian alder. Significant alder dieback began in 2003 and peaked between 2011 and 2014; since then, alder canker damage has been decreasing. We have mapped it on all alder shrub species throughout most of the state (Map 11). Alder dieback has frequently been aerially mapped throughout Southeast, however canker diagnosis on the ground has mainly been along the Stikine River.

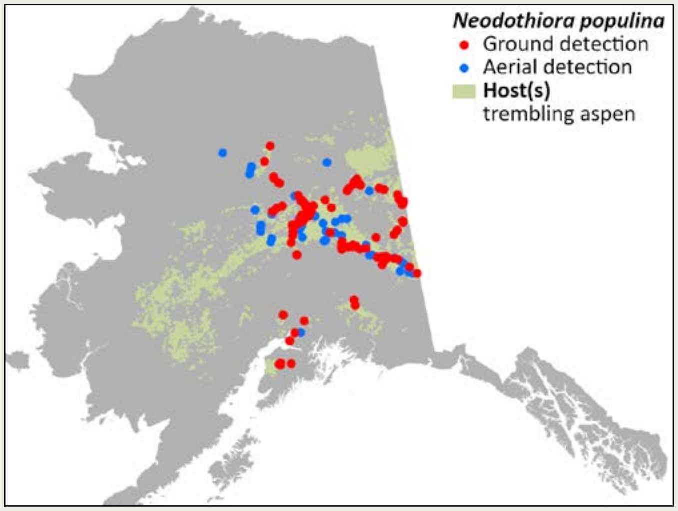


Map 11 | Alder canker cumulative mapped locations. Host tree and shrub distributions are not shown but include alder species in Alaska.

ASPEN RUNNING CANKER

Neodothiora populina Crous, G.C. Adams & Winton

Aspen running canker has been mapped throughout the surveyed areas of the Interior and Southcentral Alaska boreal forest (Map 12). In 2021, eleven locations were recorded in the Interior ground surveys, mainly along the Parks Highway between Fairbanks and Healy and along the Richardson Highway south of Delta Junction. The aerial detection survey mapped about 56 acres in the Interior. First found in 2015, the lack of diagnostic fruiting bodies made determining a causal agent difficult for several years. At last, in partnership with Dr. Gerry Adams (University of Nebraska Lincoln) and Dr. Pedro Crous (Westerdijk Fungal Biodiversity Institute, Netherlands), we have completed pathogenicity tests (Winton et al. 2021 https://doi.org/10.1080/07060661.2021.1952487) and determined that the causal agent is a fungus new to science that we have named *Neodothiora populina* Crous, G.C. Adams & Winton (Crous et al. 2020. https://www.fungalplanet.org/content/pdf-files/FungalPlanet1141.pdf, Figure 13) . A third publication described a survey of 16,576 aspen trees across 88 study sites located within six ecoregions (Ruess et al. 2021. https://doi.org/10.1371/journal.pone.0250078). Sites in the Tanana-Kuskokwim Lowlands had the highest disease incidence (averaging 30% infected trees). Canker induced mortality was invariant across all sites averaging of 70% of the trees that had canker. Sites with higher canker incidence and mortality had higher summer vapor pressure deficits. This indicator of drought combined with the persistent aspen leaf miner outbreak suggest conditions favoring the pathogen which leads to canker-caused mortality.



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

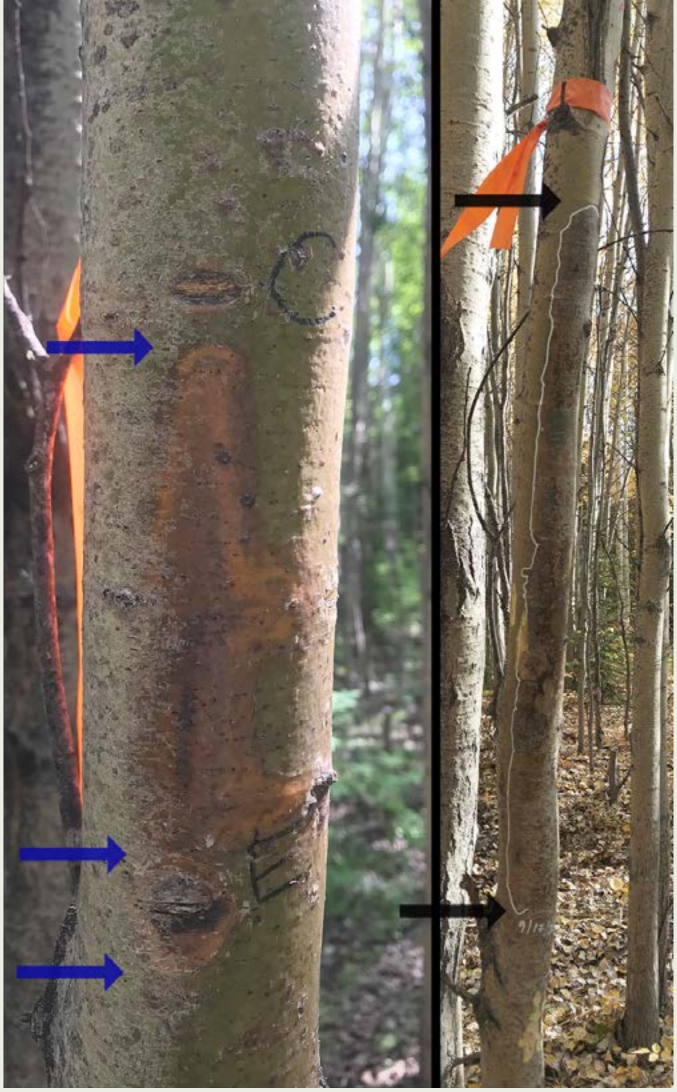
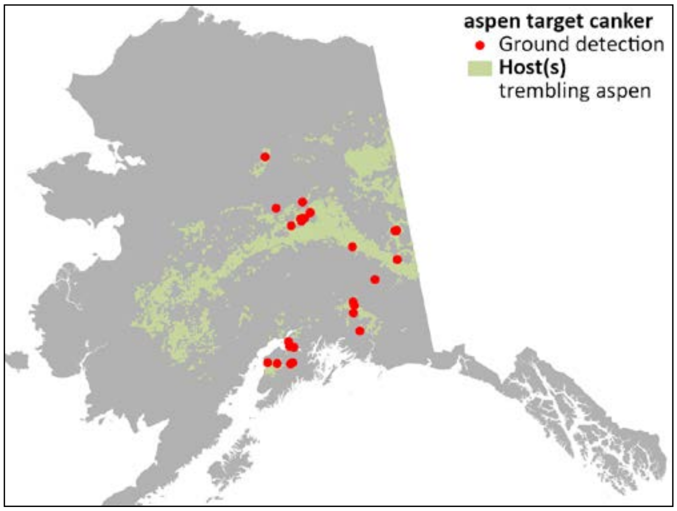


Figure 13 | Two photos of an aspen tree that was inoculated with *Neodothiora populina* isolate E in September 2019. **Left:** About one year after inoculation (October 2020), the lesion margins were between the two lower blue arrows (2.9 cm vertical distance). Twenty-one months after inoculation (June 2021), the lesion had expanded to the two outer blue arrows (13.5 cm). The small upper lesion designated C is the wound control. **Right:** Two years after inoculation (September 2021) the lesion (outlined in white paint) was 54 cm long (between the two black arrows). USDA Forest Service photo by Lori Winton.

ASPEN TARGET CANKER

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

Aspen target canker was mapped in Interior and Southcentral at a site near Nenana and on several trees near Glennallen in 2021. In recent years, we have mapped aspen target canker across Alaska from the Kenai Peninsula to Chicken near the Canadian border, and north of the Yukon River (Map 13). In contrast to aspen running canker, these cankers are distinctly target-shaped with flaring bark. Although we have isolated the fungus *Cytospora notastroma* from these cankers, more work is needed to determine whether this is the main pathogen involved in aspen target canker in Alaska.

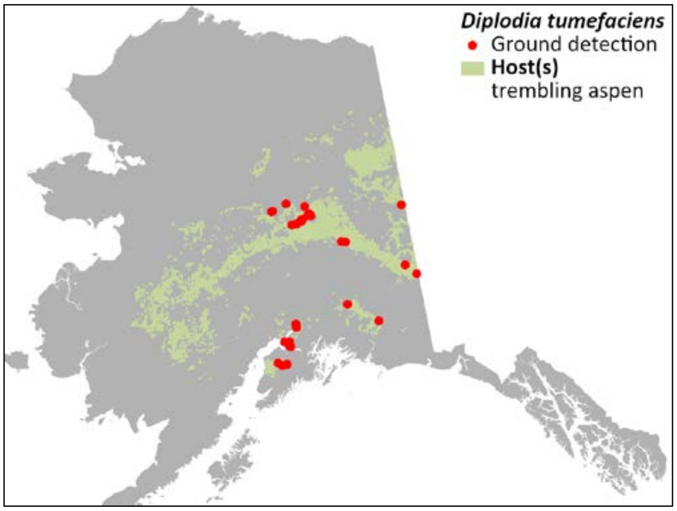


Map 13 | Aspen target canker cumulative mapped locations and modeled host tree distribution(s).

DIPLODIA GALL

Diplodia tumefaciens (Shear) Zalasky

This year, FHP staff recorded Diplodia gall on several trees in the Interior near Delta Junction and two research grade iNaturalist observations were made in Southcentral near Anchorage and another in the Interior near Fairbanks. This disease is well distributed throughout the surveyed range of aspen in Alaska (Map 14). Here, we have only recorded this disease on aspen, but it has also been reported on balsam poplar and other *Populus* species elsewhere in North America. The patches containing affected trees are generally small and discrete, less than two acres in size. When occurring on the trunk, it strongly resembles Chaga, which is also known as the cinder conk (*Inonotus obliquus*). However, Diplodia gall has only been found on aspen in Alaska, whereas the cinder conk occurs mainly on birch.



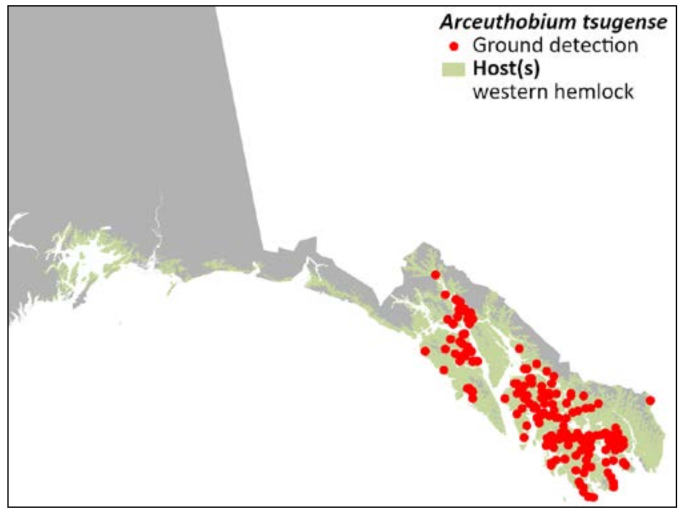
Map 14 | Diplodia gall cumulative mapped locations and modeled host tree distribution(s).

HEMLOCK DWARF MISTLETOE

Arceuthobium tsugense (Rosendahl) G.N. Jones

Figure 14 | A hemlock dwarf mistletoe shoot parasitizing western hemlock in Sitka, AK. This observation was submitted to iNaturalist. Photo courtesy of Paul Norwood.

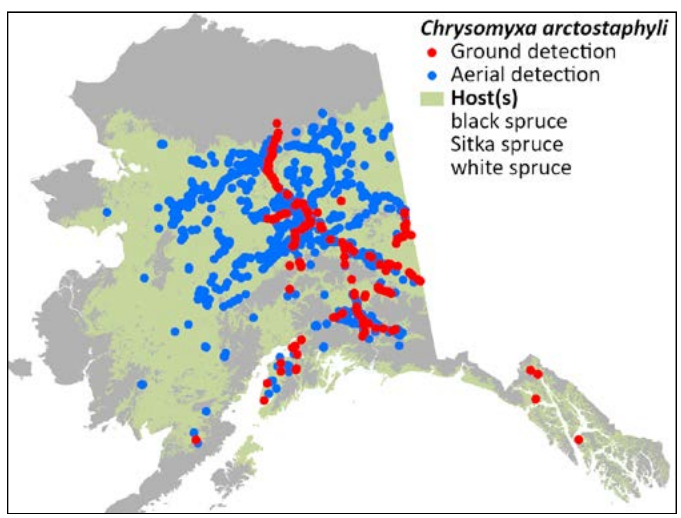
Hemlock dwarf mistletoe, a parasitic plant, is the leading disease of western hemlock in unmanaged old-growth stands in Southeast Alaska. Hemlock dwarf mistletoe brooms (prolific branching) provide important wildlife habitat and serve as infection courts for decay fungi, while tree mortality caused by severe infection creates canopy gaps. The incidence of hemlock dwarf mistletoe does not vary noticeably between years, but we made six observations of the disease in Juneau, on the Chilkat Peninsula, and on northern Admiralty Island. Additionally, six research grade observations were contributed through iNaturalist near Sitka; each record included beautifully detailed photos of dwarf mistletoe shoots (Figure 14). 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). Hemlock dwarf mistletoe is one of seven disease examples that we presented to demonstrate how a conceptual framework based on the plant disease triangle can be applied to better understand how climate change may influence tree disease behavior (Hennon et al. 2021, https://onlinelibrary.wiley.com/doi/10.1111/efp.12719). Other examples from Alaska include Dothistroma needle blight and yellow-cedar decline.



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

SPRUCE BROOM RUST

Chrysomyxa arctostaphyli Diet.



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

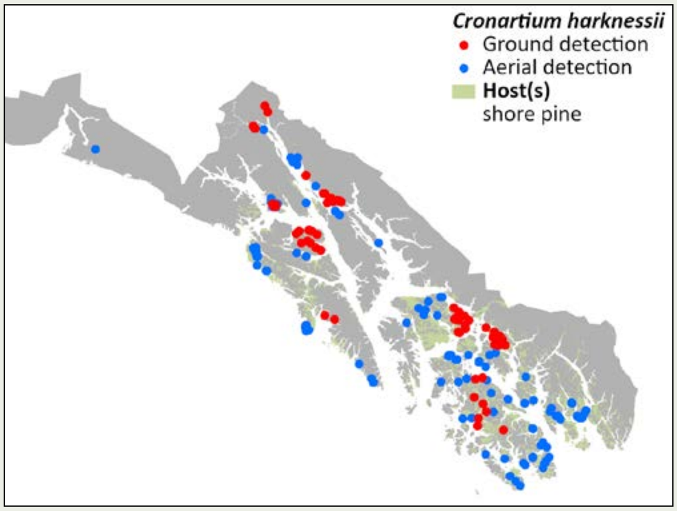
Spruce broom rust is one of the most easily identifiable diseases in Alaska, therefore we have a remarkably comprehensive map of both ground and aerial observations (Map 16). During 2021 ground surveys in Interior and Southcentral, we documented spruce broom rust on both white and Sitka spruce at 10 locations between Delta Junction and Homer. In addition, 12 research grade observations were recorded through iNaturalist. From the air, about 120 acres were mapped, mostly north of the Alaska Range between the Kanuti, Yukon Flats, and Tetlin National Wildlife Refuges, and towards Denali National Park and Preserve. The brooms are perennial, with relatively steady incidence from year to year. In 2018, an observation was made on the Seward Peninsula, over 100 miles west of previous detections and west of the proposed range of kinnikinnick (*Arctostaphylos uva-ursi*), the alternate host plant (based on Hulten, 1968, Flora of Alaska). This part of the state has not since been flown to confirm the record. Broom rust is common and widespread on white and black spruce branches and stems throughout Southcentral and the Interior. It is absent from most of Southeast aside from Glacier Bay, northern Lynn Canal, and Halleck Harbor on Kuiu Island.

Figure 15 | Fruiting structures of *Nectria cinnabarina* were common on western gall rust galls in 2021, contributing to elevated dieback of shore pine trees like these near Gustavus, AK. USDA Forest Service photo by Robin Mulvey.

WESTERN GALL RUST

Cronartium harknessii E.Meinecke (= *Endocronartium harknessii*)

Western gall rust is prevalent throughout the range of shore pine in Southeast Alaska and its incidence does not change much from year to year (Map 17). In 2021, we observed an increase in galls that were infected by the fungus *Nectria cinnabarina* (Figure 15), which leads to bole and branch mortality. As an obligate parasite, it is uncommon for western gall rust to kill branches and boles directly; however, when secondary insects and fungi invade galls they girdle stem tissue, causing greater impacts to shore pine health. In 2021, aerial surveyors recorded 73 acres of new dieback (flagging red branches) associated with western gall rust. In permanent plots established to evaluate shore pine health in Alaska, infection was found to be ubiquitous and frequently contributed to top kill or tree mortality. In 2017, western gall rust was observed sporulating at the edge of a large, diamond-shaped canker on a shore pine tree bole in Gustavus, suggesting that it likely causes this common type of bole canker (i.e., hip canker). Another stem rust, stalactiform blister rust caused by *Cronartium coleosporioides*, was recently detected on shore pine near Haines (molecularly confirmed) and Gustavus (suspected). An additional suspected stalactiform blister rust observation was recorded in iNaturalist near Hoonah.



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

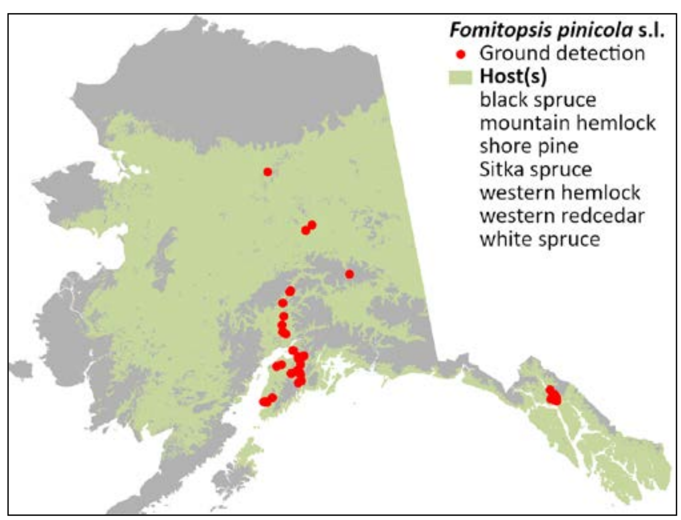
Figure 16 | A Sitka spruce tree with abundant decay and mycelial felts of *Fomitopsis* sp. shows how stem decays predispose large trees to failure during wind events. USDA Forest Service photo by Robin Mulvey.

BROWN CRUMBLY ROT

Fomitopsis pinicola sensu lato
Fomitopsis mounceae J.-E. Haight & Nakasone
Fomitopsis ochracea Ryvarden & Stokland

Ten observations of *Fomitopsis pinicola* sensu lato (a species complex that has recently been redescribed) were recorded in 2021 by FHP staff. Recent phylogenetic work has revealed that three species from this complex are present in North America and two occur in Alaska: *F. mounceae*, which has the red-orange band that inspired the "red belt conk" common name, and *F. ochracea*, which does not (Haight et al. 2019, https://doi.org/10.1080/00275514.2018.1564449). *F. pinicola* sensu stricto was originally described from Europe and is now thought to be restricted to Eurasia. In iNaturalist, there were 31 research grade observations of *F. mounceae* and 82 of *F. ochracae* in 2021. iNaturalist is improving our ability to capture georeferenced and photo-documented observations of this very common species complex. Members of the *Fomitopsis pinicola* complex are presumed to occur throughout their spruce and hemlock host ranges in Alaska (Map 18).

Near Juneau in Southeast, numerous large Sitka spruce that snapped during fall storms contained brown rot decay and abundant white mycelial mats typical of *F. pinicola* sensu lato, although fruiting structures were absent. Occasionally, *Laetiporus conifericola*, *Climacocystis borealis*, or *Phaeolus schweinitzii* fruiting structures were found nearby; therefore, multiple fungi may predispose individual live trees to bole snap during high wind events (Figure 16). In Southcentral, conks of the *F. pinicola* complex were associated with white spruce bole snap during the recent spruce beetle activity in the Matanuska-Susitna valley. It is assumed that the trees had been infected long before they snapped because of the extensive advanced decay.

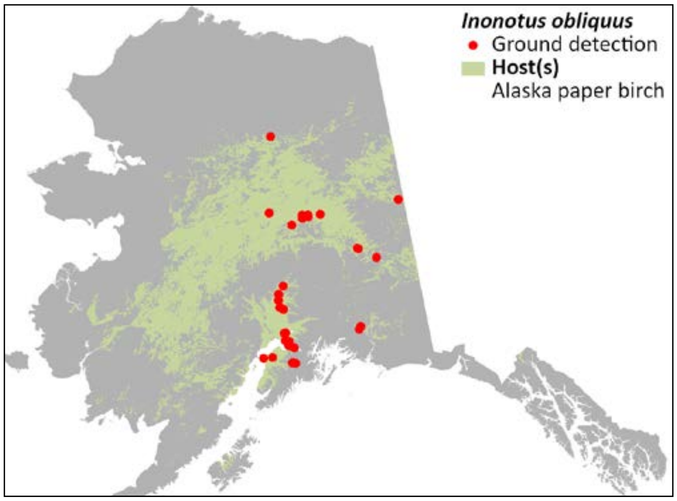


Map 18 | Brown crumbly rot cumulative mapped locations and modeled host tree distribution(s).

CANKER-ROT OF BIRCH

Inonotus obliquus (Pers.:Fr.) Pilat

Inonotus obliquus, also known as Chaga, is widespread in Southcentral Alaska and Interior Alaska on birch and has been mapped from the Kenai Peninsula north to the Brooks Range, and east to the Canadian border (Map 19). In 2021, FHP staff recorded two new locations of *I. obliquus* in the Interior near Fairbanks and Delta Junction. In addition, thirteen research grade observations were recorded in iNaturalist around Fairbanks, Anchorage, and Palmer. As a true stem decay, *I. obliquus* does not require a wound as an infection court, nor does it invade dead trees. Diplodia gall appears superficially similar but occurs on aspen rather than birch.

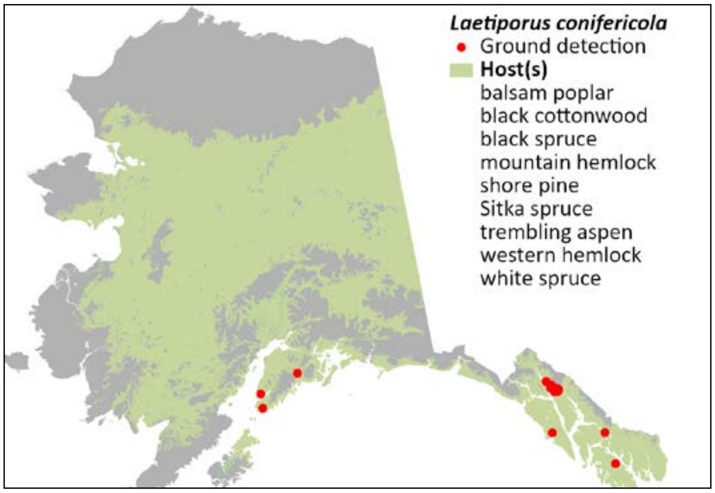


Map 19 | Canker-rot of birch cumulative mapped locations and modeled host tree distribution(s).

SULFUR FUNGUS

Laetiporus conifericola Burds. & Banik

In Alaska, *Laetiporus conifericola* causes brown cubical rot of conifers, primarily spruce and hemlock in coastal Southeast and Southcentral Alaska (Map 20). Five closely related species have been identified in North America based on morphological characteristics, mating studies, and molecular data (Linder and Banik 2008, https://doi.org/10.3852/07-124R2). We have adopted the proposed name change from *L. sulphureus* to *L. conifericola*. The brightly colored, ephemeral fruiting structures, popular among fungal foragers, were exceptionally abundant in coastal Alaska this year (Figure 17). While FHP recorded *L. conifericola* at seven locations clustered around Juneau, 97 research grade observations were submitted in iNaturalist spanning coastal Alaska from Ketchikan to Haines and Gustavus in Southeast, throughout much of the Southcentral coastal rainforest from Cordova to Seward and around to Kachemak Bay on the Kenai Peninsula, and Kodiak Island. The iNaturalist application can be particularly helpful in cataloging the occurrence of popular, easily identified fungi, like the sulfur fungus, with ephemeral fruiting structures.



Map 20 | Sulfur fungus cumulative mapped locations and modeled host tree distribution(s).

Figure 17 | The "chicken of the woods" fruiting bodies of *Laetiporus conifericola* on a dead western hemlock near Juneau. USDA Forest Service photo by Isaac Dell.

RED ALDER STEM DECAYS

Phellinus sp.
Fuscoporia ferrea (Per.) G. Cunn.

Figure 18 | Until this year, *Phellinus lundellii* had not been previously noticed on large red alder trees near Juneau and Admiralty Island but is likely common and understudied. USDA Forest Service photo by Robin Mulvey.

In 2021, a previously unnoticed conk from the genus *Phellinus* (Figure 18) was found in Southeast on multiple large red alder trees at Pt. Bridgett State Park, northern Douglas Island, and on northern Admiralty Island. Genetic sequences from our specimen matched most closely with the birch bristle bracket *P. lundelli*. Recent phylogenetic work indicates that there are eight species of *Phellinus* that cause white trunk rot of hardwoods in North America: *P. alni, P. arctostaphyli, P. nigricans, P. laevigatus, P. lundellii, P. populicola, P. tremulae* and *P. tuberculosus* (Brazee 2015, http://dx.doi.org/10.3390/f6114191). We hope to explore relationships between *P. lundelli* and the *Phellinus* species that commonly occur on birch, willow, and alder. Another pink, resupinate conk was observed on dead red alder stems at three sites near Juneau is likely *Fuscoporia ferrea* (Figure 19) and is apparently saprophytic.

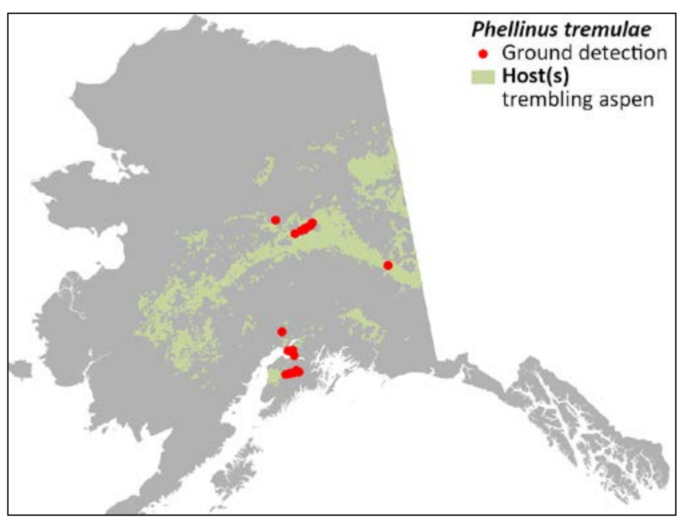
Figure 19 | The pink, resupinate (flattened) fruiting structure of *Fuscoporia ferrenea* on a dead red alder stem near Juneau. USDA Forest Service photo by Robin Mulvey.

Figure 20 | A "false tinder conk" of *Phellinus tremulae* on trembling aspen near Moose Pass on the Kenai Peninsula. USDA Forest Service photo by Elizabeth Gilchrist.

TRUNK ROT OF ASPEN

Phellinus tremulae (Bord.) Bond et Boriss

Eleven new observations of *Phellinus tremulae* were recorded in the Interior and Southcentral near Fairbanks, Anchorage, and on the Kenai Peninsula near Moose Pass by FHP staff (Figure 20). Five research grade observations were made through iNaturalist in 2021 near Anchorage, on the Kenai Peninsula, and near Fairbanks. We have mapped a total of 41 observations of *P. tremulae* although it is common and occurs throughout the range of aspen (Map 21). This fungus is considered the most important decay pathogen of aspen species in the Northern Hemisphere. *P. tremulae* appears identical to its close relative *P. igniarius* but only occurs on aspen.

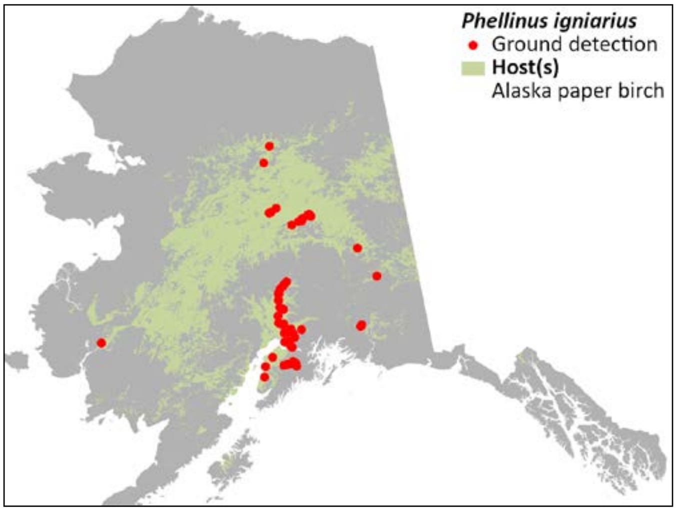


Map 21 | Trunk rot of aspen cumulative mapped locations and modeled host tree distribution(s).

TRUNK ROT OF BIRCH

Phellinus igniarius (L.:Fr.) Quel.

Phellinus igniarius was recorded at six new locations in 2021; several trees were found at two Southcentral locations on the Kenai Peninsula near Moose Pass and four Interior locations near Fairbanks. Up to 15 infected trees were found at one location near Fairbanks, although most sites have smaller numbers. Nineteen research grade observations were made in iNaturalist, with two notable finds in Southeast near Skagway and in Southwest near Dillingham where we had not previously recorded this disease. This disease is extremely widespread and common in Alaska on both live and dead birch trees (Map 22). Although reported on many hardwood species elsewhere, in Alaska we have only observed it on birch, alder, and willow species. This fungus is known as an important white rot of hardwoods in the cooler regions of northern temperate forests.

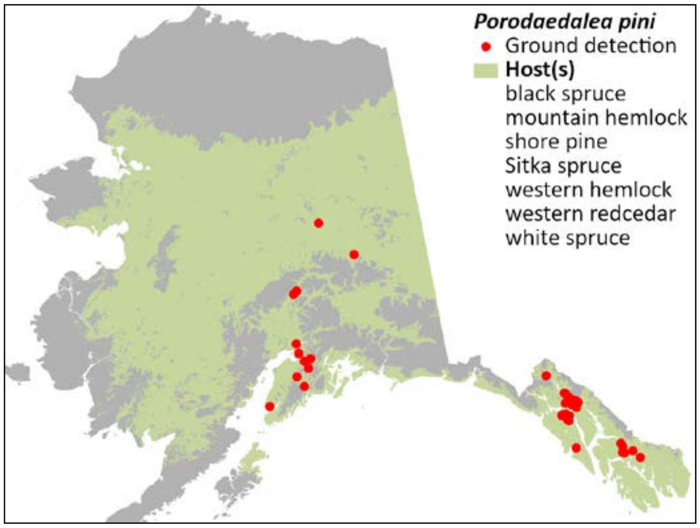


Map 22 | Trunk rot of birch cumulative mapped locations and modeled host tree distribution(s).

RED RING ROT

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

Porodaedalea pini was recorded in Southeast on western hemlock at 16 locations and Sitka spruce at four locations in 2021, all in the Juneau area. In Southcentral, this pathogen was found on white spruce at two locations near Anchorage (Figure 21). Seven research grade observations were recorded in iNaturalist in Southeast on Baranof Island near Sitka and Green Lake, Kruzof Island, the Flower Mountain Trail west of Klukwan and in Southcentral on the Kenai Peninsula, and around Anchorage. Although more common in coastal forests, *P. pini* can also be found in the Interior (Map 23). 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.



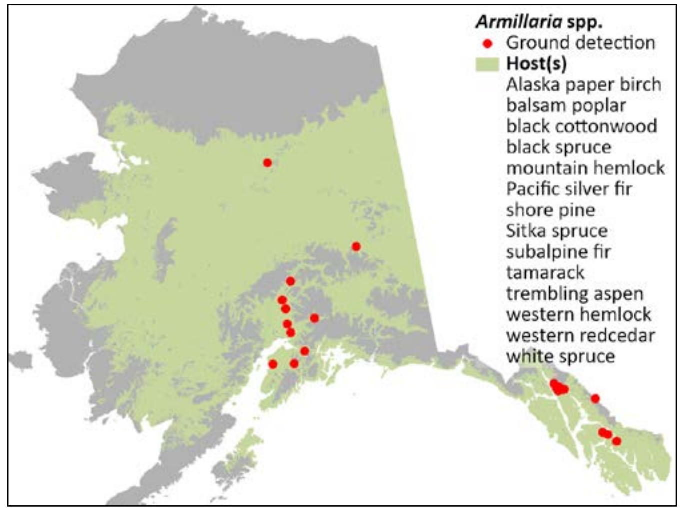
Map 23 | Red ring rot cumulative mapped locations and modeled host tree distribution(s).

Figure 21 | Numerous *Porodaedalea pini* conks on a white spruce snag near Anchorage. USDA Forest Service photo by Steve Swenson.

ARMILLARIA ROOT DISEASE

Armillaria spp.

Armillaria root disease was recorded in Southeast on several red alder trees near Juneau in 2021. Members of the genus have been mapped on paper birch and white spruce in several locations in Interior and Southcentral Alaska and on nearly all the native tree species in Southeast Alaska (Map 24). Distinguishing among species of *Armillaria* is generally not possible without specialized experience and equipment. Drs. John Hanna and Ned Klopfenstein (Rocky Mountain Research Station) led a west-wide project on determining the identity and distribution of Armillaria species and found *A. sinapina* and *A. nabsnona* in Southeast Alaska. Collections from hardwood and conifer hosts from the Kenai Peninsula to the Arctic Circle were all identified as *A. sinapina*.



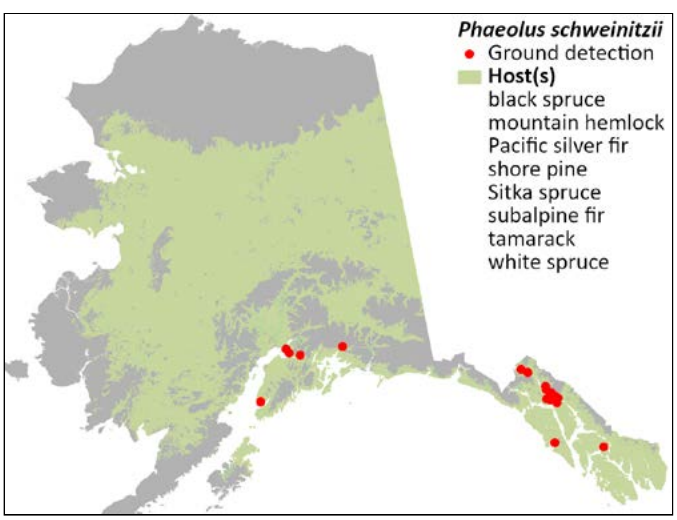
Map 24 | Armillaria root disease cumulative mapped locations and modeled host tree distribution(s).

Figure 22 | *Phaeolus schweinitzii* fruiting structures showing fresh and old, brown fruiting structures (left), as well as the upper and lower surfaces (middle, right). USDA Forest Service photos by Robin Mulvey.

BROWN CUBICAL BUTT ROT

Phaeolus schweinitzii (Fr.:Fr.) Pat.

Phaeolus schweinitzii is most common in Southeast on Sitka spruce of the coastal forest but has also been recorded on shore pine and white spruce (Map 25). In 2021, it was recorded by FHP on Sitka spruce at 15 locations near Juneau. Twenty-one research grade observations were contributed through iNaturalist, mostly in coastal forests of Southeast and Southcentral, but also in Fairbanks and on Kodiak Island. The fruiting bodies (Figure 22) are most noticeable when they emerge from the decayed wood of broken tree boles or from below ground roots in late summer and fall. Root and lower bole damage can encourage infection, an important management consideration at developed recreation sites.

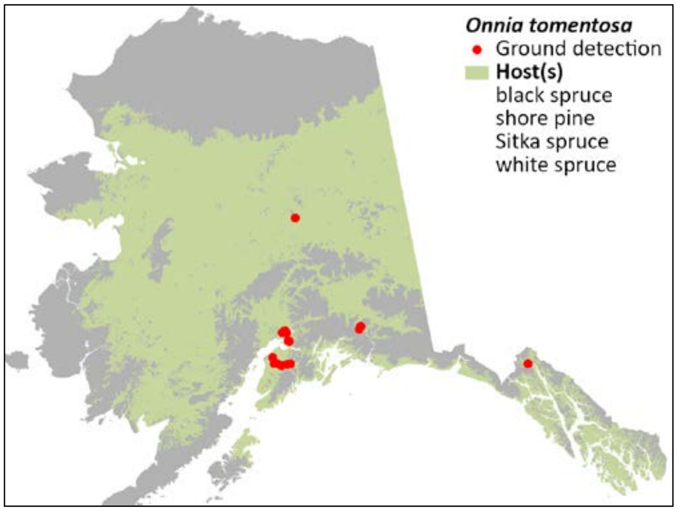


Map 25 | Brown cubical butt rot cumulative mapped locations and modeled host tree distribution(s).

TOMENTOSUS ROOT ROT

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

Six research grade observations of *Onnia tomentosa* were submitted to iNaturalist in 2021, all in the vicinity of Anchorage. Over the last two years, 18 iNaturalist observations spanned across Southcentral and the Interior, from Anchorage to Cooper Landing, complementing FHP detections farther west on the Kenai, the Chugach Mountains, and near Fairbanks (Map 26). Since *O. tomentosa* produces fruiting structures that are both uncommon and ephemeral (Figures 23, 24), iNaturalist observations could enhance our understanding of this pathogen's distribution in Alaska.

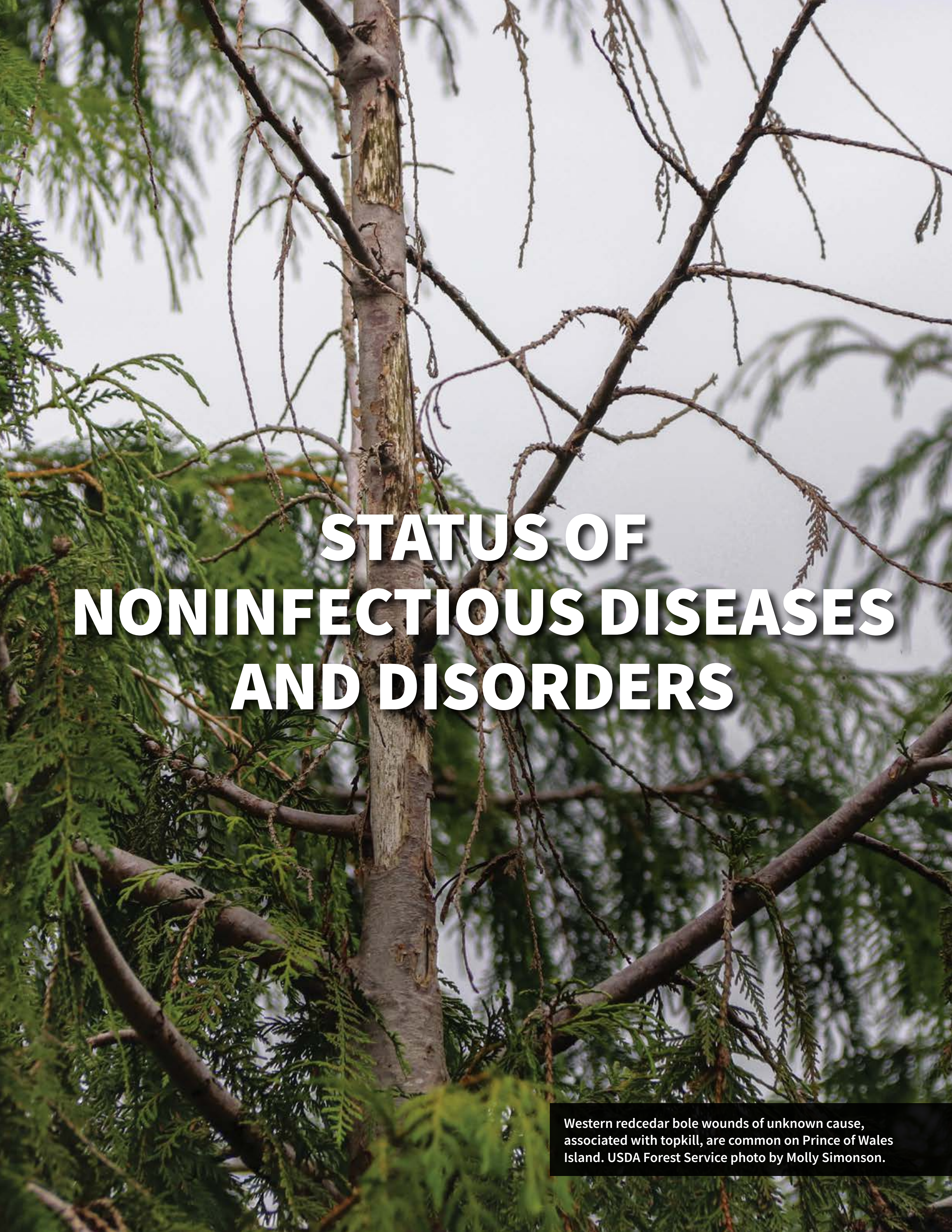


Map 26 | Tomentosus butt rot cumulative mapped locations and modeled host tree distribution(s).

Figure 23 | Pore structure of *Onnia tomentosa* in Chugach State Park documented through iNaturalist. Photo courtesy of Leah Breitenstine.

Figure 24 | Fruiting structures of *Onnia tomentosa* in Chugach State Park documented through iNaturalist. Photo courtesy of Leah Breitenstine.

STATUS OF NONINFECTIOUS DISEASES AND DISORDERS



Western redcedar bole wounds of unknown cause, associated with topkill, are common on Prince of Wales Island. USDA Forest Service photo by Molly Simonson.

Status of Noninfectious Diseases & Disorders > Abiotic Damage

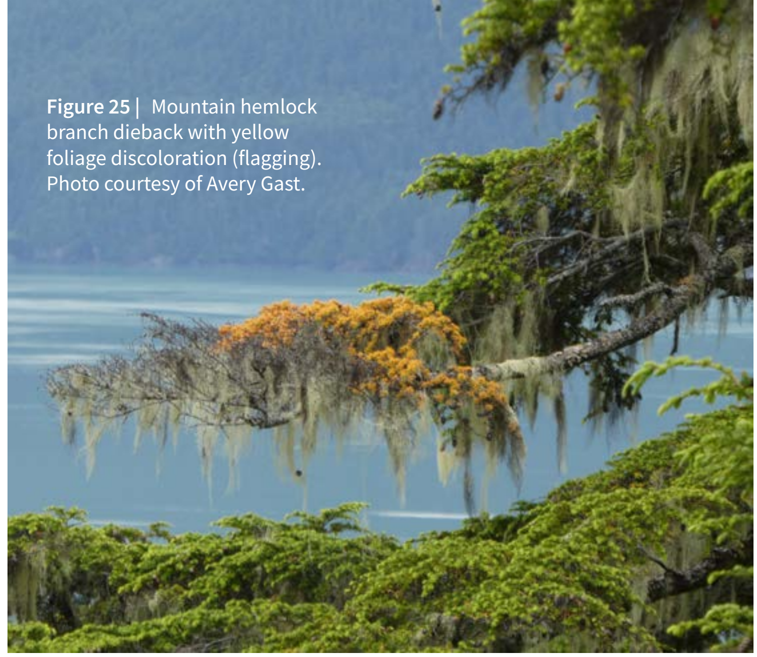


Figure 25 | Mountain hemlock branch dieback with yellow foliage discoloration (flagging). Photo courtesy of Avery Gast.

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, not mapped during our forest health surveys, causes extensive tree mortality in Alaskan boreal forests and may be especially severe after bark beetle outbreaks or in times of drought. In 2021, the Alaska Interagency Coordination Center reported that 387 fires burned across 254,414 acres (https://fire.ak.blm.gov/).

FLOODING

Nearly 14,000 acres of flooding were mapped in 2021, an increase from recent years. Most of the damage was mapped in the Interior, where 13,000 acres of moderate to severe flooding occurred in the Tanana and Yukon Flats, and along many rivers and low-lying areas. Flooded patches were typically about 100 acres, but the largest flooded area consisted of over 7,000 acres of low severity damage in a low flood plain along the Tanana River between Nenana and Manley Hot Springs. Personal communications with pilots in the area suggest that many areas were also flooded in 2020. In Southcentral, only 250 acres of light to severe flooding damage were mapped along the Susitna, Skwentna, and upper Yentna Rivers, as well as on the Kenai Peninsula along the Resurrection River outside of Seward and the Fox River and Sheep Creek outside of Homer. In Southeast, light flooding was mapped on 450 acres, generally in small patches. However, nearly 200 acres of high severity damage were recorded in coastal areas in and around Glacier Bay National Park.

MOUNTAIN HEMLOCK FLAGGING

Yellow-flagged branches of mountain hemlock are occasionally mapped during aerial survey. The damage is showy and can occur anywhere in the tree crown, but usually only affects one or two branches. In 2021, six polygons (two to ten acres each) were mapped along southern Turnagain Arm in Southcentral, while five points of hemlock flagging were mapped near Skagway in Southeast. Also in Southeast, we received a report of this damage near Lake Dorothy, east of Taku Inlet near Juneau (Figure 25). The cause of branch flagging and dieback is not known. Branches with yellow foliage that have been evaluated over the years have lacked obvious mechanical damage or insect or pathogen activity. Branch flagging is associated with exposed sites.

WESTERN REDCEDAR TOPKILL

The cause of western redcedar topkill on Prince of Wales Island is under investigation. Two points of suspected western redcedar damage were detected during the aerial detection survey, and several areas of potential damage were identified in high-resolution satellite imagery from Prince of Wales Island last year. Ground checks are needed to verify the host species and damage type. Widespread topkill of small and medium western redcedar trees and some full tree mortality was initially reported on central Prince of Wales Island in 2017. The damage has been noted in both managed stands and in old-growth forests. Based on the observed patterns, we now believe there are two distinct causes of western redcedar damage in Southeast Alaska: (1) girdling damage that leads to topkill and (2) direct drought impacts (Table 4).

Bole wounds with missing bark are common in trees with topkill (Figures 26, 27). Trees are typically girdled within five feet of the top of the tree. Wounds are also present farther down the stem (there are often several wounds on individual trees), but girdling occurs where the stem circumference is smallest. Multiple iterations of topkill, progressing down the stem, have been observed on individual trees. In 2021, *Phloeosinus cupressi* larvae and adults were detected in dying western redcedar tops collected on Prince of Wales by Tongass silviculturist Molly Simonson. These secondary beetles are attracted to stressed trees; in this case, we suspect that bole wounds restricting water access to the upper tree crown are the primary stressor, possibly in conjunction with abiotic factors that exacerbate water limitation. Molly also observed a high occurrence of bole wounds, top kill, and shoot dieback in three adjacent young-growth stands on Prince of Wales southwest of Thorne Bay that were harvested in 1992 and precommercial thinned last year. Our top priority is determining what causes these bole wounds, and why bole injury is concentrated in certain locations. There may be multiple causes of bole wounding, though one theory is that northern flying squirrels preferentially peel western redcedar bark for use in nesting cavities, as the bark has anti-fungal and anti-microbial properties that may reduce nest-borne ectoparasite loads. Similar activity has been

Table 4 | Observations associated with two distinct types of damage impacting western redcedar on Prince of Wales Island.

	Topkill	Drought Damage
Timing/Rate of Progression	Slower (months to years); crown fading can onset any time of year.	Faster (months); note the side-by-side red tops pictured below; the one on the right occurred rapidly and lacked stem wounds.
Crown Patterns	The crown is faded red to bright red in color above the point of damage, with a clear demarcation below which the crown is healthy.	The crown reddens or dramatically thins from the top-down and moves inward from branch tips (no clear damage demarcation).
Associated Characteristics	Areas of missing and loose bark around the dead stem; some trees with topkill lack missing bark, some trees with missing bark lack topkill; patches of missing bark may extend up and down dead parts of affected stems; can be many iterations of new leader development.	Bark is intact. No girdling damage is evident.
Landscape Patterns	Common, scattered, apparently random rather than clumped.	Abiotic cause may lead to different degrees of damage to individual trees, but is more likely to be clumped due to hydrology and aspect patterns (a hypothesis to test).
Cause of Damage	Unknown, but possibly caused by a canker fungus or animal damage; reason for bark sloughing is unknown.	Acute drought events in 2018 and 2019 associated with the damage.

Figure 26 | Wounds on a western redcedar tree bole. The cause of wounding is not known. USDA Forest Service photo by Molly Simonson.

Figure 27 | Western redcedar with topkill. USDA Forest Service photo by Molly Simonson.

Figure 28 | A drought-impacted western redcedar with a thinning tree crown, observed north of Thorne Bay on Prince of Wales Island in 2020. USDA Forest Service photo by Molly Simonson.

reported with eastern white cedar in northeastern hardwood forests (Patterson et al. 2007, http://doi.org/10.22621/cfn.v121i3.479). However, there are no teeth marks on the wounds, so the damage is best explained if the bark is pulled off rather than scraped off with teeth.

Western redcedar is sensitive to drought damage, which may increase susceptibility to secondary forms of damage. Elevated topkill was first noticed in 2017, prior to the drought conditions in 2018 and 2019, which further supports that there are other significant causes of topkill. Drought-affected trees tend to become thin and discolored downward from the top of the crown (Figure 28), and inward from branch tips, with symptoms progressing rapidly over weeks to months. The return of normal precipitation to Southeast Alaska in 2020 and 2021 is expected to result in less drought-induced damage in the near-term.

A multi-regional and -agency effort is underway to investigate western redcedar mortality and crown dieback throughout the Pacific Northwest. A collaborative survey has been created by the Oregon Department of Forestry in the Survey123 and iNaturalist applications to facilitate range-wide data collection. Learn more about the Western Redcedar Dieback Map project in iNaturalist here: https://www.inaturalist.org/projects/western-redcedar-dieback-map.

WILLOW DIEBACK

Willow dieback was mapped in Southcentral on 12 acres east of Turnagain Arm during the aerial detection survey in 2021. More work is needed to determine if fungal pathogens cause this damage or if endophytic fungi are colonizing tissue killed by abiotic factors. Stems with dieback were collected from one site near locations mapped during the survey and close to Anchorage. Multiple fungal fruiting structures were present on affected stems. Fungi isolated from the infected stems remain to be identified. Elsewhere in North America and Europe, black canker of willow is caused by *Glomerella miyabeana*, often in combination with the willow scab fungus, *Venturia salciperda*. Cytospora canker also commonly occurs on willows, generally considered to be secondary to other causes. Willow dieback has been mapped during the past aerial detection surveys, but ground checks are required to distinguish dieback caused by severe defoliation, canker fungi, or abiotic causes.

WINDTHROW

About 1600 acres of windthrow were mapped through aerial detection surveys, with the most concentrated damage in northern Southeast Alaska (Admiralty and Baranof Islands and the coastal mainland) on west-facing slopes. In spring, dieback of spruce, alder, and hemlock was noted in coastal forests near Juneau (Figure 29) exposed to prevailing winds during fall storms. We believe that an unusual combination of high-tide and heavy wind deposited toxic levels of salt spray, impacting multiple species immediately on the forest edge. After aerial detection survey in 2021, fall gales in Southeast brought down individual trees and clumps of trees, especially trees predisposed to breakage by stem decay fungi (Figure 30).

Figure 29 | Dieback and small tree mortality of western hemlock, Sitka spruce, and red alder along the coastal fringe forest at the Outer Point Trail on Douglas Island near Juneau. USDA Forest Service photo by Robin Mulvey.

Figure 30 | A large Sitka spruce predisposed to stem breakage in high wind by the stem and butt rot *Phaeolus schweinitzii*. USDA Forest Service photo by Robin Mulvey.

Status of Noninfectious Diseases & Disorders > 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 2021, just over 200 acres of tree mortality from porcupine feeding damage were aerially detected in Southeast Alaska. As usual, damage was mapped on Etolin and Wrangell Islands and the coastal mainland near Hobart Bay, as well as scattered along the outer coast of Glacier Bay National Park. In recent years, several thousand acres of porcupine damage have been reported annually. The reduction in acreage this year is in part due to the extensive matrix of reddish crowns defoliated by western blackheaded budworm that decrease detection of trees killed by porcupines. Porcupines can be major pests in managed young-growth stands where they girdle Sitka spruce and western hemlock managed for timber. They often wound the largest and fastest growing trees. Historic porcupine migration patterns have influenced their current distribution in the Alexander Archipelago: porcupines are absent from Admiralty, Baranof, Chichagof, Kupreanof, Zarembo, and Prince of Wales Islands near to the Gulf of Alaska but are abundant on the mainland and nearby islands.

Figure 31 | Yellow-cedar decline along Nakwasina Passage northwest of Sitka. USDA Forest Service photo by Robin Mulvey.

Status of Noninfectious Diseases & Disorders > Forest Declines

YELLOW-CEDAR DECLINE

Yellow-cedar decline (Figure 31), caused by root-freezing injury in the absence of insulating snowpack, is the most significant threat to yellow-cedar populations in Southeast Alaska. We continue to monitor yellow-cedar decline in old-growth forests and in previously harvested stands that continue to be managed for timber (young-growth).

Active and Cumulative Yellow-Cedar Decline Detection in 2021

In 2021, 8,151 acres of active yellow-cedar decline (dying trees with discolored crowns) were mapped during the aerial detection survey, about half as many acres as usual. Decline detection was likely hindered by the extensive western blackheaded budworm outbreak this year, since both types of damage cause tree crowns to appear reddish-brown. West Chichagof-Yakobi Wilderness was aerially surveyed to track decline progression and intensification at the northern edge of yellow-cedar decline; additionally, surveys were conducted by boat in this area along Lisianksi Strait and Inlet. Active decline was mapped on Chichagof and Yakobi Islands (1,100 acres), Baranof Island (1,100 acres), Kuiu, Kupreanof, and Mitkof Islands (2,000 acres), Wrangell, Zarembo and Etolin Islands (200 acres), Prince Wales (2,900 acres), and Revilla Island and the Cleveland Peninsula (850 acres) (Map 27). Three small pockets (less than ten trees each) of yellow-cedar mortality were mapped near La Perouse Glacier, Finger Glacier, and Icy Point along the outer coast of Glacier Bay National Park. Yellow-cedar forests in this area have been considered healthy, so yellow-cedar mortality in this area will be closely tracked. We hope to ground confirm that the signs and symptoms of tree mortality are consistent with yellow-cedar decline.

Landscape patterns of snowpack (and recent snowpack loss) influence the distribution of cumulative and active yellow-cedar decline. Active decline tends to occur at relatively higher elevations in yellow-cedar forests in the southern Panhandle compared to farther north, in conjunction with where snowpack levels are most dynamic; in the southern portion of the range, decline has already impacted lower elevation yellow-cedar forests. This year, we evaluated latitude and elevation patterns of the mapped active decline and these same trends emerged. Overall, active yellow-cedar decline acreage was highest in the 56-57° and 57-58° latitude bands between sea level and 500 ft elevation (where yellow-cedar is also most common), followed by the 55-56° latitude band at mid-elevation (800-1200 ft). We estimate that approximately 32% of yellow-cedar forest in Alaska was surveyed this year (based on the modeled range of yellow-cedar produced by FHTET/FHAAST in 2011, 30 m-resolution, clipped using the forest mask described below). We aim to continue with this type of geospatial approach moving forward, including multiple years of active mapped decline for a more complete analysis.

In total, nearly 700,000 acres of yellow-cedar decline have been mapped across Southeast Alaska (Map 27, page 34 and Table 5, page 33). This year, a revised land ownership GIS layer (Bureau of Land Management Administered Lands Feature Class, published 09/20/2021, https://navigator.blm.gov/data?id=cafb6b42d4683327) was used to create the table of cumulative yellow-cedar decline. The change reflects recent land transfers and other updates, as well as adjustments to Tongass National Forest Ranger District boundaries, but does not alter the cumulative total. Over the last several years we have used GIS tools to improve our cumulative decline 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 more than 67,645 acres compared to the unfiltered total.

Future Detection

Each method of mapping yellow-cedar decline has its advantages. The differences in the areal extent and pattern of damage captured by different methods correspond to differences in survey scale. Imagery-based remote-sensing techniques enable surveyors to map active yellow-cedar decline in greater detail and with better spatial accuracy than is possible while surveying by airplane at 100 mph. The use of high-resolution satellite imagery to map new or cumulative decline may help us to develop the most fine-scale and comprehensive decline layer. Satellite imagery quality and availability has increased substantially over the past decade. Our team hopes to pursue this approach, especially along the northern margin of decline (the outer coasts of Chichagof and Yakobi Islands) and around the small pockets of yellow-cedar mortality in Glacier Bay National Park.

Dr. Benjamin Gaglioti (University of Alaska- Fairbanks) and others used a dendrochronology approach to assess yellow-cedar snags at a site alongside La Palouse Glacier in Glacier Bay National Park with localized yellow-cedar mortality (Gaglioti et al. 2021, https://cdnsciencepub.com/doi/abs/10.1139/cjfr-2021-0004). They assessed 30 snags that were already dead when they were buried by aggrading outwash and advancing glacial ice around 1862, and 31 snags in the adjacent old-growth forest, where other healthy cedar trees are also present. Almost all the snags had lost their outermost rings to decay, so timing of tree death was estimated based on wood-ablation (deterioration) rates measured in six live trees with partial cambial dieback. All but one snag had been standing for over 100 years since tree death. The authors report greater longevity of standing snags than previously known, which could support the idea that decline events initiated earlier than thought. It is unknown whether these very old mortality events at this location were caused by yellow-cedar decline or other factors.

Young-Growth Yellow-Cedar Decline & Forest Management

Young-growth yellow-cedar decline 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; before that, decline had only been observed in old-growth forests. To facilitate young-growth yellow-cedar decline monitoring, we compiled a database of 338 managed stands on the Tongass National Forest with yellow-cedar, but more remain to be added. Alongside the database, low-altitude aerial imagery and aerial detection surveys are used to identify stands with discolored tree crowns and suspected decline, which are then inspected on the ground. Through aerial detection survey in 2021, we identified 19 managed stands with potential decline, 12 of which are accessible for ground check. None are in our current database, indicating that the stands should be added or that they represent false positives. To date, decline has 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, precommercial thinned between 2004 and 2012, and growing on south to southwest aspects.

In 2018, we installed 41 permanent plots in the five most severely affected stands to quantify the impacts of yellow-cedar decline. Although only 2% of yellow-cedar trees were dead overall, this percentage was still eight times higher than for all other species combined and varied substantially by stand and by plot. In the most severely affected stand, 8% of yellow-cedar trees were dead, while 26% of yellow-cedar trees were dead in the plot with greatest impacts. The most notable recent yellow-cedar death occurred where secondary bark beetles (*Phloeosinus* spp.) had attacked stressed trees, which resulted in more rapid tree death than occurs with freezing injury alone. We plan to reassess yellow-cedar mortality in these stands in 2022.

Now that yellow-cedar decline is known to occur in young-growth stands, we must consider how precommercial thinning and other management activities may influence soil temperature fluctuation, particularly in stands that are not expected to retain consistent snowpack in the decades to come. Yellow-cedar planting sites should be carefully selected with both snowpack and rooting depth in mind, promoting yellow-cedar where it is expected to thrive long-term. Planting methods that deter deer browse, such as planting cedar adjacent to spikey spruce seedlings (avoided by deer) that are later thinned out, may be necessary for successful establishment.

A new study has been published that evaluated the economic returns and ecological impacts of salvage logging on forest succession (Bidlack et al. 2022, https://doi.org/10.1016/j.foreco.2021.119815). They found that small-scale salvage harvest did not impact forest succession or yellow-cedar abundance, and that economic returns were small to moderate but varied by location.

Table 5 | Cumulative acreage affected by yellow-cedar decline in Southeast Alaska as of 2021 by ownership[1] and Ranger District[2]. Estimates were limited to affected areas occurring within upland forest and forested wetlands[3].

Ownership	Cumulative Acres
NATIONAL FOREST	**657,724**
Admiralty NM	**5,384**
Admiralty Is.	5,384
Craig RD	**51,612**
Dall Is. & Long Is.	1,649
Prince of Wales Is.	49,962
Hoonah RD	**816**
Chichagof Is.	816
Juneau RD	**1,297**
Mainland	1,297
Ketchikan Misty Fjords RD	**92,131**
Duke Is.	15
Gravina Is.	2,432
Mainland	48,236
Revillagigedo Is.	41,448
Petersburg RD	**201,794**
Kuiu Is.	81,759
Kupreanof Is.	94,946
Mainland	11,948
Mitkof Is.	10,203
Woewodski Is.	2,938
Sitka RD	**134,169**
Baranof Is.	61,171
Chichagof Is.	47,420
Kruzof Is.	25,578
Thorne Bay RD	**88,193**
Heceta Is.	1,605
Kosciusko Is.	15,045
Prince of Wales Is.	71,543
Wrangell RD	**82,296**
Etolin Is.	28,386
Mainland	22,945
Woronofski Is.	1,448
Wrangell Is.	14,223
Zarembo Is.	15,293
Yakutat RD	**32**
Mainland	32

Ownership	Cumulative Acres
NATIONAL PARK	**43**
Glacier Bay[4]	**43**
Mainland	43
OTHER FEDERAL	**213**
Mainland	1
Revillagigedo Is.	212
BUREAU OF INDIAN AFFAIRS	**2,367**
Annette Is.	2,367
NATIVE	**22,219**
Baranof Is.	591
Chichagof Is.	166
Dall Is. & Long Is.	1,278
Kosciusko Is.	380
Kruzof Is.	87
Kuiu Is.	6
Kupreanof Is.	4,418
Mainland	1,377
Prince of Wales Is.	12,992
Revillagigedo Is.	924
STATE & PRIVATE	**15,071**
Admiralty Is.	<1
Baranof Is.	2,592
Chichagof Is.	230
Etolin Is.	19
Gravina Is.	1,581
Heceta Is.	<1
Kosciusko Is.	189
Kruzof Is.	192
Kuiu Is.	821
Kupreanof Is.	1,363
Mainland	1,290
Mitkof Is.	1,129
Prince of Wales Is.	3,168
Revillagigedo Is.	1,833
Woewodski Is.	3
Wrangell Is.	448
Zarembo Is.	213
GRAND TOTAL	**697,636**

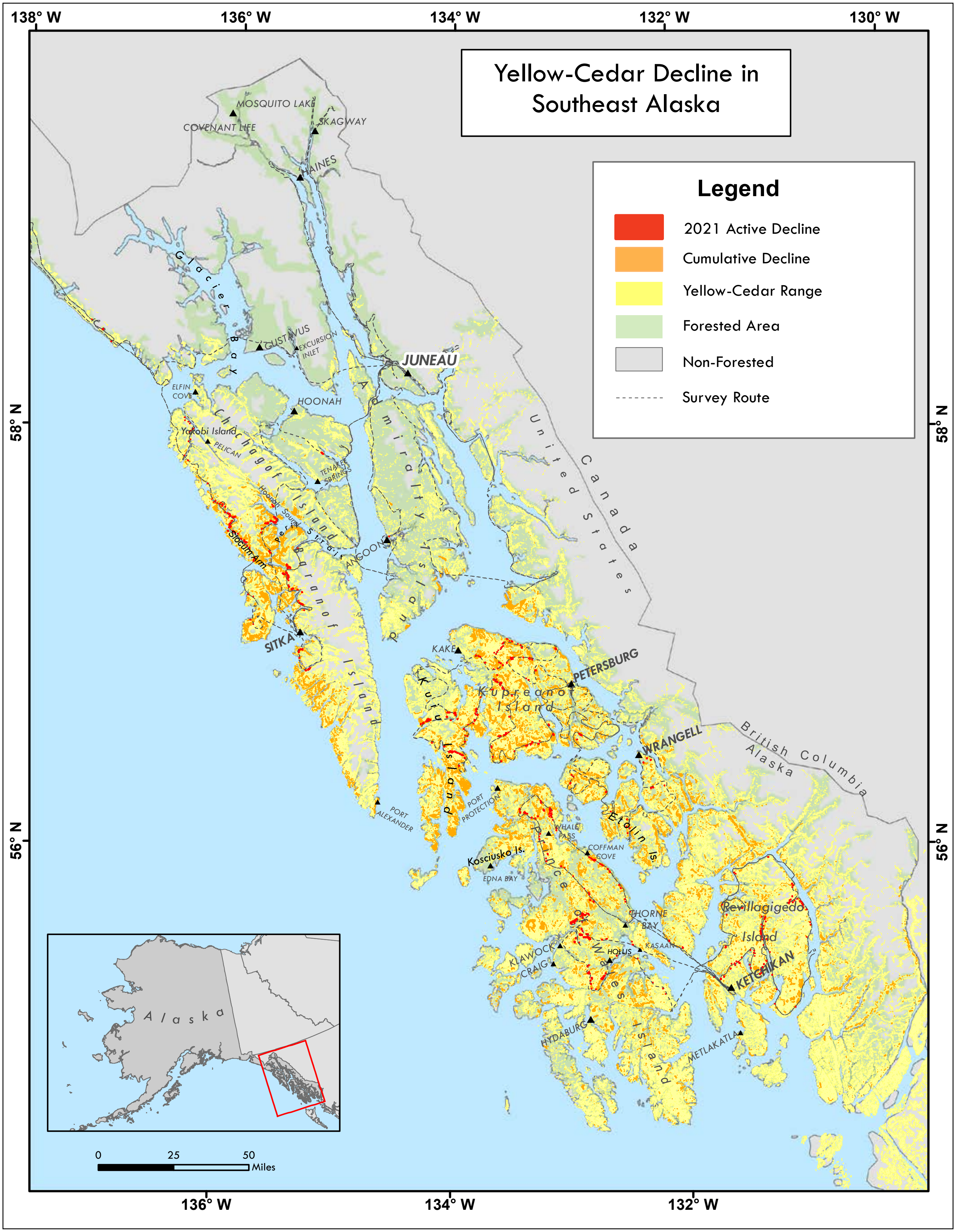
[1] The ownership layer used to process cumulative yellow-cedar decline is the Bureau of Land Management Administered Lands Feature Class, Administered Lands/Surface Management Agency (SMA) (published 09/20/2021, https://www.blm.gov/services/geospatial/GISData/alaska#data). This update does not alter the grand total, but affects the cumulative acreage within ownership categories compared to what is reported in recent Forest Health Conditions in Alaska reports.

[2] Tongass National Forest Ranger District boundaries have been updated to reflect recent changes.

[3] The cumulative yellow-cedar decline layer was clipped/restricted to areas occurring within upland forest and forested wetland cover classes in the NLCD-modified dataset (Frances Biles, USFS PNW Research Station), which reduces the cumulative acreage from its unaltered total of 765,281 acres.

[4] Yellow-cedar mortality in GBNP was detected in 2021 and remains to be ground-verified.

Map 27 | Current (2021) and cumulative yellow-cedar decline mapped by aerial detection surveys in Southeast Alaska.



INVASIVE PLANTS

Volunteers pull white sweetclover along the Seward Highway near Portage. National Park Service photo by Christina Kriedeman.

TONGASS NATIONAL FOREST

Southeast Alaska experienced another rainy year, which hampered invasive plant treatment activities. Despite the weather and COVID-19, the Tongass National Forest completed two notable projects.

First is the invasive brass buttons (*Cotula coronopifolia*) inventory and treatment on the Petersburg Ranger District. Brass buttons are a perennial invasive plant found in the Petersburg Creek-Duncan Salt Chuck Wilderness and adjacent to Towers Arm (Figure 32), which have been identified by the Petersburg R.D. as a priority species for treatment. There is concern that this plant is creating vegetation-type changes within the estuary and outcompeting native vegetation. The plant also poses a potential risk for spread into other mud flat habitats, including the Stikine River Delta, which is an important stopover in the Pacific Flyway. The Sitka Conservation Society partnered with the U.S. Forest Service to conduct an inventory of adjacent areas to identify where else these plants might occur as part of the Petersburg R. D. invasive treatment plan. Goose Flats in Portage Bay, and Indian Point, McDonald Arm, North Arm and Towers Arm in the Duncan Salt Chuck were surveyed by Kent Bovee (formerly of the Sitka Conservation Society) and his field partner. In addition, drone footage was acquired to see how effective a tool it would be for detecting brass buttons in the extensive mud flats. No brass buttons were found in these outlying areas. However, the number of known brass buttons in Towers Arm has increased from the 11 found in 2018 to 180 plants that were hand-pulled by Petersburg Ranger District employees in 2021.

The second project is the Hyder hempnettle (*Galeopsis tetrahit*) treatment on the Ketchikan Misty Fjords Ranger District. Hempnettle is a State of Alaska "prohibited noxious" invasive plant species. It is an annual that only reproduces via seed, for which manual treatment has proven effective in population management. Infestations occurring in the Salmon River Watershed along the banks of Marx Creek and Fish Creek in Hyder have been manually treated in 2017, 2019, and 2021. In 2021, when a crew of four was able to walk the creeks farther than in previous years, approximately 10 acres (Figure 33) were able to be treated. In three days, the crew removed three large trash bags of hempnettle that were taken to the Hyder dump to be incinerated. District staff commented that the size of the infestation has decreased by roughly 70% since treatment began in 2017. Work to eradicate hempnettle in the Salmon River Watershed is planned to continue in 2022.

Figure 32 | Brass buttons growing in the Petersburg Creek-Duncan Salt Chuck Wilderness. Sitka Conservation Society photo by Kent Bovee.

Figure 33 | SCA Botany participants, Bridget Duba and Kaito Lopez, and KMRD FWWB Staff Officer Jon Hyde wade in Marx Creek to treat hempnettle. USDA Forest Service photo by Valeria Cancino Hernandez.

Figure 34 | An infestation of creeping thistle in Moose Pass. USDA Forest Service photo by Peter Frank.

Figure 35 | Stream Watch Invasive Species Task Force members clip reed canarygrass seed heads at the Russian River Recreation Area. Kenai Watershed Forum photo by Maura Schumacher.

Figure 36 | Volunteers from multiple agencies and community groups help to remove white sweetclover along the Seward Highway near Portage. National Park Service photo by Christina Kriedeman.

CHUGACH NATIONAL FOREST

As a member of the Kenai Peninsula Cooperative Invasive Species Management Area (KP-CISMA) the Chugach National Forest coordinates with local partners to identify, prioritize, and control invasive plant species found in or near the forest. Invasive species know no boundaries, so to effectively manage them, it is essential that state, federal, and private stakeholders work closely to curb their spread. Forest staff highlight four projects accomplished in 2021.

This summer, the Chugach NF worked closely with the Homer Soil and Water Conservation District and Kenai Watershed Forum, to manage invasive species in the rights-of-way and gateway communities on the forest. Through these partnerships, they were able to identify and treat a small patch of creeping thistle (*Cirsium arvense*), a state prohibited noxious weed (https://plants.alaska.gov/invasives/noxious-weeds.htm), which was reported in Moose Pass (Figure 34). Managing invasive species through early detection and rapid response like this is an efficient and effective means to prevent the spread of invasive species.

The forest is also working with researchers at the Alaska Center for Conservation Science to develop a standardized survey protocol for freshwater aquatic invasive species. The protocol was beta tested on three lakes on the Seward Ranger District. Bear Lake, Trail Lake, and Summit Lake were surveyed, and no invasive species were found. These lakes were identified through a Forestwide analysis of waterbody vulnerability, which utilized the institutional knowledge of forest staff to help understand which lakes are being used heavily and are therefore at greater risk of infestation.

One of the largest and most concerning infestations on the forest is that of reed canarygrass (*Phalaris arundinacea*) found in the Russian River area. Reed canarygrass can infest and degrade the integrity of wetland, stream, and river habitats and is therefore one of the terrestrial team's top management priorities. For the last three years, the forest has been partnering with the Kenai Watershed Forum to manage infestations (Figure 35) in the Russian River watershed. While progress has been slow in some areas, significant declines have been documented in the overflow parking lot and along the Russian Falls trail.

KP-CISMA members noticed a rapid expansion of white sweet clover (*Melilotus albus*) along the Seward Highway between Portage and Turnagain Pass following recent DOT projects. Harnessing the power of the CISMA, partners from the Homer Soil and Water Conservation District, Kenai Watershed Forum, National Park Service, and U.S. Forest Service came together on short notice to hand pull the infestation before it went to seed (Figure 36). These agencies are working hard to keep the Kenai Peninsula free of white sweetclover.

INVASIVE PLANTS

Figure 37 | One-acre infestation of meadow hawkweed and bird vetch that was discovered and treated in July 2021. Alien Species Control, LLC photo by Tim Stallard.

Invasive Plants > Partner Updates

2021 ALASKA INVASIVE PLANT MINI-GRANTS

Another year of Alaska's Invasive Plant Mini-Grant Program was successfully implemented, through an agreement with R10 FHP and the Copper River Watershed Project, who administer the Mini-Grants. 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. Higher numbers assigned to an invasive plant correspond to potentially more devastating environmental impacts, necessitating urgency in control and eradication. With funding from the mini-grant program, organizations conducted outreach on invasive plants in their local communities, surveyed new areas, and manually or chemically treated infestations. Eight projects were funded in 2021.

CANWIN: Citizens Against Noxious Weeds Invading the North supports follow up efforts to control spotted knapweed (*Centaurea stoebe*) along Turnagain Arm with the long-term goal of eradication. They also worked on orange hawkweed (*Hieracium aurantiacum*), reed canarygrass, white sweetclover, and bird vetch (*Vicia cracca*) in Girdwood DOT ROW's with the goal of containment and preventing the spread from the community to public lands. CANWIN also installed five boot brush stations in Chugach State Park to help prevent the spread of invasive plants into the park and to educate the public about invasive species concerns (Figure 37).

CRWP: Copper River Watershed Project conducted invasive control and outreach in collaboration with federal, state, and private organizations, across land boundaries, throughout the Copper River watershed. Targeted infestations for treatment included reed canarygrass and Bohemian knotweed (*Fallopia × bohemica*) in the Cordova area, and white sweetclover and bird vetch near Glennallen, Chitina, Gakona, and Gulkana.

FSWCD: The Fairbanks Soil and Water Conservation District has the overarching aim to take actions to prevent the spread of invasive plants into pristine natural areas. They have implemented early detection and rapid response of high impact invasive plants in targeted remote areas adjacent to rural communities along the Yukon River. They have worked toward the development of a Weed Free Gravel program in Interior Alaska and increased public awareness about invasive plants. Work has been accomplished in partnership with private, tribal, borough, and local community organizations in the region.

HSWCD: The Homer Soil and Water Conservation District has coordinated with KP-CISMA, taking a regional approach to collaborate on survey, monitoring, education/outreach, and invasive species treatment throughout the six-million-acre Kenai Peninsula, the 10-mile Kenai Isthmus at Portage Valley, and along Turnagain Arm. This year the HSWCD has 1) continued treatment of orange hawkweed in Girdwood; 2) controlled and eradicated priority invasive plants in DOT ROWs; 3) trained new herbicide applicators; 4) continued the chokecherry (*Prunus* spp.) cost-share program for private landowners; and 5) purchased weed-whackers for Seldovia Village Tribe for mechanical control of reed canarygrass.

KWF: The Kenai Watershed Forum works in conjunction with the KP-CISMA to control populations of high priority invasive species to ensure the best chance for Peninsula-wide eradication of these species. Targeted sites include roadsides and public areas. They also assist the Chugach NF to manage a powerline corridor adjacent to the Russian River that is heavily infested with reed canarygrass. In addition, they have conducted numerous weed pulls in the communities of Seward, Kenai, and Soldotna, and worked with stakeholders to establish appropriate permissions, conduct surveys, and implement management strategies.

KSWCD: Kodiak Soil and Water Conservation District supports a project coordinator and field crew for surveys, outreach, education, and control of invasive plants throughout the Kodiak Archipelago. They partner with the Kodiak Archipelago Cooperative Weed Management Area as well as other public and private land managers. This year they employed a field crew to develop invasive plant management plans, conduct surveys, eradicate small infestations, and control invasive plants in vulnerable subsistence and natural areas.

S-D SWCD: The Salcha-Delta Soil and Water Conservation District conducted invasive control work to manage the spread of invasive species present in ROWs, pull-offs, and rest stop areas on frequently traveled roads within the boundaries of the S-D SWCD.

TTCD: Tyonek Tribal Conservation District proposed treatment to eradicate isolated infestations of high priority invasive species along the roadways between Tyonek and Beluga on the western side of the Cook Inlet. They performed surveys and Integrated Pest Management (IPM) treatments on numerous high priority species. In addition, TTCD installed two additional boot brush stations at points of entry to educate visitors on how to mitigate the further spread of high priority invasive species in the district.

ANCHORAGE PARK FOUNDATION

State and Private Forestry partnered with the Anchorage Park Foundation (APF) to conduct invasive species work on public lands within the Anchorage municipality. Through their agreement, the APF has contracted invasive species work with CANWIN and their contractor Alien Species Control. Utilizing IPM techniques, CANWIN controlled the following species throughout the municipality of Anchorage: European bird cherry (*Prunus padus*), spotted knapweed, creeping thistle, orange hawkweed, white sweetclover, bird vetch, and reed canarygrass. A total of 121 acres have been treated this year.

Nearly 37 acres of creeping thistle were treated along DOT ROW sites within the municipality of Anchorage. Creeping thistle has been a top priority for management for the past couple of years.

Chokecherry control continues to be a priority within the municipality of Anchorage. Through the APF, CANWIN controlled 46 acres within various municipal parks. Other high priority species were treated at several trailheads throughout Anchorage.

CANWIN also treated 27 acres of various high priority species within the DOT ROW in the Girdwood community. Other sites in Girdwood were also treated using other sources of funding, including the Mini-Grants mentioned above, as well as funds from Girdwood Parks and Recreation to add an additional 55 acres treated.

Part of APF's invasive species duties under this agreement has been to lead the Anchorage CISMA. A major accomplishment this year was revising the Anchorage Invasive Species Management Plan, which was reviewed by Anchorage CISMA members. Additionally, funds were used to organize and lead numerous weed pulls throughout the summer (Figure 38).

Figure 38 | Weed warriors volunteer at the June 2021 weed pull at Campbell Park in Anchorage. USDA Forest Service photo by Betty Charnon.

Figure 39 | Enlarged fruit galls of the chokecherry midge on *Prunus virginiana*. UAF Cooperative Extension Service photo by Alex Wenninger.

Figure 40 | Galled chokecherry fruit containing several chokecherry midge larvae. Note the shriveled seed within the galled fruit. UAF Cooperative Extension Service photo by Alex Wenninger.

UNIVERSITY OF ALASKA FAIRBANKS COOPERATIVE EXTENSION SERVICE (UAF CES)

State and Private Forestry (SPF) has an agreement with UAF CES to support their IPM program through education for professionals, adult public, youth, and citizen science groups regarding forest health and invasive species topics. Other tasks include dissemination of information about surveys and documentation of invasive plants and forest pest locations and trends. Some accomplishments are highlighted below.

The chokecherry midge (*Contarinia virginianiae*) was first recorded in Alaska in 2021. The chokecherry midge is the larval stage of a fly which induces fleshy galls of chokecherry fruit (Figure 39). Affected fruit becomes enlarged and hollowed and often contains several larvae within (Figure 40). Of particular interest and importance is that the induction of these galls by the larvae causes abortion of the seed within the gall which has the potential to reduce the propagation of invasive chokecherry by seed. This species was found at several locations throughout Anchorage, Alaska on *Prunus virginiana* hosts. UAF CES plans to continue to collect observations of the distribution and hosts of the chokecherry midge in Alaska in 2022.

Continuing education for professionals remains a large component of what UAF-CES does, with workshops for pesticide applicators, the Alaska Weed Free Certification, and the Alaska Forum on the Environment. They also conduct numerous public, youth, and citizen science events, as well as provide identification and reporting tools (e.g., the Alaska Weeds ID App) (https://alaskainvasives.org/?page_id=117).

UAF CES also supports the Alaska Invasive Species Partnership (AKISP). This year, they created a new website for AKISP (www.alaskainvasives.org), which provides the group with more brand recognition and organized information in a much simpler fashion. They consolidated all information on reporting invasive species of any taxa on this site. This allows the person who initially detected an invasive species to visit the website in order to find out how to report any invasive animals, plants, and insects.

One of the largest events is the AKISP Annual Workshop. Due to the COVID-19 pandemic, the workshop was offered virtually and over 200 people registered to attend. This year the theme was "join the persistence: working behind the screen to prevent and manage invasive species." Topics included 1) Insects and Forest Pests; 2) Aquatic/Elodea; 3) Invasive Species Management; 4) Successes and Barriers; and 5) Management and Outreach Strategies.

As in past years, awards were presented. This year awards were given to Galen Hecht (Figure 41) for Outreach, Gary Freitag (Figure 42) for Lifetime Achievement, Brian Okonek for Volunteerism, Matt Van Daele for Leadership, and Representative Geran Tarr for Advocate of the Year.

Figure 41 | Galen Hecht is the Coordinator of the Kenai Peninsula Stream Watch volunteer program. This year he was given the Outreach award during the annual Alaska Invasive Species Partnership workshop. Photo courtesy of Emma Kimball.

Figure 42 | Gary Freitag with the University of Alaska Southeast received the Lifetime Achievement award during the annual Alaska Invasive Species Partnership workshop. Gary has been a force of nature working on marine invasive species in Alaska. Photo courtesy of Gary Freitag.

STATE GRANTS

SPF and Alaska State, Division of Forestry (DOF), and Urban and Community Forestry Program (CFP) have grant monies available for local governments and non-profits to remove invasive trees. In 2021, seven grants were awarded to CANWIN, Fairbanks Soil and Water Conservation District (SWCD), Municipality of Anchorage, Palmer SWCD, Talkeetna Community Council, University of Alaska Anchorage, and Wasilla SWCD.

As part of a larger effort to control the spread of invasive chokecherries, Alaska DOF developed the *Prunus* Remove and Replace program to address two common *Prunus* spp. used as landscape trees that are negatively affecting forest health across Alaska. This program provides a $100 voucher to homeowners who choose to remove their invasive chokecherry and replace it with a non-invasive tree (Figures 43 and 44). Vouchers may be used to purchase replacement trees from select nurseries. The intent of this program is to raise awareness about the issues associated with the invasive chokecherries. This year the program was made available to residents of the Municipality of Anchorage and the public response has been overwhelming with 120 applications received for 80 available vouchers.

Figure 43 | A large chokecherry tree in Anchorage before removal with the Remove and Replace program. Alaska Division of Forestry photo by Josh Hightower.

Figure 44 | The same site after removal of chokecherry tree with the Remove and Replace program. Alaska Division of Frestry photo by Jim Renkert.

Figure 45 | USFWS technician John Davis conducting Cold Bay roadside surveys. US Fish and Wildlife Service photo by Ben Wishnek.

Partner Updates *continued*

Figure 46 | James Landal, Fairbanks SWCD technician, holds an Elodea plant at Eielson Airforce Base. Fairbanks SWCD photo by Colin McKenzie.

OTHER UPDATES

There are many invasive species activities that occurred throughout Alaska beyond National Forests or organizations with formal agreements. Most of the activities have been conducted by other federal, state, and local agencies, local Cooperative Weed (Invasive Species) Management Areas, Soil and Water Conservation Districts, or other organizations. Often, staff from these organizations coordinate and consult with invasive species experts across the state to work effectively. The Alaska Invasive Species Partnership helps facilitate this coordination through monthly calls and a vast listserv that increases communication across the state. The following updates have been provided by local organizations and are organized by general geographic areas.

Southwest Alaska area: This year, the US Fish and Wildlife Service (USFWS) conducted intensive surveys for invasive plants along some of their road systems. Specifically, on the King Salmon/Naknek Road system, they surveyed 81 10mx10m sites across 70 miles of roads for high priority terrestrial invasive plant species. No detections of species ranked greater than or equal to 60 in the Alaska Exotic Plants Information Clearinghouse (AKEPIC) were found. However, they also surveyed an additional 44 sites with greater risk of invasive species introductions and found small populations of white sweetclover, foxtail barley (*Hordeum jubatum*), and oxeye daisy (*Leucanthemum vulgare*).

On the Cold Bay/Izembek National Wildlife Refuge road system, USFWS surveyed 45 10mx10m sites across 62 miles of road and found no invasive species with an invasiveness ranking greater than or equal to 60 in AKEPIC (Figure 45). An additional 81 sites with great risk of invasive species via area-constrained searches led to detections of small infestations of orange hawkweed, creeping thistle, and oxeye daisy.

Fairbanks/Interior Alaska area: The Fairbanks Soil and Water Conservation District has been at the forefront of invasive plant work in this region, with a focus on controlling elodea (*Elodea* sp.) for the past several years. During the 2021 season, the FSWCD team worked on elodea eradication efforts in the following sites: 1) Manley Hot Springs, 2) Chena Slough, 3) Totchaket Slough, 4) Chena Lakes and Bathing Beauty Pond, 5) Birch Lake, and 6) Piledriver Slough, Harding Lake, and Chisolm (Lost) Lake. All sites have seen significant improvement with likely eradication in Totchaket Slough. In addition, no live fragments were found in Chena Lakes and Bathing Beauty Pond.

The FSWCD invasive species team conducted early detection surveys for elodea (Figure 46). Unfortunately, ten new infestations were found. Nine were found on Eielson Air Force Base and one was found on Fort Wainwright military lands.

South Central Alaska/Kenai Peninsula area: Much of the work in this region has been conducted by the Kenai Cooperative Weed Management Area, the Homer Soil and Water Conservation District, and the Kenai Watershed Forum. A large emphasis has been on invasive chokecherries in this region with HSWCD and KWF assisting private landowners with the removal of invasive trees from 14 different parcels. Approximately 71 chokecherry trees were removed from the Homer and Cooper Landing areas and an additional 100+ sprouting saplings and suckers were also removed at well-established sites. All known infestation (10 sites) along the upper Kenai River were treated by KWF.

Southeast Alaska area: While the Southeast Alaska Watershed Coalition (SAWC) has led many activities in Southeast Alaska, the weather in 2021 was unfortunately not conducive to control work. Despite the weather constraints, SAWC was able to focus on treating numerous chokecherry trees (Figure 47).

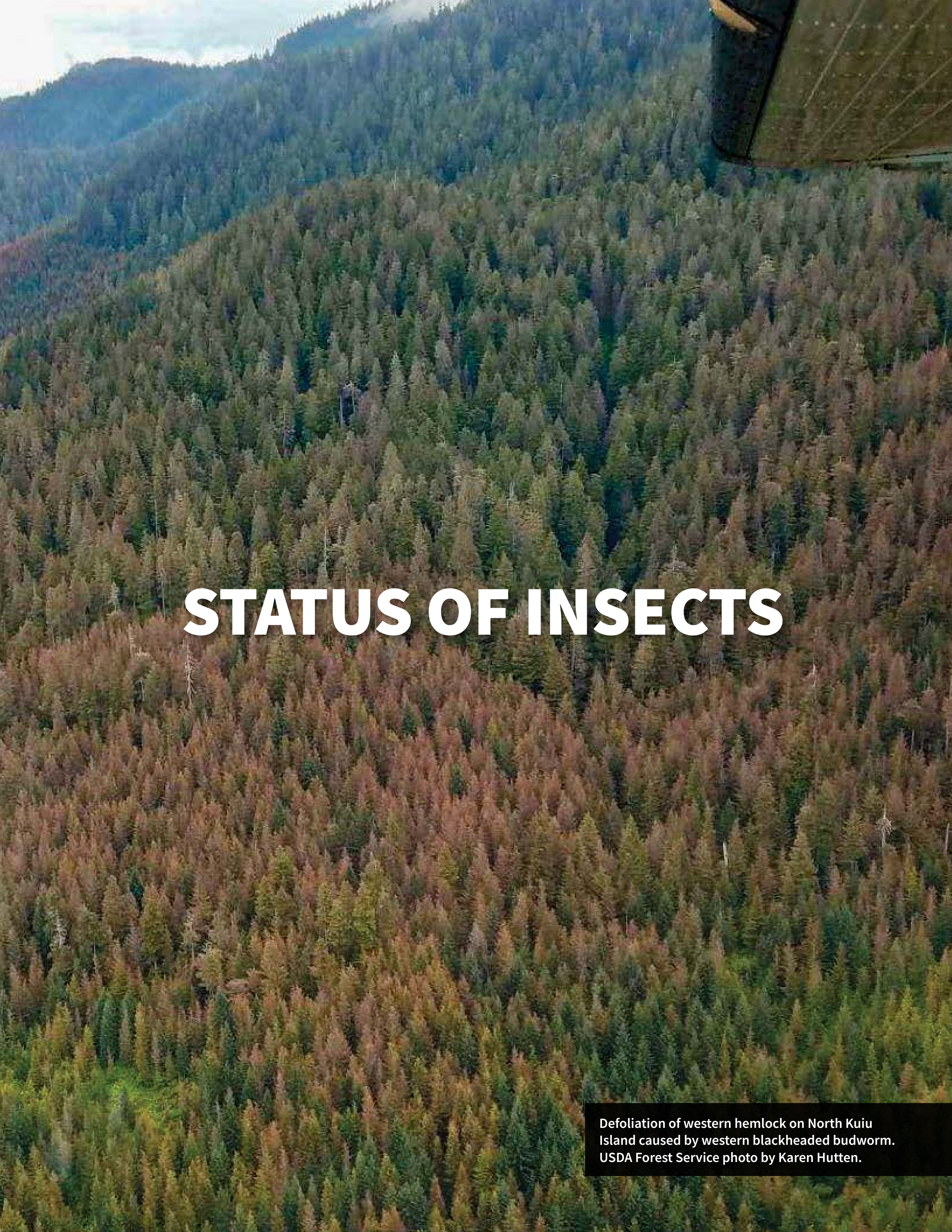
Figure 47 | Controlling chokecherries in Juneau. Southeast Alaska Watershed Coalition photo by John Hudson.

STATEWIDE UPDATES

University of Alaska Fairbanks, Cooperative Extension Service staff have been busy with invasive plant work beyond that conducted under the agreement with SPF. With financial support from the Animal and Plant Health Inspection Service (APHIS), they are working with the State of Alaska Division of Agriculture to approve for trial release, biocontrol agents for trial release that are suitable for current or future invasive plant management. The first species they are utilizing is *Apahalara idatori*, a psyllid that is attracted to the invasive knotweed complex. In the coming year, they will broaden their reach with partners to determine the next biocontrol agent to consider for approval and release.

UAF CES will use funding from the USDA Hatch program to continue work on basal bark control studies of European bird cherry. The original study focused on herbicide soil residues and non-target impacts from aminopyralid that was sourced from herbicide root exudates. The expanded study explores if those soil herbicide residues and non-target impacts can be decreased by using lower application rates and concentrations, while still maintaining control efficacy.

STATUS OF INSECTS



Defoliation of western hemlock on North Kuiu Island caused by western blackheaded budworm. USDA Forest Service photo by Karen Hutten.

ALDER DEFOLIATION

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

Alder defoliation was observed on over 3,000 acres during 2021 aerial detection surveys. This is about 25% more acres than the average over the last four years of surveys. The highest concentration of current year damage was in Southcentral in the Susitna River valley (>2,000 acres). Three areas of about 200 acres each were also mapped: just south of Cantwell, along Turnagain Arm, and southeast of Tok near Tetlin Lake. Additionally, there were 25 acres mapped in Southeast. The damage mapped in the Susitna River valley was possibly caused by rusty tussock moth. Some areas with alder defoliation along the road system were ground checked and confirmed as rusty tussock moth and mapped as such; however, we could not ground check and verify all acres, so they have been included as general alder defoliation. For more information about rusty tussock moth damage see the update on page 47. Additional alder defoliation was noted around the state during ground surveys but was relatively minor. In Southeast, green alder sawfly was noted as the most common defoliator on alder in several areas. The spotted tussock moth was notably low in abundance in 2021 after several years of high caterpillar populations throughout Southeast.

ASPEN DEFOLIATION

Sunira verberata (Smith)

In 2020, a few large areas of aspen defoliation were found in Southcentral during ground surveys on the Kenai Peninsula. Observed defoliation, likely caused by *Sunira verberata*, was severe enough to be seen from the air, but since no aerial detection surveys were flown in 2020, none of this damage was mapped. In areas of the Chugach National Forest where aspen defoliation was found in 2020, only light defoliation was found in 2021.

In 2021, over 4,000 acres of aspen defoliation were mapped during aerial detection surveys; this is 45 times fewer acres than were mapped during the average of the last four years of surveys. Most of the aspen defoliation mapped in 2021 was in the Interior and included over 2,500 acres in and around the Tetlin National Wildlife Refuge and about 700 acres in the Kanuti National Wildlife Refuge. The aspen in these Interior Alaska locations looked thin and a little faded, but the cause of this damage could not be determined. In Southcentral Alaska, almost 600 acres were mapped on the northwestern Kenai Peninsula in trees that appeared thin and slightly brown or tan. Reports and photos of this damage were received from several landowners in the affected areas. The damage appeared to only be affecting aspen, despite other hardwood species being present. No definitive signs of a causal agent were observed, and ground checks were unable to be completed. The damage is suspected to be abiotic, and the area will be monitored in 2022. Additionally, about 250 acres of aspen defoliation were mapped in the Yanert Fork drainage east of McKinley Village.

Figure 48 | Birch aphid defoliation in June (top), and trees re-foliated in July (bottom) at the same location near Rex Bridge. USDA Forest Service photos by Garret Dubois.

BIRCH APHID

Euceraphis betulae (Koch)

In 2021, birch aphid damage was mapped during Interior aerial detection surveys on 79 acres along the Parks Highway just south of Anderson. There were also large areas of birch defoliation mapped in the Salcha area and along the Richardson Highway that were likely birch aphid damage, though they were not able to be ground checked (see birch defoliation update on page 47). During 2020 ground surveys, over 850 confirmed and suspected acres of birch aphid activity were mapped.

A substantial amount of birch aphid damage was observed in early June of 2021 between mileposts 270 and 280 of the Parks Highway near the Rex Bridge. Many birches were found to have either been defoliated completely or had very thin crowns and tops. Remaining foliage was somewhat discolored and tattered or wrinkled in appearance with aphids present in low numbers. Much of the birch re-grew leaves to some extent by early July (Figure 48), and as a result, much of the damage was not visible during aerial detection surveys.

Birch aphids were also observed during ground surveys in 2021. One site in the Interior, north of Anderson along the Parks Highway had low severity damage on about a dozen trees. Another site was in Southwest Alaska in Bethel, where just a few trees had trace amounts of aphids with little to no damage observed.

BIRCH DEFOLIATION

Over 7,700 acres of birch defoliation were mapped during aerial detection surveys in 2021, up from 1,500 acres in 2019. In 2020, only 850 acres of birch defoliation were mapped during Scan and Sketch surveys using satellite imagery. Birch defoliation consisted of thin tops and slight yellowing in some areas.

Several hundred acres of damage were mapped in the Interior between the Steese Highway and Chena Hot Springs Road. More than 1,400 acres over several small areas were also mapped near the Richardson Highway and Johnson Road in the Salcha area. Although many of these areas were in the general vicinity of known birch aphid defoliation in 2020, it was not possible to ground truth the 2021 damage, so it was mapped as general birch defoliation. A small area adjacent to known birch aphid damage was also mapped west of the Parks Highway and near Anderson. In Southcentral, over 4,300 acres were mapped along the Parks Highway in Denali State Park. This area was ground checked but the agent was undetermined and remains unknown. An additional 1,500 acres were mapped in the Susitna River valley, near Talkeetna, on Point McKenzie, in Wasilla, and in Eagle River. Less than 100 acres were also mapped on the Kenai Peninsula just west of Hope.

BIRCH LEAFROLLER

Caloptilia spp. (Hübner)
Epinotia solandriana (Linnaeus)

Birch leafroller was not mapped during aerial detection surveys in 2021. Based on ground observations, the frequency (number of trees infested) of infestations in Interior and Southcentral Alaska has remained relatively constant. However, the intensity (number of rolled leaves per tree) has been low, making it difficult to detect during aerial detection surveys. During ground surveys in Southcentral between Talkeetna and Kenai Lake, most sites had low leafroller activity. Additionally, birch leafroller damage in the Interior was noted at several locations during ground surveys along the road system. No area had damage severe enough to be seen from the air.

RUSTY TUSSOCK MOTH

Orgyia antiqua (L.)

The rusty tussock moth outbreak occurring in the Matanuska-Susitna Borough continued in 2021, with roughly 44,000 acres of moderate-to-severe defoliation observed during the annual aerial detection surveys. This outbreak appears to be in its second year. Reports and observations of substantial numbers of caterpillars and defoliation were prevalent in the northerly portions of the region in 2021, from roughly Petersville north to the Alaska Range. Approximately 93% of the mapped damage was occurring in the Chulitna River valley between roughly mile 135 and 190 of the Parks Highway, with near complete defoliation of alder observed near Hurricane Gulch. Presumed rusty tussock moth activity was also mapped near Cantwell and in a few locations near the Susitna River along the Denali Highway. While rusty tussock moths were observed across the lower Matanuska-Susitna valley as well, fewer reports of widespread defoliation were received from this part of the region in 2021, including in the Hatcher Pass area, where activity was high in 2020. As with activity reported in 2020, very high populations and associated defoliation were reported in several areas near or above tree line, notably within Denali State Park on Curry and Kesugi Ridges. Across the outbreak area, the dominant hosts being affected are alder, dwarf birch, and blueberry.

Surveyors conducted a ground assessment of the damage on Curry Ridge, where varying levels of defoliation were observed in alder, blueberry, dwarf birch, and resin birch. Rusty tussock moth feeding was notably absent on fireweed. Minor defoliation was observed on scattered individual branches of large white spruce, with defoliation occurring more fully on white spruce seedlings; it is unclear whether this defoliation in seedlings was severe enough to cause mortality. Nearly every white spruce in the area had rusty tussock moth defoliation, webbing, and remnant dead caterpillars on the terminal leader (the very top of the tree). This is presumed to be related to a behavior called ballooning, where the caterpillars spin a silk thread and harness the wind to disperse themselves to other locations.

Over the winter of 2020-2021, the Alaska Division of Forestry provided rusty tussock moth egg masses to Dr. Stephen Cook of the University of Idaho for a research study he was conducting. Egg masses were collected from Hatcher Pass, Houston, and Nancy Lakes and, with all the necessary permitting requirements in place, were shipped to Idaho for the project. Dr. Cook reported this fall that the egg masses from Alaska were heavily parasitized ranging from a ratio of approximately 5:1 (parasitoids to larvae) to a high of almost 8:1. The parasitoids are all one species and have been tentatively identified as being in the genus *Telenomus*. Specimens are being reviewed by a taxonomist and will be provided to the University of Alaska Fairbanks Museum of the North insect collection. Future efforts in Alaska should evaluate whether rusty tussock moth parasitism rates may be a useful predictor of population dynamics.

WESTERN TENT CATERPILLAR

Malacosoma californicum (Packard)

Western tent caterpillars were reported in Southeast from Annette Island, Ketchikan, and Hyder in 2020. The brightly colored and gregarious caterpillars were not known to occur in Alaska; however, their native range extends into northern British Columbia. A survey of the Ketchikan road system took place in June 2021 to delineate the distribution of western tent caterpillars. Western tent caterpillars were found in red alder along the bike path for 0.25 miles starting at approximately mile five on the Tongass Highway, known as Mountain Point (Figure 49). The tents were limited to small diameter, shrubby red alder. Within tree damage severity was low, and the number of infested trees at each point ranged from one to over 16. Reports from the public suggest the population has been established for at least five years. No other western tent caterpillars were observed outside the main infestation area of Mountain Point and no new observations were reported in iNaturalist.org.

Figure 49 | Western tent caterpillars were reported in Ketchikan in 2020. A survey in 2021 found the gregarious caterpillars were only established in one area along the Mountain Point bike path. USDA Forest Service photo by Elizabeth Graham.

Figure 50 | Generalist hardwood defoliation was found at the east end of Powerline Pass with heavy defoliation of a couple different willow species and dwarf birch. This unknown generalist defoliator was found at lesser amounts on crowberry and Sitka alder. USDA Forest Service photo by Steve Swenson.

MISCELLANEOUS HARDWOOD DEFOLIATORS

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) | *Phyllocolpa excavata* (Marlatt)
Rheumaptera hastata (L.) | *Sunira verberata* (Smith)

Almost 450 acres of general hardwood defoliation were mapped in 2021, most of it located in Southcentral along the lower portions of the Susitna River between the Yentna River and the Caswell area. The damage was adjacent to the river on alder and willow and not easily accessible from the ground; no causal agent(s) could be identified. Heavy generalist hardwood defoliation was also noted in eastern portions of Powerline Pass in Chugach State Park, where caterpillars of an unknown species were primarily found defoliating a couple different willow species and dwarf birch (Figure 50). This generalist defoliator was found in lesser amounts on crowberry and Sitka alder.

Leaf-folding in seedling and sapling-sized balsam poplar was observed during ground surveys in many areas of the Interior (primarily along the Steese Highway and Chena Hot Springs Road) and at one site in Southcentral, just south of Glennallen. This damage was all likely caused by *Phyllocolpa excavata*, which is a leaf-folding sawfly that occurs on *Populus* and *Salix* species in Alaska.

In Southeast, defoliation was also noted on red alder in the Ketchikan area along the South Tongass Highway. The cause of this minor damage found along the South Tongass Highway is unknown.

ASPEN LEAFMINER

Phyllocnistis populiella Chambers

In 2021, aspen leafminer was mapped on over 146,000 acres of the Interior. Moderate to severe levels of damage were observed throughout all areas it has been historically observed with some areas around Fairbanks and west along the Tanana River appearing to be more heavily infested this year. In 2019, 132,000 acres were mapped while only 39,000 acres were mapped during the 2020 season using Scan and Sketch survey with satellite imagery. No Southcentral aerial detection survey routes were flown in the Copper River valley or the Glenallen area in 2021 where aspen leafminer levels have been moderate to very severe for most of the last decade.

During ground surveys, several Interior locations were reported to have aspen leafminer. Most observations were along the Steese Highway, Chena Hot Springs Road, the Parks Highway, and the Richardson Highway with trace to moderate levels of damage. In Southcentral, ground surveys in the vicinity of Glenallen in 2021 also confirmed that aspen leafminer was present at low levels, which is similar to ground observations in 2020. However, ground surveys were conducted in September, therefore some leafminer damage may have been missed. Damage was only discernable upon close inspection due to the silvery-colored mines turning yellow in the fall (Figure 51). More than half of the 2021 records were on quaking aspen and located mostly in the Interior, though a few observations were in the vicinity of Glenallen. Trace to moderate levels of damage were observed in quaking aspen as well as a few locations with high levels of damage spread across the landscape. Several observations were also recorded on balsam poplar though the causal agent is not yet confirmed. Most of those records were spread throughout Interior Alaska, with one located in Southcentral near the Knik River along the Old Glenn Highway. Trace to low levels of infestation were observed across all of the balsam poplar records.

Figure 51 | From a distance, aspen leafminer damage can look like fall color during late season ground surveys. USDA Forest Service photo by Steve Swenson.

BIRCH LEAFMINERS

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

Almost 48,000 acres of birch leafminer damage were mapped in Southcentral and the Interior during aerial detection surveys. Birch leafminers have been in outbreak for several years in the Anchorage and Wasilla areas as well as in and around Fairbanks and North Pole. This damage is easily observed on the ground at all severity levels but is usually not severe enough to map during aerial detection survey until early- to mid-August. In 2018 and 2019, late season flights were flown to capture leafminer damage caused by *Profenusa thomsoni* and *Heterarthrus nemoratus*. It was decided that mid-August flights would continue, and the temporal change has resulted in a substantial increase in birch leafminer acres mapped, even though ground surveys showed there was not a substantial increase in birch leafminer activity. During the late-season aerial detection surveys, over 100,000 acres were mapped in 2018, over 280,000 in 2019, and over 47,000 in 2021. Fewer acres were mapped in 2021, which is likely due to a decrease in birch leafminer activity in Southcentral and overall decrease in area flown from recent years.

Figure 52 | It was unusual that there was more leaf damage on Southcentral birch in 2021 caused by leaf beetles than by leafminers. USDA Forest Service photo by Steve Swenson.

Over 20,000 acres were recorded in Southcentral with most of those acres mapped between Talkeetna and Little Coal Creek. Although *H. nemoratus* seems to be spreading in the Fairbanks area, it is still likely that damage in Interior is predominately from *P. thomsoni*, whereas *H. nemoratus* had been predominate in Southcentral in recent years. In the Interior, over 27,000 acres of birch leafminer damage was recorded during aerial detection surveys. Almost 25,000 of those acres occurred in the region around Fairbanks and along portions of Chena Hot Springs Road, the Steese Highway, and areas in between. A substantial amount of damage also occurred along the north side of the Tanana River from Birch Lake west to Nenana. Much of Fairbanks proper was difficult to survey due to increased aviation traffic, and as a result, areas in Fairbanks and around Fairbanks International Airport may have been under-surveyed.

During ground surveys in Southcentral, the percentage of leaves per tree with birch leafminer activity was virtually unchanged from 2020. However, there were noticeably fewer mines per leaf and noticeably less leaf surface affected by mines in 2021 compared to prior years. While we observed less damage caused by both *P. thomsoni* and *H. nemoratus* in 2020 and 2021 relative to recent years, it is unclear why such a large decrease occurred. Due to the decrease in leaf mines in 2021, much of the leafminer activity noted in the

Anchorage and Wasilla areas may not have been severe enough to be visible during aerial detection surveys. Additionally, unusual amounts of damage caused by leaf beetles were observed on birch in Southcentral in 2021 suggesting there could be an impact to leafminers due to competition for host resources (Figure 52, page 49).

During Interior ground surveys, both *P. thomsoni* and *H. nemoratus* were recorded along the Steese Highway, Chena Hot Springs Road, and the Richardson and Parks Highways. *Heterarthrus nemoratus* was observed all along the Steese Highway and Chena Hot Springs Road while *P. thomsoni* was found at several sites on Chena Hot Springs Road but at just one location on the Steese Highway. On the Parks Highway, *P. thomsoni* was present closer to Fairbanks while *H. nemoratus* was observed in a few locations near Anderson. Additionally, *P. thomsoni* was found from Fairbanks to Delta Junction on the Richardson Highway while *H. nemoratus* was found closer to Fairbanks and at one site in Delta Junction where both leafminers were present. Most sites outside of the Fairbanks and North Pole areas had trace to low levels of damage present with moderate levels of damage observed closer to population centers. High damage from *P. thomsoni* was observed in several locations within Fairbanks and North Pole though ground surveys were limited in those areas.

In 2021, what appeared to be *H. nemoratus* was also observed in Southwest Alaska at two separate locations in Bethel. One site was at the Yukon Delta National Wildlife Refuge main office where three small pole-sized birch had low-level infestations and at least one Sitka alder had trace levels of infestation (Figure 53). The second site was in a neighborhood approximately one mile away from the refuge main office where one pole-sized birch along a driveway (Figure 54) had low levels of infestation. The very few birch trees nearby were not inspected. Although only low levels of infestation were observed, it may still indicate that leafminers have been in the area for several years, though the exact number of years is difficult to establish. This detection is important because many remote but developed areas off the road system, such as Bethel, are rarely surveyed. The closest leafminer population to Bethel is at least 350 air miles away with no road system connecting it to Bethel. However, substantial amounts of cargo, boat traffic, and aviation traffic do move through Bethel on a year-round basis and the final destination of passengers or cargo may be Bethel or any number of villages in the region. It is difficult to determine how leafminers arrived in Bethel, but it is possible that leaves from heavily infestated areas could have been transported there inadvertently with cargo or people.

Figure 53 | Birch leafminer larvae present inside mines nearly ready to overwinter. USDA Forest Service photo by Garret Dubois.

Figure 54 | Birch leafminer damage was low to moderate in two different locations in Bethel. USDA Forest Service photo by Garret Dubois.

Birch leafminers were also mapped off the road system in 2019 near the west side of Cook Inlet in the Big River Lakes area. This damage was located across Cook Inlet, approximately 45 miles west of the nearest known infestation on the Kenai Peninsula. The Big River Lakes area is a popular recreation and lodge site visited by many tourists and residents of Southcentral and though not confirmed, humans and movement of cargo are the most likely vector in this case. Consequently, this problem may not be unique to Bethel or the Big River Lakes recreational sites, and further survey of remote areas may be warranted.

WILLOW LEAFBLOTCH MINER

Micrurapteryx salicifoliella (Chambers)

Willow leafblotch miner was mapped on just over 14,000 acres in the Interior during aerial detection surveys. This continues a downward trend of the past few years with 31,000 acres mapped in 2019 and 35,000 acres in 2018. No acres of willow leafblotch miner were mapped during Scan and Sketch surveys in 2020 due to limited availability and poor resolution of available satellite imagery.

Nearly 11,000 acres of willow leafblotch miner damage were mapped in the Yukon Flats and adjacent areas, where the bulk of the damage has been historically mapped. Over 2,200 acres were mapped in and near Tok and the Tetlin National Wildlife Refuge. Several hundred acres were also mapped in the Tanana Flats, along the Tanana River near Nenana, and in the Kanuti National Wildlife Refuge. Other smaller sites were also mapped across the landscape. Light to severe damage was common in all areas, while very severe damage was limited to a few sites in the Yukon and Tanana Flats.

During ground surveys, several observations of willow leafblotch miner were made. Nearly all the records were spread across the Interior road system, with a few located in Southcentral on the Richardson Highway near Glennallen. Most sites had trace to moderate damage levels. Although willow leafblotch miner damage is not typically found in Southcentral, moderate to heavy damage was also recorded in 2020 at several locations in the Glenallen area and the Copper River valley.

Figure 55 | Western blackheaded budworm feeding damage on western hemlock. Caterpillars feed on new foliage, leaving behind half eaten needles that cause the trees to have a reddish appearance. USDA Forest Service photo by Elizabeth Graham.

Figure 56 | Western hemlock on Admiralty Island near Chaik Bay killed after severe hemlock sawfly defoliation in 2018 and 2019. USDA Forest Service photo by Elizabeth Graham.

WESTERN HEMLOCK DEFOLIATION

Neodiprion tsugae Middleton
Acleris gloverana Walsingham

Hemlock sawfly and western blackheaded budworm are endemic to the forests of Southeast Alaska. Hemlock sawfly larvae feed on the older foliage of western hemlock, while western blackheaded budworm larvae feed on the buds and new foliage of western hemlock. Both insects occasionally feed on other conifers as well (Figure 55). Outbreaks of these insects occur cyclically, making them one of the most significant disturbance agents in Southeast forests. A hemlock sawfly outbreak started in 2018, peaked in 2019, and crashed in 2020. Western blackheaded budworm populations began to increase in 2020 exploding into a large-scale outbreak in 2021 that extends across much of Southeast Alaska. All active hemlock defoliation reported in 2021 was for western blackheaded budworm, while any hemlock mortality (Figure 56) or topkill was presumed to be related to the hemlock sawfly outbreak. In many of these areas, topkill occurred on trees with active western blackheaded budworm defoliation on the remaining portion of the crown. Distinguishing between mortality and topkill can be difficult from the air; Tongass National Forest staff helped to ground truth many accessible areas to confirm the damage. Topkill was recorded on >186,000 acres, mostly in the central part of the Tongass National Forest. Mortality from severe defoliation was observed on another 21,000 acres, half of which was on Admiralty Island. Defoliation was recorded on 520,000 acres, of which 313,000 acres were rated as >75% defoliation. The damage occurred throughout the panhandle from Juneau to Ketchikan though defoliation was heaviest in the central Tongass area including Kuiu, Kupreanof, Mitkof, and Zarembo Islands as well as Chichagof and Admiralty Islands and several drainages on the mainland. Other notable areas of defoliation were along the outer coast where only small, scattered pockets of defoliation were recorded. A few areas of defoliation were also noted as far north as Haines. Ground surveys on Mitkof, Wrangell, Admiralty, and Chichagof Islands and the Juneau road system revealed western blackheaded budworm to be the most abundant defoliator at all sites. Caterpillars were reported hanging from silk threads (Figure 57) and large amounts of frass were observed in the understory. On occasion other conifers including Sitka spruce, mountain hemlock, and ornamental subalpine fir were also attacked, but damage was moderate and sporadic and not recorded during aerial detection surveys. Hemlock sawfly larvae were found to be at endemic levels. The following is a summary of the damage by sub-regions recorded for 2021 (Map 28; Table 6).

Figure 57 | Western blackheaded budworm caterpillar hanging from a silk thread. Caterpillars were commonly observed exhibiting this behavior in heavily infested areas. USDA Forest Service photo by Elizabeth Graham.

ENTOMOLOGY

Map 28 | Hemlock damage in Southeast Alaska separated by sub-regions. This does not reflect property ownership and is for summarizing purposes only. For a breakdown by ownership see Table 1. USFS Ranger Districts may include small parcels of adjacent state, private, or tribal land.

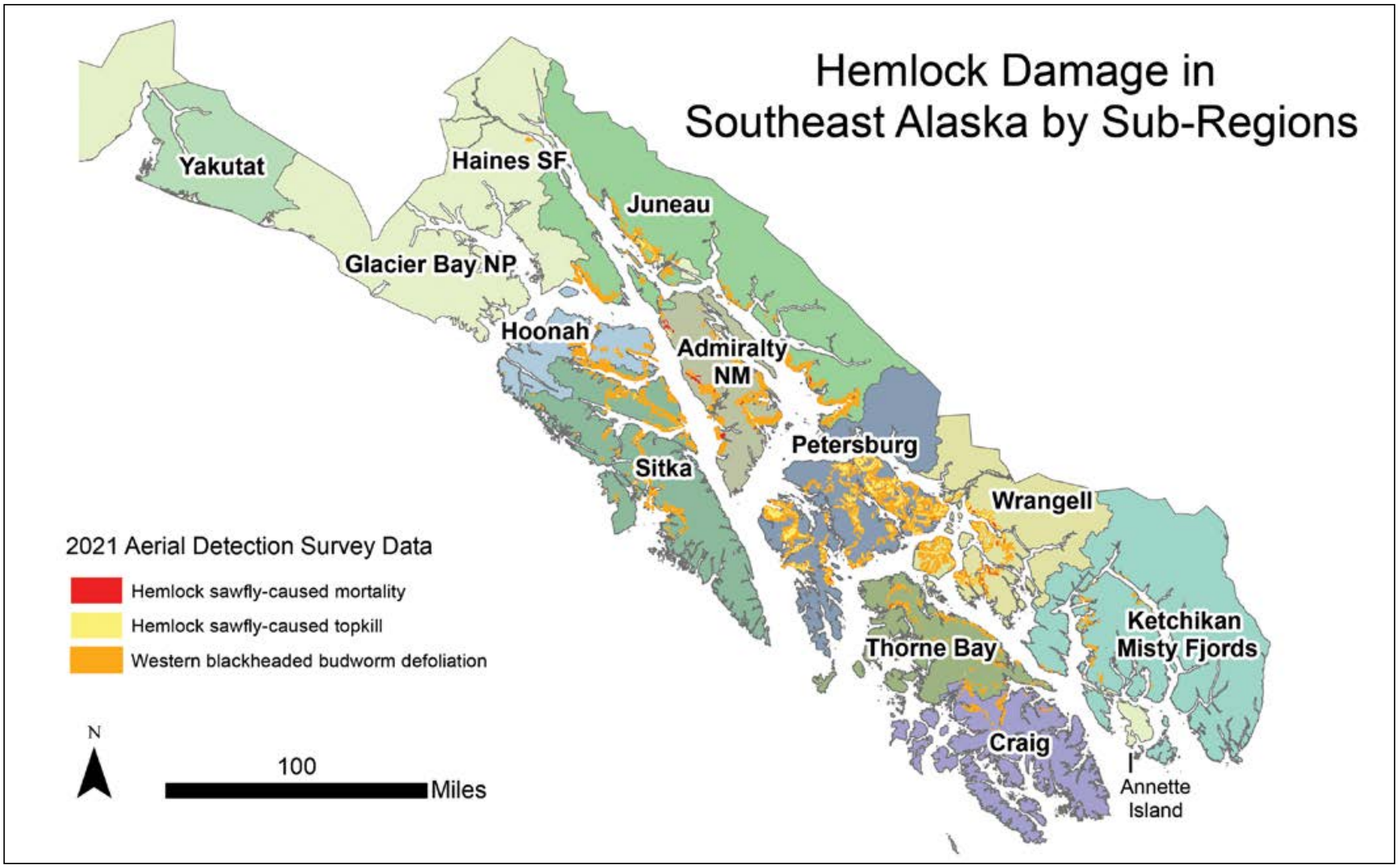


Table 6 | Hemlock damage in Southeast Alaska separated by sub-regions. This does not reflect property ownership and is for summarizing purposes only. For a breakdown by ownership see Table 1. USFS Ranger Districts may include small parcels of adjacent state, private, or tribal land.

Sub-Region	Acres of Western Blackheaded Budworm Defoliation	Acres of Hemlock Sawfly Topkill	Acres of Hemlock Sawfly Mortality
Petersburg Ranger District	187,769	128,808	997
Juneau Ranger District	79,519	7,122	1,245
Sitka Ranger District	73,637	4,408	261
Wrangell Ranger District	70,578	36,373	6,341
Admiralty National Monument	54,122	4,401	10,021
Hoonah Ranger District	20,316	391	0
Thorne Bay Ranger District	14,630	4,112	1,375
Craig Ranger District	8,650	6	397
Ketchikan Misty Fiords Ranger District	6,063	531	392
Glacier Bay National Park	3,683	0	0
Haines State Forest	1,033	0	0
Totals	**520,000**	**186,153**	**21,030**

Softwood Defoliators *continued*

Petersburg Ranger District

Damage was high throughout the Petersburg Ranger District. Western blackheaded budworm defoliation was consistently rated at >75% and topkill associated with the hemlock sawfly outbreak occurred in most areas as well. Northern Kuiu was especially hard hit with large areas recorded with heavy defoliation affecting >50% of the trees. Mortality associated with hemlock sawfly was recorded in several locations on the southern end of Kuiu, Kupreanof, and Mitkof Islands.

Juneau Ranger District

Western blackheaded budworm defoliation was nearly continuously mapped on the mainland from Port Houghton to Holkham Bay though mortality and topkill were less common than in the areas further south. Notable exceptions include large areas of topkill in Port Houghton and severe mortality between Hobart and Windham Bays. Defoliation continued north to Berners Bay, generally with less intensity. However, heavy defoliation and topkill were observed from Montana Creek to Eagle River. Defoliation was also observed on the western side of Excursion Inlet and the northern end of Douglas Island.

Sitka Ranger District

The Sitka Ranger District had the second most western blackheaded budworm defoliation; fortunately, it also has the least topkill and mortality. Defoliation was consistently recorded throughout Chichagof and Baranof Islands with the notable exception of the outer coast. Mortality was recorded in Katlian Bay on Baranof Island and north of Gilmer Bay on Kruzof Island.

Wrangell Ranger District

Mortality associated with hemlock sawfly was heavy on Etolin Island in several areas including Burnett Inlet, from Quiet Harbor across Anita Bay to Olive Cove. Two areas of mortality were recorded on Wrangell Island, south of the Eastern Passage as well as north on the mainland. Active western blackheaded budworm defoliation was recorded throughout Etolin, Wrangell, and Zarembo Islands as well as several drainages along the mainland. Topkill from the hemlock sawfly outbreak overlaps in many of these areas.

Admiralty National Monument

Western blackheaded budworm defoliation was observed on both sides of Admiralty Island. Large areas of mortality were recorded from Chaik to Hood Bay, between Thayer and Florence Lakes, and south of Hawk Inlet. Topkill was recorded south of Hawk Inlet as well as in Angoon, Pybus Bay, and north of Mole Harbor (Figure 58). Admiralty Island was surveyed first and therefore defoliation may be underrepresented.

Hoonah Ranger District

Western blackheaded budworm damage was contiguous across the northern side of Tenakee Inlet and in parts of Port Frederick. Damage was also heavy in Freshwater Bay and the community of Hoonah. The peninsula west of Hoonah and east of Mud Bay was missed during aerial detection survey; however, the use of satellite-image change detection tools and ground observations indicate that this location was also hard hit by western blackheaded budworm.

Figure 58 | Reports of hemlock sawfly and western blackheaded budworm activity were initially reported from Killisnoo Island, near the city of Angoon on Admiralty Island. Defoliation continued in 2021 and included observations of western blackheaded budworm, hemlock sawfly and western hemlock looper. USDA Forest Service photo by Elizabeth Graham.

Thorne Bay Ranger District

Western blackheaded budworm was recorded throughout most of the surveyed area though it was not as extensive as in other ranger districts. Topkill was also recorded less often than other districts; however, surveyors flew this portion of the forest early on and were not as comfortable attributing multiple damage agents. Notable areas of mortality were recorded near El Capitan Lake and Cave and Thorne Bay. In 2020, 80,000 acres of mortality were recorded during Scan and Sketch surveys of satellite imagery.

Craig Ranger District

Mortality was recorded south of Skowl Arm Bay and near the Hollis Ferry Terminal. As with Thorne Bay, active defoliation was not as extensive.

Ketchikan Misty Fjords Ranger District

Western blackheaded budworm damage was most abundant on the western side of Revillagigedo Island. The only area of notable damage on the eastern side was near Portage Cove. A few areas of mortality were observed near Traitors Cove and Moser Bay. Topkill was recorded along Neets Bay and Clover Passage.

Glacier Bay National Park

Western blackheaded budworm defoliation was recorded on the west side of Excursion Inlet. No topkill or mortality associated with hemlock sawfly was recorded.

Haines State Forest

Few pockets of defoliation from western blackheaded budworm were recorded. The largest was along the Chilkat Inlet and accounted for most of the damage north of Juneau. Few scattered pockets were found north of Lynn Canal.

Status of Insects > Bark Beetles

Bark beetles are an ever-present risk to forest health in Alaska (Map 29), 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.

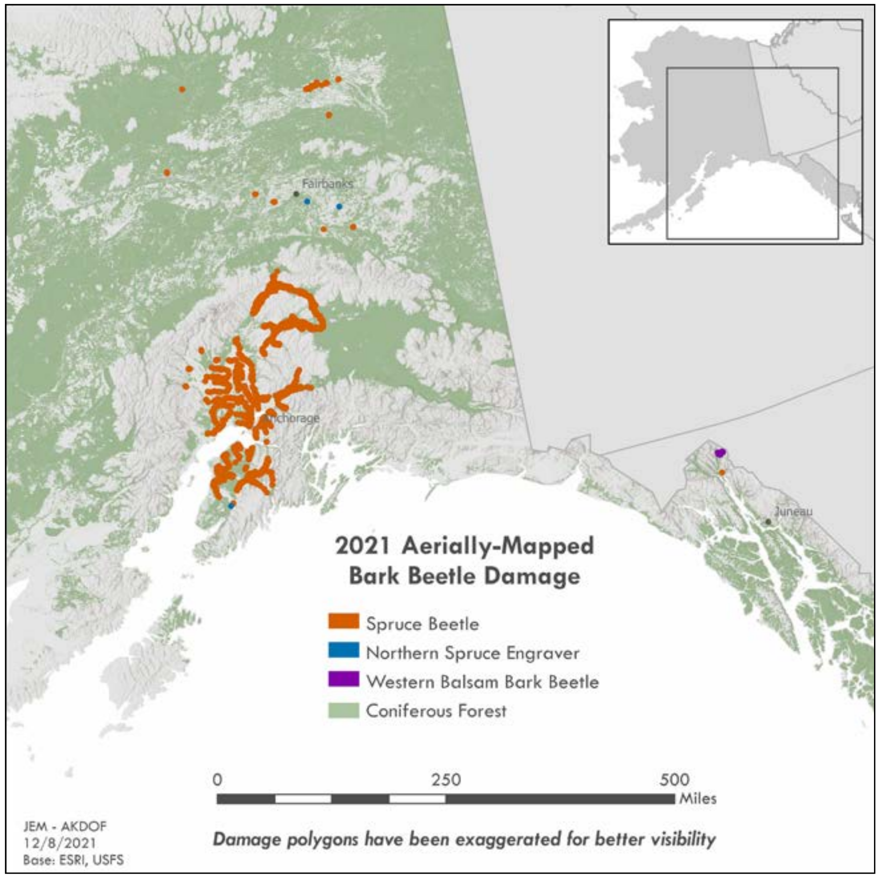
SPRUCE BEETLE

Dendroctonus rufipennis (Kirby)

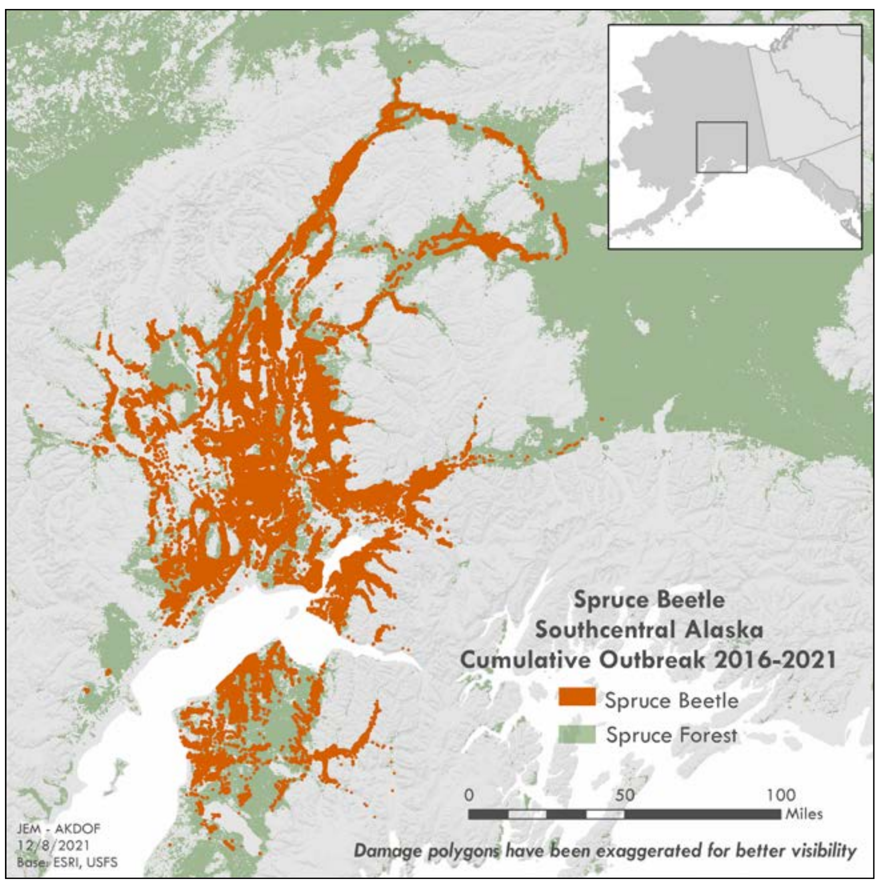
Spruce beetle activity was observed on approximately 193,500 acres statewide during aerial detection surveys in 2021, slightly higher than the 139,500 acres mapped in 2019; no aerial detection surveys occurred in 2020. More than 98% of all spruce beetle activity mapped in 2021 was within Southcentral Alaska, where an ongoing spruce beetle outbreak is now estimated to be in its sixth year. The outbreak has affected at least 1.6 million cumulative acres of mixed spruce and birch forests since 2016, when it was first documented (Map 30). In 2021, the outbreak was most active in the northern Matanuska-Susitna Borough, the lower Denali Borough, and in parts of the Kenai Peninsula; activity has greatly declined in the areas that were impacted most severely early in the outbreak. The cooperative website www.alaskasprucebeetle.org continues to be regularly updated and is the go-to location for spruce beetle information in Alaska.

In areas that were initially impacted by the spruce beetle outbreak, such as the central and lower Susitna River valley, a near exhaustion of susceptible white spruce is visible in many areas and most current activity in these areas is confined to black spruce and widely scattered residual small white spruce. Within the outbreak area this year, nearly 30,000 acres of black spruce forests were impacted. Numerous field observations over the past few years have confirmed spruce beetle successfully attacking and killing black spruce. Not all black spruce mortality observed in 2021 could be confirmed as being solely caused by spruce beetle. During ground assessments of a small subset of recently killed black spruce, signs of both spruce beetle and northern spruce engraver were observed, with neither being more likely the cause of the mortality than the other. Additional investigation is needed.

In 2021, Region 10 FHP and Alaska Division of Forestry (AKDOF) staff worked with Dr. Christopher Fettig and Dr. Jackson Audley,



Map 29 | All bark beetle damage mapped during aerial detection surveys in 2021.



Map 30 | Cumulative area impacted by the spruce beetle outbreak in Southcentral Alaska 2016-2021.

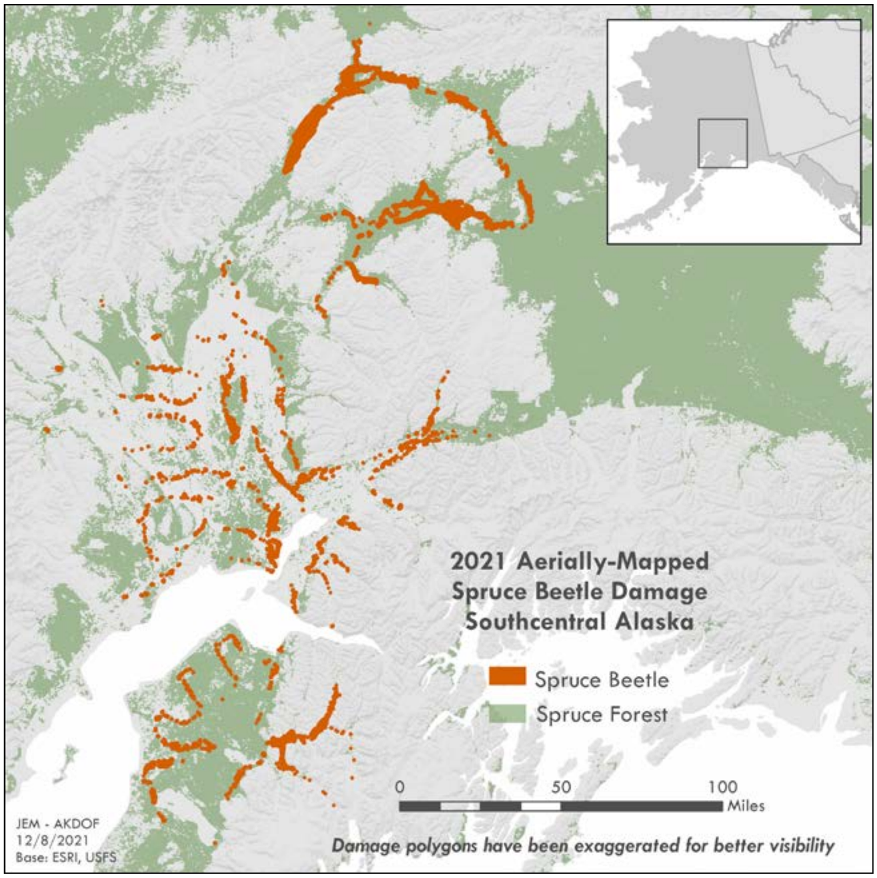
both with the USFS Pacific Southwest Research Station on a new study to continue evaluating SPLAT-MCH (ISCA Technologies Inc) for single tree protection from spruce beetles. This study aims to assess the efficacy of SPLAT-MCH in combination with additional semiochemicals in repelling spruce beetles. The 2021 efforts focused simply on whether different combinations would reduce the number of beetles in traps. Continued efforts in 2022 will evaluate promising combinations applied to trees to determine if they can reduce or eliminate attacks on individual trees.

In 2021, the Alaska Division of Forestry was awarded an Evaluation Monitoring grant to remeasure Cooperative Alaska Forest Inventory plots across Southcentral Alaska. This project is a joint effort between the AKDOF Forest Inventory and Forest Health Programs and will run yearly through 2023. Many of the plots had last been measured just prior to the start of the spruce beetle outbreak. This effort will help determine the severity of the outbreak, the residual forest composition, the volume of timber lost, and assess decay in the dead trees.

The following is a breakdown of spruce beetle conditions throughout the state.

SOUTHCENTRAL (191,000 ACRES)

This area, including all or portions of the Denali, Matanuska-Susitna, and Kenai Peninsula Boroughs, as well as the Municipality of Anchorage, encompasses the ongoing spruce beetle outbreak, now in its sixth year (Map 31). In addition to the current activity observed in 2021, the cumulative outbreak extent for each borough is also noted. The cumulative outbreak acreage includes only those acres directly associated with the outbreak and may not include all spruce beetle activity in a given borough. The affected boroughs in this region are described below from North to South.



Map 31 | Spruce beetle damage mapped in Southcentral Alaska during aerial detection surveys in 2021.

Denali Borough (22,900 acres; 23,700 acres cumulative)

The spruce beetle outbreak was very active in the Cantwell area in 2021, with damage readily observed along the Parks Highway from the borough boundary north around all sides of the Reindeer Hills to approximately mile 225 near Carlo Creek, as well as east along the Nenana River and Denali Highway to where the latter exits the borough. One small clump of about four spruce beetle-killed trees, two of which were actively infested, was mapped on Revine Creek about five miles east of McKinley Village. This marked the only visible spruce beetle activity between Carlo Creek and the Denali National Park entrance.

The northward expansion of the outbreak is being closely monitored through both air and ground surveys. There are many variables that can influence spruce beetle populations and overwintering survival of the beetles, and it is unknown at this time how the outbreak-level population may progress as the beetles encounter more Interior Alaska-type conditions.

Matanuska-Susitna Borough (141,225 acres; 1,359,000 acres cumulative)

As with the portions of the Denali Borough near Cantwell, the outbreak was also very active in the northern portions of the Matanuska-Susitna Borough. Extensive damage was observed in the Chulitna River valley from about Hurricane Gulch north along the Parks Highway to the borough boundary. Current activity was also prevalent along parts of Talkeetna River from its start to the confluence with Iron Creek and along the Susitna River east from Devil's Canyon upstream to the Denali Highway and west along the highway to the borough boundary. Due to weather and fuel constraints, surveyors were unable to survey any farther upstream on the Susitna River, east on the Denali Highway, or southeast into the Copper River valley. These areas will be prioritized for survey in 2022.

ENTOMOLOGY

While the activity observed along the Susitna River near the confluence with the Tyone River is not as extensive at present as other nearby areas, this area lacks any potential terrain-related barrier to eastward expansion of the outbreak if conditions favor such. As noted previously, this will be a high priority area for surveys in 2022.

Elsewhere in the Matanuska-Susitna Borough, scattered activity was observed along the lower Chickaloon River and southwest along the Matanuska River to about Wolverine Creek. Activity was also observed on the north side of the Knik River valley. From Palmer west to the Talachulitna River and north to Talkeetna and along portions of the Talkeetna River, the majority of spruce beetle activity was concentrated in black spruce. These areas represent those that were most severely impacted early in the outbreak.

Municipality of Anchorage (2,275 acres; 30,100 acres cumulative)
The annual aerial detection 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. That was again the case in 2021.

Spruce beetle activity continues to be most damaging in the more northerly portions of the Municipality. Scattered activity was observed along the western front of the Chugach Mountains from the northern edge of the Municipality south to Ship Creek, as well as in the Eklutna, Eagle River, and Ship Creek valleys. Additional activity was mapped on the southeast side of Anchorage from near Campbell Airstrip south along the Anchorage Hillside to Potter Creek. As with 2020 surveys, an area of suspected spruce beetle activity was observed in the Bird Creek valley; surveyors were unable to ground check this location.

Kenai Peninsula Borough (24,500 acres; 195,300 acres cumulative)
Spruce beetle activity increased substantially in the Cooper Landing area and Chugach National Forest in 2021. Within this portion of the peninsula, damage was observed along the Sterling Highway and Kenai River from roughly Jean Lake east and north to about mile 52 of the Seward Highway, just north of Summit Lake. Spruce beetle-caused mortality was also extensive along the Russian River upstream to Upper Russian Lake and along the eastern shore of Skilak lake and southwest along the hills to the Killey River. Scattered activity was also observed along the Seward Highway east of Tern Lake to Upper Trail Lake, and a few very small clumps of activity were noted between Moose Pass and the Snow River valley. Several comparably small pockets of activity were also noted along the Resurrection River, primarily upstream of Exit Glacier.

On the western side of the peninsula, activity was prevalent from the outlet of Skilak Lake west and north to just above Kenai and southwest to the Kasilof River and upriver to Tustumena Lake. Multiple areas of damage were also observed southwest of Tustumena Lake, between the lake and Crooked Creek. While some scattered spruce beetle activity in white/Lutz spruce was observed in the northwestern portion of the Kenai Peninsula, most of the activity in this part of the peninsula was concentrated in black spruce.

INTERIOR (2,650 ACRES)

Small pockets of endemic level spruce beetle damage were observed scattered widely across the Interior, though there were two areas with more concentrated activity. They are described below.

Approximately 81% of the total acres of observed spruce beetle damage in the Interior was scattered along a nearly 40 mile stretch of the Yukon River just southwest of Fort Yukon (2,150 acres) (Figure 59). While this activity doesn't necessarily represent an outbreak at present, it will be closely monitored going forward.

Additionally, light activity was noted in a couple locations southwest of Fairbanks: in the hills south of Goldstream Creek near Minto Flats and along the Tanana River near the village of Minto. An additional area of possible spruce beetle activity was observed within Bonanza Creek Experimental Forest just southeast of the Parks Highway (214 acres); however, root rot is known to be prevalent in this location and it is possible the mapped damage is root rot related. These acres are not included in the total above, and this area will be ground checked in 2022.

Figure 59 | Several small areas of what appeared to be spruce beetle damage were observed between Beaver and Fort Yukon. USDA Forest Service photo by Garret Dubois.

SOUTHEAST

Less than 10 acres of spruce beetle activity were observed in Southeast Alaska during the 2021 aerial detection surveys. The small amount of activity mapped in the region was at a single location near Haines on the western slope of Mt. Villard, just upslope from Chilkoot Inlet.

Northern spruce engraver
Ips perturbatus (Eichhoff)

Less than 10 acres of northern spruce engraver activity were observed during the 2021 aerial detection surveys. During ground surveys and general fieldwork conducted in 2021, however, northern spruce engraver was observed as the probable cause of or at least a contributing factor to the mortality of scattered black spruce in Southcentral. As mentioned in the spruce beetle section above, in several cases where black spruce mortality was investigated, signs of both spruce beetle and northern spruce engraver were observed with neither the more obvious cause of the mortality.

Damage from northern spruce engraver is typically mapped in Interior Alaska along streams and rivers and in areas of natural disturbances such as fire and wind, though it occurs throughout Alaska's boreal forest.

Western balsam bark beetle
Dryoceotes confusus (Swain)

Western balsam bark beetle damage was observed on roughly 90 acres in 2021. The majority of the observed activity was concentrated in the Skagway River drainage near its junction with the White Pass Fork. Two additional small areas of activity were observed in the Taiya River drainage, on the western slope of Mt. Carmack and Mt. Clifford. Western balsam bark beetle attacks subalpine fir, which has a limited distribution in Alaska. As such, even small amounts of affected acreage are notable.

Status of Insects > Urban Pests

URBAN PESTS

Dendroctonus rufipennis (Kirby)
Orgyia antiqua (Linnaeus)
Urocerus flavicornis (Fabricius)
Heterarthrus nemoratus (Fallén)
Profenus thomsoni (Konow)
Gracillaria syringella (Fabricius)

Spruce beetle (*D. rufipennis*) continues to be the most notable damage agent of urban trees in Southcentral Alaska. Requests for spruce beetle identification and prevention information continue. Additionally, there has been an increase in the volume of calls regarding sourcing seedlings and replanting trees after a loss of spruce due to spruce beetle. A detailed update on spruce beetle is available on page 53.

The outbreak of rusty tussock moth (*O. antiqua*) in the Matanuska-Susitna Borough sparked public interest in 2021. Most of the damage was reported from popular recreation areas in the northern portions of the Sustina River valley; however, caterpillars were also reported feeding on urban birch trees, apple trees, and a variety of shrubs and garden vegetables in Willow, Palmer, and Wasilla. A detailed update on rusty tussock moth is available on page 47.

Also of note in 2021 was a high volume of calls from the public regarding the yellow-horned horntail (*U. flavicornis*) (Figure 60), especially from Anchorage. This insect is intimidating in appearance due to its large size and bright coloration but is harmless to humans and aids in the decomposition of dying and recently killed spruce trees. It is unclear whether the increased reports of this insect are due largely to the media hype regarding the Asian giant hornet (which has not been found in Alaska as of the date of this publication) or whether this horntail has become more common in the urban environment due to an abundance of dead and dying spruce caused by spruce beetle.

Figure 60 | An adult yellow-horned horntail lays eggs on a downed log. UAF Cooperative Extension Service photo by Alex Wenninger.

In recent years, birch leafminers (*H. nemoratus, P. thomsoni*) as well as lilac leafminer (*G. syringella*) have been major pests of urban birch and lilac; however, very little damage was reported from urban areas by these agents in 2021.

ENTOMOLOGY

APPENDICES

Late summer view of the Alaska Range from the Richardson Highway. USDA Forest Service photo by Garret Dubois.

Appendix I: Aerial Detection Survey

INTRODUCTION

Aerial detection surveys (ADS) 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, aim to monitor up to 25 million acres of forest annually. Much of the damage acreage referenced in this report was generated by ADS, 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 currently available detects the subtle vegetation damage signatures over large areas as effectively and economically during the short growing season when damage is most evident.

Each year approximately 15-20% of Alaska's 126 million forested acres are surveyed, which equates to approximately 3% of all forested land in the United States. Unlike many regions of the United States, ADS in Alaska does not cover 100% of the forested lands. Preparations for the survey season begin in early spring with the training of personnel and updates to data-collection software and equipment. Planes, pilots, and fuel sources are secured, inspected, and authorized. Finally, flight routes are planned, accommodations are secured for remote flights, and flight requests are submitted to dispatch to ensure effective communication and automatic flight following (AFF). AFF is a GPS based system that allows dispatchers to track the location of aircraft in real time for safety purposes.

Even with excessive planning, surveyors must remain adaptable (Figure 61). Atmospheric conditions change on a daily, sometimes hourly basis. Low clouds, wind, precipitation, wildfire smoke (Figure 62), and poor light conditions all have the potential to reduce damage signature visibility and can create unsafe flying conditions. As a result, flights are often rerouted, and some areas cannot be surveyed due to safety concerns. Additional complications include a short summer season, vast land areas, challenging terrain, and limited time and personnel. Despite these challenges, the forested areas that are surveyed annually are quite large.

One advantage to ADS is that trained observers witness the forest conditions and see foliar damage with their own eyes. The aircraft fly at about 100 knots (115 mph) and 1,000-1,500 feet above ground level. The use of aircraft with floats (Figure 63) allows observers to land on remote waterbodies when practical to inspect tree damage and identify damage agents. While in flight, surveyors can work with pilots to adjust their perspective by observing damage areas from multiple angles and altitudes. 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 known as a "damage signature" and is often pest-specific; for example, silver foliage seen in aspen is almost unmistakably aspen leafminer. Knowledge of the common damage signatures allows trained surveyors to identify the causal pest and to be alerted to new or unusual signatures, such as those that may be caused by uncommon or invasive species.

Figure 61 | Aerial Surveyor Isaac Dell is joined by entomologist Liz Graham (middle) and pathologist Robin Mulvey (left) on Alaska Seaplanes for the first flight of the season to observe damage patterns made by insects and pathogens that they have been seeing on the ground. USDA Forest Service photo by Karen Hutten.

Figure 62 | Whether you are in it or near it, smoke can have a negative impact on safety, visibility and the ability to accurately map damage. USDA Forest Service photo by Garret Dubois.

Figure 63 | Float planes similar to this one operated by Misty Fjords Air are the most used aircraft for aerial detection surveys in Alaska. USDA Forest Service photo by Karen Hutten.

Figure 64 | Damage area polygons are drawn on a digital 1:63,000 USGS quadrangle map. USDA Forest Service photo by Garret Dubois.

Figure 65 | Integrated GPS allows surveyors to see the location of the aircraft on the currently active basemap, whether it be a USGS quadrangle or uploaded satellite imagery. This feature allows for a more accurate placement of damage area polygons. USDA Forest Service photo by Karen Hutten.

Aerial surveyors employ a method known as aerial sketch-mapping to document forest damage observed from the aircraft. When an observer identifies forest damage, a georeferenced polygon (area) or point is drawn with a stylus on a computer touch screen (Figure 64). 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. Today, forest damages are sketched on 1:63,000 scale (1 inch = 1 mile) digital USGS quadrangle maps or satellite 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 (Figure 65) via GPS and has many advantages over paper maps including greater accuracy and resolution in polygon and point 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 ADS data has been collected in Alaska, giving a unique perspective of Alaska's dynamic and changing forests.

Many of the maps in this document are presented at a very small scale, up to 1:6,000,000. Depicting small, damaged areas on a coarse scale map is a challenge. Damaged areas are often depicted with thick borders, so they are visible on the map, 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 time and terrain allow for safe landing and take-off. Due to the nature of ADS, 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 ADS data because these agents are not detectable from an aerial view; separate ground surveys are used to collect this data.

For the most part, surveys in Alaska provide a non-systematic sampling via flight transects. Due to survey priorities, client requests, known outbreaks, and several 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 that data was collected only along the approximately 4-mile visibility corridor of the survey flightline, in which visibility is sometimes affected by ridgelines, clouds, smoke, or sun angle (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 ADS 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 continue to work on development of satellite-based remote sensing methods for Alaska. With ADS in near full operation this year, less time was afforded for additional remote sensing applications compared to last year. Sentinel imagery (20 m spatial resolution) change detection maps were provided by the USFS Geospatial Technology and Applications Center (GTAC) prior to 2021 ADS for flight route planning in Southeast Alaska. However, limited early season imagery resulted in snow and cloud contamination so the change detection maps were not reliable enough for planning. Observations made during ADS improved our understanding of noise versus damage signals and may help with early satellite-image map interpretation next year. End-of-season change detection has alerted us to areas we will prioritize for ADS next year.

Landsat imagery (30 m spatial resolution) change detection methods developed by the Kennedy lab at Oregon State University will be applied during the winter months. These methods successfully detected defoliation damage that occurred in Southeast Alaska in 2018-2020 but were not refined enough to report damage acres. Upon further methodology improvements, we will attempt a complete assessment of the extent of hemlock damage in Southeast Alaska from 2018 to 2021, including recent damage from western blackheaded budworm.

High-resolution imagery (0.5 m spatial resolution) can be useful for closely observing damage in areas that are difficult to access during ADS or ground surveys. High-resolution imagery can also help in identifying areas for inspection and aid in communications about damage seen from the aircraft in current and previous years. This high-resolution imagery was instrumental in our 2020 survey with Scan and Sketch methodology to map tree damage. In the future we would like to find ways to incorporate high-resolution imagery to assess priority areas that are difficult to survey, perhaps in conjunction with satellite-based change detection, though we are currently limited by staff capacity and other obstacles. High-resolution imagery can be difficult or costly to acquire for specific areas and time periods or for extensive areas. It also takes time to acquire, process and inspect the imagery. Follow-up discussions about how to integrate this into our workflow are planned for this winter.

GROUND-TRUTHING

Ground-based verification improves the quality of present and future ADS data. The objective is to verify aerially mapped data, 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.

Timing of ground checks is critical because the physical evidence of many of the insects or pathogens observed is often ephemeral. Ideally, one to two weeks are scheduled for ground checks immediately following ADS. Additional ground checks may be conducted outside of this time frame for some agents or opportunistically incorporated into other fieldwork that is being conducted. However, all ground checks must be completed prior to final reporting. 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 checks 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.

In some situations, a closer view can be achieved from a roadside overlook with the aid of binoculars, while in other instances surveyors may need to 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 66) 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 mission is excellent preparation for ground-truthing.

Figure 66 | Jason Moan and Steve Swenson on a special mission in the Susitna valley to assess unknown defoliation. USDA Forest Service photo by Garret Dubois.

Whereas ground-truthing is generally considered to be conducted by aerial surveyors at the completion of ADS, valuable ground checks are also made during the survey at refueling or lunch stops or when damaged areas are safely accessible (Figure 67). Furthermore, communication between surveyors and entomologists, pathologists, other specialists, and the public, informs surveyors about damage area locations and agents that are active on the landscape.

In 2021 approximately 1% of all mapped ADS polygons were ground checked, this amounts to nearly 10% of the total mapped damage areas being confirmed or updated. Ranger district personnel provided essential eyes on the ground to confirm damage severity and agent for many high priority damaged areas in their districts. Most of the remaining damage patterns were well understood and did not need to be visited on the ground. Many other polygons were too difficult to inspect due to location, weather, or time constraints.

Figure 67 | Andy Greenblatt Andy Greenblatt of Shadow Aviation and Jason Moan on a lunch break near McGrath. Breaks are a good time for opportunistic ground checks. USDA Forest Service photo by Garret Dubois.

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, ADS provides 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/. Other applications available on the Portal include Forest Pest Conditions, Data Summaries, Alien Forest Pest Database, Forest Disturbance Monitor (not available for Alaska), 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 these data in maps and publications.

Appendix II: R10 Ground Detection Survey (GDS) Methodology

DEVELOPMENT

Alaska Forest Health Protection staff began to use mobile ESRI apps in 2013 to conduct annual ground detection surveys (GDS) for both detection and monitoring purposes. Our primary goal was to standardize georeferenced forest health ground observations by using a mobile-friendly, form-based survey. The GDS survey includes more than 160 forest pathogens, insects, and non-infectious damage causing agents (DCA) known to occur in Alaska, as well as options to record symptoms with unknown DCA and negative data at locations that are monitored for change.

A secondary survey goal was to ensure that GDS records collected in Alaska could feed directly into the National Insect and Disease Survey (IDS) database managed by the U.S. Forest Service Forest Health Assessment and Applied Sciences Team (FHAAST). To accomplish this, we used identical DCA codes, host plant codes, and the available damage type (symptom) codes as well as 14 other fields required for IDS. Similarly, we adopted tree and site (surrounding environment) attributes from the Forest Inventory and Analysis Alaska program Field Manuals. In 2020, we implemented protocols to conduct "20-minute timed meander" surveys at regular intervals along roads and trails. The goal is to annually monitor the same areas to record where DCAs both did and did not occur.

Our cumulative ground observations are presented in the Alaska FHP Ground Detection Survey dashboard (an ESRI product), which is available to the public and updated in near real-time. The dashboard includes records collected with Survey123 (2015-present) and the Collector app (2013-2014). It also includes records dating back to 1974 that were entered manually from annual forest health conditions reports, special surveys, and published literature. The dashboard is interactive, and records can be filtered by host, damage agent, survey year, and other attributes.

Survey Types

We developed two survey types within a single survey form to meet different objectives.

Exploratory/Opportunistic observations: Exploratory surveys can take place anywhere in Alaska at any time of the year and damage is recorded anywhere it is detected. During special project surveys concerning specific DCAs, the exploratory survey is used to record each DCA present at the site, including those not the focus of the special survey. This ensures that all observed agents are incorporated in the ground survey database.

20-Minute Timed Meander Surveys: Timed meanders are generally conducted by revisiting locations across Alaska to monitor change. The 20 minutes is split between the number of surveyors; for example, two forest health specialists would survey simultaneously for 10 minutes. All records from a timed meander are located within a roughly 1/10th acre area. Each record is represented by its own GPS coordinates. Damage information is collected for each host tree species present, including negative data when no damage is detected on a host species present at the site. Negative data is important to monitor incidence and severity of damage agents on each host species. The distance between scheduled survey locations varies by region based on the size of the road system, while restricting surveys to public lands and rights-of-way. In Southcentral and Interior Alaska, survey sites are scheduled every 20 miles on highways and byways and every five miles along local roads. In Southeast, survey sites are scheduled every five miles on the road system. On trails, survey sites occur at the trailhead and approximately every mile for no more than five miles of trail. In all regions, damage observed between meander sites are recorded as exploratory/opportunistic observations.

SCHEMA

Location

Survey Type (Required)

Selectable choice list: Exploratory/Opportunistic Observation or 20-Minute Timed-Meander

GPS Point (Required)

Automatically populated, optimal accuracy within 10 m.

Agent and Host

Damage Agent Category (Required to filter large DCA list)

Selectable choice list: Disease, Insect, Abiotic, Non-infectious or Unknown, or None (to record lack of damages for timed meanders)

Damage Causing Agent (Required core field)

Selectable choice list of 167 Alaska relevant damage causing agents (DCA). Selected choice automatically populates the core IDS field DCA_CODE from a lookup table of FHAAST DCA codes.

Host Tree or Host Tree Group (Required core fields)

Selectable choice list of 53 Alaska relevant hosts. Selected choice automatically populates the core IDS fields HOST_CODE and HOST_GROUP_CODE from a lookup table of FHAAST codes.

Size Class (Optional)

Selectable choice list of classification based on tree diameter: Seedling (<2" DBH), Sapling (2-4" DBH), Poletimber (4-10" DBH), Small sawtimber (10-15" DBH), Large sawtimber (>15" DBH), or Shrub. If more than one tree is affected, estimate the average stand diameter.

Damage Symptoms

First Damage Type (Required core field)

Selectable choice list of 33 symptoms seen on different tree parts (e.g., bark/cambium damage, bud damage, defoliation, crown dieback, decay, gall, open wound, etc.). First damage type should be the one with the most impact. Selected choice automatically populates the core IDS fields DAMAGE_TYPE_CODE from a lookup table of FHAAST codes. However, only 14 FHAAST damage type codes are available, therefore many records will use the code for "Other damage, known". For example, the code for "Other damage, known" must be used for both canker diseases and bark beetles because there is no code for bark/cambium damage. IDS damage codes for defoliation are combined with severity, therefore it requires a manual cross-walk with the "Within Tree Damage Severity" field.

Second Damage Type (Optional)

Same choice list as above. Individual damage agents often cause more than one damage type, for example bud damage, which can lead to deformed growth and mortality.

Third Damage Type (Optional)

Same choice list as above. Individual damage agents often cause more than one damage type, for example bud damage, which can lead to deformed growth and mortality.

Damage Severity

Number of Damaged/Affected Trees (Required core field)

Selectable choice list of 5 classes for the number of affected trees: 1, 2-5, 6-15, 16-30, and >30. Automatically populates the IDS field NUMBER_OF_TREES_CODE.

Within Tree Damage Severity (Required)

Selectable choice list of 6 severity classes for first damage type: Trace to 5%, 6-35%, 36-50%, 51-67%, 68-75%, 75-100%. Severity assessment depends on the damage type selected. For defoliating agents, within tree severity is the percentage of leaves affected. For stem canker, severity is the percent of stem circumference affected. For bud blights, severity is the percent of buds affected. For evidence of decay on the tree bole or roots, the highest rating is assigned (75-100%).

Surrounding Forest Environment

Definitions and classes for land cover, forest type, and canopy cover were adopted from the Forest Inventory and Analysis Alaska program Field Manuals.

Land Cover (Optional)

Selectable choice list of 20 FIA descriptions of site cover such as: developed, forest, shrubland, herbaceous, planted, wetland, non-natural. Sub-categories further describe vegetation composition and structure.

Forest Type (Optional)

Selectable choice list of 16 FIA forest type classes defined as the species with the plurality of stocking for all live trees that are not overtopped (i.e., the dominant tree species).

Canopy Cover (Optional)

Selectable choice list of 5 FIA canopy cover classes: Closed forest (60-100% canopy cover), Open forest (25-60% canopy cover), Woodland (10-25% canopy cover), Scrub (at least 10% cover of dwarf trees less than 10 ft tall), Non-forest (less than 10% tree cover).

Diagnostics

Specimen Collected (Optional)

Yes/No choice list. If a sample is collected the sample ID is automatically created based on the date, time, and surveyor.

Photos (Required)

If damage is found, one photo is required to be used for identification or verification purposes. Multiple photos can be collected per record.

Comment (Optional)

Hidden fields

Other core fields specifically for IDS and automatically populated

SURVEY_YEAR, AREA, CREATED_DATE, MODIFIED_DATE, REGION_ID, US_AREA, IDS_DATA_SOURCE, ACRES

Other fields for IDS and automatically populated with special usage

NOTES (unique identifying number), PROJECT_NAME (GDS), PROJECT_LINK (website for project)

Automatically created by Survey123

CreationDate, Creator, EditDate, Editor, ObjectID, GlobalID

CONTACT

Dr. Lori Winton, R10 FHP Pathologist,
loretta.winton@usda.gov

Dr. Karen Hutten, R10 ADS Program Manager,
karen.hutten@usda.gov

Appendix III: Damage Type by Category

APPENDIX III

Abiotic
Drought
Flooding
Landslide/avalanche
Western redcedar topkill
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
Rusty tussock moth
Speckled green fruitworm

Hemlock Defoliation
Hemlock looper
Hemlock sawfly
Western blackheaded budworm

Hemlock Mortality
Hemlock canker
Hemlock mortality
Hemlock sawfly 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
Western blackheaded budworm
Conifer defoliation

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

Appendix IV: Information Delivery

INTERNET AND SOCIAL MEDIA:

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

Forest Health Conditions Reports, ADS Damage Maps and Story Maps: http://www.fs.usda.gov/goto/ForestHealthReports

Forest Health Highlights 2021 Story Map: https://arcg.is/vWmnS

Alaska Forest Health Protection Aerial Detection Survey Interactive Map 2021: https://usfs.maps.arcgis.com/apps/webappviewer/index.html?id=4d7f29990485484ba3dea6222e4ec3bc

Ground Survey Map Dashboard: https://arcg.is/1SH58a

Western Blackheaded Budworm Outbreak Outreach Video: https://vimeo.com/584107779

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

Facebook: https://www.facebook.com/AKForestService/; https://www.facebook.com/ChugachNF/; https://www.facebook.com/TongassNF/

Twitter: @AKForestService; @ChugachForestAK; @TongassNF; #AlaskaForestHealth, #AlaskaSpruceBeetle

Alaska Forest Health Highlights 2020 Story Map- released early Feb 2021. https://arcg.is/05nLLS

MEDIA:

Alaska Magazine https://alaskamagazine.com/authentic-alaska/wildlife-nature/how-spruce-beetles-are-changing-forests-in-alaska/

Homer News (reprint of Juneau Empire) https://www.homernews.com/news/find-out-more-about-the-very-hungry-caterpillars-munching-on-southeast-alaskas-hemlock-trees/

Juneau Empire https://www.juneauempire.com/news/find-out-more-about-the-very-hungry-caterpillars-devouring-southeast-alaskas-trees/

KCAW https://www.kcaw.org/tag/elizabeth-graham/

KINY https://www.kinyradio.com/news/news-of-the-north/bud-worms-defoliate-southeasts-hemlock/

KINY/KJNO Action Line. https://www.kinyradio.com/podcasts/action-line/episode/action-line-4-1-21/

KTOO http://www.ktoo.org/2021/08/13/warmer-summers-fuel-western-blackheaded-budworm-infestation-of-southeast-hemlocks/

Sitka Nature Show https://www.sitkanature.org/photojournal/2021/08/15/sitka-nature-show-243-elizabeth-graham/

PUBLICATIONS:

Graham E. E. 2021. Hemlock Sawfly Forest Insect and Disease Leaflet 31. FS-1181 October 2021 (revised).

Hennon, P. E., S. J. Frankel, A. J. Woods, J. J. Worrall, T. D. Ramsfield, P. J. Zambino, D. C. Shaw, G. Ritó ková, M. V. Warwell, D. Norlander, R. L. Mulvey, G. C. Shaw III. 2021. Applications of a conceptual framework to assess climate controls of forest tree diseases. Forest Pathology, 00e1-25. https://doi.org/10.1111/efp.12719.

Mafra-Neto, A., M. Wright, C. Fettig, R. Progar, S. Munson, D. Blackford, J. Moan, E. Graham, G. Foote, R. Borges, R. Silva, R. Lake, C. Bernardi, J. Saroli, S. Clarke, J. Meeker, J. Nowak, A. Agnello, X. Martini, M. Rivera and L. Stelinski. 2021. Chapter 15: Repellent semiochemical solutions to mitigate the impacts of global climate change on arthropod pests. In Advances in Arthropod Repellents, Eds. C. Corona, M. Debboun and J. Coats. (pp.279-322).

APPENDIX IV

Ruess R. W., L. M. Winton and G. C. Adams. 2021. Widespread mortality of trembling aspen (Populus tremuloides) throughout Interior Alaskan boreal forests resulting from a novel canker disease. PLOS ONE 16(6): e0253996. doi.org/10.1371/journal.pone.0253996.

Winton L. M., G. C. Adams and R. W. Ruess. 2021. Determining the novel pathogen Neodothiora populina as the causal agent of the aspen running canker disease in Alaska. Canadian Journal of Plant Pathology doi.org/10.1080/07060661.2021.1952487.

PRESENTATIONS:

Brannoch, S. K. Using iNaturalist to augment forest insect and disease observations in Alaska. Forest Health Monitoring Workshop. February 23, 2021. Oral Presentation.

Brannoch, S. K. Crowd sourcing data: How the U.S. Forest Service is using iNaturalist and other social media platforms to collect forest health observations across Alaska. Southeast Alaska Discover Center Friday Night Insight program. May 7, 2021. Oral Presentation.

Brannoch, S. K. Interior Alaska FIA DOF Crew Training: Guidance on recording and reporting insect-related forest damage. Interior, AK Forest Inventory Analysis Training. May 14, 2021. Oral Presentation.

Brannoch, S. K. Crowd sourcing data: How the U.S. Forest Service is using iNaturalist as a citizen science platform. TA Office Hours. August 12, 2021. Oral Presentation.

Brannoch, S. K., G. D. Dubois and L. M. Winton. Forest Health Outreach Session. McKinley Village Community Center. August 2, 2021. Oral Presentation.

Charnon, B. H. Invasive Plants in Southeast Alaska. Friday Night Insight Lecture Series, Southeast Alaska Discover Center, May 28, 2021. Oral Presentation

Graham E. E. Forest Pests in Southeast Alaska: rise of a familiar foe and new players advancing their range. Friday Night Insight Lecture Series, Southeast Alaska Discovery Center, May 2021. Oral Presentation.

Graham E. E. Western Blackheaded Budworm: a tiny moth orchestrating change in an old growth forest. Evening at Egen Lecture Series, University of Alaska Southeast. September 2021. Oral Presentation.

Graham E. E. Western Blackheaded Budworm: a tiny moth orchestrating change in an old growth forest. Alaska Wildlife Alliance Lecture Series, October 2021. Oral Presentation.

Graham E. E. and K. Hutten. Hemlock sawfly in Southeast Alaska: using an interdisciplinary approach to monitor a large-scale defoliation event. Alaska Entomological Society Meeting. January 2021. Oral Presentation.

Hutten K. and E. E. Graham. From satellite imagery to ground surveys: challenges and successes of describing a major defoliation event in Southeast Alaska. Western North American Defoliator Working Group Meeting. October 2021. Oral Presentation.

Moan, M. J. Spruce aphids on the Kenai Peninsula. Kenai Peninsula Cooperative Invasive Species Management Area Workshop. April 14, 2021. Oral Presentation.

Moan, M. J. 2021 Spruce beetle updates. Chugach National Forest All Anchorage Meeting. May 26, 2021. Oral Presentation.

Mulvey, R. L. Yellow-Cedar Planting Sites on Prince of Wales 2020. Alaska Region Silviculture Meeting. April 14, 2021. Oral Presentation.

Mulvey, R. L. Invasive Forest pathogens of North America: Learning from the past may hold the key to maintaining Alaska's healthy forests. Southeast Alaska Discovery Center Friday Night Insight Series. May 21, 2021. Oral Presentation.

Mulvey, R. and M. Simonson. Tracking western redcedar topkill, dieback & mortality in Southeast Alaska, Tongass Silviculture Meeting. August 10, 2021. Oral Presentation.

Peralta S. M., N. Gambhir, G. Adams, L. Winton, K. Cerny, and S. Everhart. Gemmamyces piceae causing bud blight disease of spruce in Alaska is different from European populations. Botanical Society of America Annual Meeting. July 21, 2021. Poster presentation.

Ruess R. W., L. M. Winton, and G. C. Adams. Widespread aspen mortality throughout interior Alaska resulting from a novel canker pathogen, International Boreal Forest Research Association. August 17, 2021. Oral presentation.

Winton L. M. Spruce bud blight(s) in Alaska. Forest Health Monitoring Workshop. February 23, 2021. Oral presentation.

Winton L. M. Hazard Tree risk assessment. Chugach National Forest Training. May 6, 2021. Oral Presentation.

Winton L. M. FIA Training for Interior Alaska. Interior Alaska Forest Inventory & Analysis Training. May 14, 2021. Oral Presentation.

Winton L. M. Climate change and forest diseases on the Chugach National Forest. Climate Change Vulnerability Assessment and Adaptation for the Chugach National Forest Workshop. November 4, 2020. Oral presentation.

Winton L. M., G. C. Adams and R. W. Ruess. Detecting and Monitoring Boreal Forest Pathogens: Landscape Pathology to the American Phytopathological Society Pacific Division annual meeting. June 16, 2021. Invited Speaker. Oral Presentation.

Winton L. M., G. C. Adams, and R. W. Ruess. Aspen Running Canker in the context of drought in Alaska. Western International Forest Disease Work Conference. June 25, 2021. Oral presentation.

TRIP REPORTS AND PROJECT UPDATES:

Charnon, B. H. Seldovia Village Tribe Reed Canarygrass and other Invasive Plants Field Visit and Control Recommendations. R10S&PF-FHP- Trip Report, August 11, 2021.

Dubois, G. D. Spruce aphid along the Parks Highway south of Anderson- General Observation. R10S&PF-FHP-Trip Report, September 29, 2021.

Dubois, G. D. Heterarthrus nemoratus observed in Bethel Alaska- General Observation. R10S&PF-FHP-Trip Report, September 30, 2021.

Gilchrist, E. Southcentral spruce beetle season trap report. September 27, 2021.

Graham E. E. and I. Dell. Western tent caterpillar survey. R10-S&PF-FHP-Trip Report. June 2021.

Swenson, S. Birch leafminer assessments for Southcentral Alaska. September 15, 2021.

Swenson, S. Autumn survey of Copper River Valley. R10-S&PF-FHP-Trip Report. September 15, 2021.