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A Forest Health Protection Report

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Forest Health Conditions in Alaska–2006

Protection Report R10-PR-11

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Introduction

This report reviews our current knowledge of forest health in Alaska. Its purpose is to help resource professionals, land managers, and other decision makers identify and monitor existing and potential forest health risks and hazards. The information in this report was generated as a combined effort with our many cooperators, partners, and other stakeholders, especially the staff of the State of Alaska, Department of Natural Resources, Division of Forestry and the University of Alaska, Cooperative Extension Service. The report is based on data collected in annual aerial detection surveys, ground surveys, permanent plot monitoring efforts, follow-ups to public requests and input, and early detection work.

Emphasis is given to damaging agents observed in 2006. Readers need to be mindful that this is not a complete survey of the over 127 million forested acres in Alaska. Aerial detection mapping data in particular are generally not taken by the same observer or from the same location each year and therefore any interpretation of trends should only be made in general terms—consult our staff if you have any questions about the source, collection protocols, or precision of the representations made in this report.

This report is organized around the status of four categories of damaging agents: insect pests, diseases and declines, abiotic agents and animal damage, and invasive plants. Each category is then structured by the extent of the individual agent's impact. Where acreage extent is not known, our staff has estimated the relative extent of these agents. Several topic areas and appendices that were covered in previous Conditions Reports (i.e., the role of disturbance in ecosystem management, submitting specimens for identification, integrated pest management, world wide web resources, and USGS quad maps showing forest damage from the 2006 aerial detection survey) are not included here, but can be found at our website http//:www.fs.fed.us/r10/spf/fhp. In the place of the appendices, we have added two sections describing our contributions in providing current information about forest health issues in Alaska and some of the various cooperative projects we help fund around the state. We have also added three focus sections as text boxes within this report to spotlight especially important and/or emerging issues pertaining to the health of Alaska forests.

The Challenge of Mapping Forest Disturbances in Alaska

The State of Alaska covers a total area of 571,951 square miles, which is more than twice the size of Texas. Since only a small percentage of this area is accessible by roads, surveying this area is a monumental task, and only limited portions of the state can be assessed during any one year.

The numerous insect pests, pathogens, and invasive plant species occurring in Alaska's forests vary in extent and the amount of damage they cause from year to year. Collecting data useful for assessing any of these disturbance agents is a significant challenge. Aerial detection surveys have traditionally been the primary tool for collecting these data. Since most of the pest distribution descriptions that follow are based on aerial surveys, and many readers may be unfamiliar with this activity, it would be useful to take a closer look at the strengths and limitations of the survey procedures we use.

State & Private Forestry, Forest Health Protection (FHP) together with Alaska Department of Natural Resources (DNR) conduct annual statewide aerial detection surveys on all land ownerships. Aerial surveys are an effective and economical means of monitoring and mapping insect, disease, and other forest disturbance at a coarse level. In Alaska, we monitor 30–40 million acres annually at a cost of less than ½ cent per acre.

Aerial detection surveys, also known as "aerial sketch-mapping," is a remote sensing technique for observing forest change events from an aircraft and documenting those events manually onto a map base. When an observer identifies an area of forest damage, a polygon or point will be marked on a paper or electronic map. Trained observers are able to recognize and associate damage patterns, discoloration, tree species and other subtle clues that distinguish a particular type of forest damage from the surrounding, healthier forest areas. These clues serve as damage "signatures," which are often pest specific. Aerial sketch-mapping could perhaps be considered "real time photo interpretation" with the added challenge of transferring the spatial information from a remote landscape view to a map or base image. Sketch-mapping offers the added benefit of adjusting the observer's perspective to study a signature from multiple angles and altitudes. However, a mapper's abilities are challenged by time limitations and other external factors. Survey aircraft typically fly at 100 knots and atmospheric conditions are variable.

Figure 1. *Angie Ambourn, biological technician in the Fairbanks field office, digitizing observed damage during aerial survey operations.*

During aerial surveys, forest damage information has traditionally been sketched on 1:250,000 scale USGS quadrangle maps, a relatively small-scale. At this scale one inch would equal approximately four miles distance on the ground. Larger scale maps are sometimes used for specific areas to provide more detailed assessments. A digital sketch-mapping system has been used in recent years in place of paper maps for recording the forest damage. This system displays the mapper's location via GPS input and allows the observer to zoom to various display scales. The digital sketch map system allows more accurate and more resolute damage polygon placement plus a shorter turnaround time for processing and reporting data.

Due to the nature of aerial surveys, the data collected provides only estimates of location and intensity for damage that is detectable from the air. Sketch-mapping is considered an art as much as a science. No two mappers will interpret and record an outbreak or pest signature in the same way but the essence of the event should be captured. While some data is ground checked, most of it is not. Because most of Alaska's rugged, unroaded terrain is largely inaccessible, often the only opportunity to verify the data on the ground is during the survey missions when there is an option to land and examine the affected foliage. Many of the most destructive diseases are not represented in aerial survey data because these agents are not detectable from an aerial view.

The surveys we conduct provide only a sampling of the forests via flight transects. Unlike many other areas in the United States, full 100 percent coverage of forested lands in Alaska is not possible. The short Alaska summers, vast area, high airplane rental costs, and short windows of time when pest damage signs and tree symptoms are most evident all require a strategy to efficiently cover the highest priority areas with available resources. Each year we survey approximately 25 percent of Alaska's 127 million forested acres. Due to survey priorities, client requests, known outbreaks, and a number of logistical challenges some areas are rarely or never surveyed while other areas are surveyed annually. We are careful to avoid extrapolating conditions of surveyed acres to those not surveyed. The reported data should only be used as a partial indicator of insect and disease activity for a given year. Establishing trends from aerial survey data is possible, but care must be taken to ensure that projections are comparing the same areas and sources of variability are considered.

While there are limitations to data collected in aerial surveys, no other method is currently available to detect subtle differences in vegetation damage signatures caused by the various forest disturbances occurring in this state within a narrow temporal window and at such low costs. Region 10 Forest Health Protection is currently working with the Pacific Northwest Research Station and various university cooperators to develop improved survey procedures based on satellite imagery and spatial modeling.

Dustin Wittwer

Figure 2. *Much of Alaska has no road access making aerial surveys a vital part of the mission of Forest Health Protection.*

Alaska Forest Health Highlights

2006 Survey Year

Aerial detection mapping is an indispensable tool in documenting the location and extent of active forest insect and disease damage. In 2006, staff and cooperators identified over 841,278 acres of forest damage from insects, disease, declines, and select abiotic agents (Table 1) out of nearly 33 million acres surveyed (Map 2). Additional information regarding forest health provided by ground surveys and monitoring efforts is also included in the report, complimenting the broad-scope aerial survey findings.

Table 1. 2006 forest insect and disease activity as detected during aerial surveys in Alaska[1,5]

Damage Agent[2]	National Forest	Native Corp.	Other Federal	State & Private	Total Acres
Alder defoliation[3]	112	1,743	697	8,111	10,663
Aspen defoliation[3]		5,614	10,526	1,087	17,228
Aspen leaf miner		101,507	101,611	254,764	457,882
Birch defoliation[3]			785	904	1,689
Birch leaf roller		2,849	279	459	3,588
Black-headed budworm	1,267	161		35	1,463
Cedar decline faders[4]	30,146	394	54	1,632	32,226
Cottonwood defoliation[3]	3	8,209	5,193	11,214	24,618
IPS and spruce beetle		1,945	256	1,099	3,300
Engraver beetle	102	4,502	1,843	1,205	7,653
Larch sawfly		33	145	2,488	2,666
Large aspen tortrix		3,335	5,329	25,766	34,431
Spear-marked black moth		2,348	2,987	2,611	7,946
Spruce aphid	3,568	1,575	345	3,632	9,120
Spruce beetle	3,145	5,526	79,765	31,174	119,610
Spruce budworm		1,449	896	50,834	53,178
Spruce/Larch budmoth		2,391		403	2,793
Subalpine fir beetle	87		35	375	498
Willow defoliation[3]	10	27,017	18,367	5,333	50,726

[1] Ownership derived from 2006 version of Land Status GIS coverage, State of Alaska, DNR/Land records Information Section. State & private lands include: state patented, tentatively approved, or other state acquired lands, and of patented disposed federal lands, municipal, or other private parcels.

[2] Acre values are only relative to survey transects and do not represent the total possible area affected. Table entries do not include many of the most destructive diseases (e.g., wood decays and dwarf mistletoe) which are not detectable in aerial surveys. Damage acres from animals and abiotic agents are also not shown in this table.

[3] Significant contributors include leaf miners and leaf rollers for the respective host. Drought stress also directly caused reduced foliation or premature foliage loss.

[4] Acres represent only spots where current faders were noticed. Cumulative cedar decline acres can be found in Table 10.

[5] All values are in acres.

Forest Health Protection staff also continually work alongside many agency partners on invasive plant issues, including roadside and high-impact area surveys, public awareness campaigns, and general education efforts. Trends this year indicate both ongoing range expansion of established invasives and new species establishment in Alaska. However, public familiarity and agency participation in addressing the issue continue to increase.

Insects

Hardwood defoliators continued to be the most significant functional group of insect pests in 2006. The most noteworthy is the **amber-marked birch leaf miner**, an invasive pest from Europe. This insect affected urban areas and some native forests throughout much of south-central and interior Alaska. Although not detected aerially in 2006, road surveys identified amber-marked birch leaf miner damage along nearly 20 percent of the road system between Livengood, the Canadian border, and the Susitna River. The biological control program initiated in 2003, continued in 2006 with new partners from the University of Massachusetts, Amherst. Monitoring efforts have been unable to show that the parasitoid has yet established at the release sites. The largest outbreak of **aspen leaf miner** on record in Alaska appears to be in decline possibly due to a disease affecting the insects. Activity mapped statewide was 30 percent less than in 2005 with lighter intensity in the center of recorded polygons. In 2006, over 34,000 acres of **large aspen tortrix** defoliation were identified. The majority of the statewide tortrix activity, 80 percent, was mapped in the central interior, nearly all concentrated in the Japan Hills, 70 miles south of Fairbanks.

Nearly 24,000 acres of **willow leaf blotch miner** activity were recorded during the 2006 aerial surveys. This is the 14^{th} year in a row that this insect has been observed—a period associated with large fluctuations of leaf blotch severity. After six years of steadily increasing populations, **Sunira** in Katmai National Park appears to be on the decline. Not quite 14,000 acres of defoliation by this insect were observed during the 2006 aerial surveys, representing a 38 percent drop in activity from the previous year.

Alder defoliation mapped by aerial observers in 2006 exceeded 7,000 acres statewide. A suite of insects are associated with alder defoliation in Alaska, the most significant is the **woolly alder sawfly**, a European invasive that is well established throughout the northern U.S. and Canada. Since the discovery of the **European yellow underwing** in Haines, Juneau, and St. Lazaria Island (near Sitka), last year, this non-native moth has spread throughout southeast Alaska as well as north and west to Anchorage in 2006. Based on the rapid movement of this species, it is likely to be found in the Mat–Su valley in the next year and will likely be in Fairbanks within three years.

Only 3,500 acres of **birch leaf roller** activity were observed during the survey this year. This represents a 46 percent decline from 2005 levels. However, low-level leaf roller populations are often difficult to ascertain during aerial surveys, and it is quite likely that the current cycle of leaf roller activity is considerably more extensive than it appears to be from the air. A substantial amount of leaf roller activity was observed at ground level as casual observations in Anchorage and on the Kenai Peninsula.

Spruce aphid defoliation in southeast Alaska occurred on approximately 9,000 acres scattered throughout southeast Alaska. The current outbreak started in 1998, the worst year was in 2003 when defoliation occurred on 30,627 acres and was distributed over more of the area surveyed than in the previous five years. In 2006, four low temperature events occurred in southeast Alaska, temperatures below -15 °C killed 94 percent of the aphids in March 2006.

Spruce budworm was mapped on 53,000 acres of the Interior, concentrated along the hills and ridges around Fairbanks. Ground surveys indicate that populations are still expanding and that the outbreak will continue to intensify.

Western black-headed budworm populations are currently at endemic levels, with approximately 1,400 acres of defoliation mapped in Prince William Sound and southeast Alaska for the past three years.

Larch sawfly defoliation decreased to just over 2,500 acres in 2006. Nearly all of the defoliation occurred on Minto Flats west of Fairbanks. Smaller infestations were also noted east of McGrath where larch sawfly has been very active for a number of years. In 2006, a special aerial survey was initiated to document the extent of healthy stands of larch in Alaska.

Spruce beetle activity in Alaska has increased for the third time in the past five years. A total of 119,610 acres were mapped in 2006, an increase of 68 percent since 2005. Katmai National Park has the most intense spruce beetle outbreak in the state. Populations at Katmai increased 300 percent since last year. Nearly 70,000 acres of mature spruce, primarily at the west end of Naknek Lake and Lake Brooks, are currently under attack. Intense beetle activity has occurred over the past 10 years in the Iliamna area to the south and the Lake Clark Pass area to the east. Throughout this period, beetle populations in the vast, mature, susceptible spruce stands around Lake Clark have remained at endemic levels. If conditions become favorable for an outbreak of spruce beetle, the forests around Lake Clark are capable of sustaining widespread activity for a number of years to come. On the Kenai Peninsula, spruce beetle activity has doubled over the last year, increasing to over 10,000 acres. In addition to beetles moving into previously uninfested stands, trees too young and too small in stands infested earlier are now mature and large enough to be susceptible. The most active spruce beetle infestations on the Kenai Peninsula are in the Kenai National Wildlife Refuge north and east of Nikiski, the Point Possession–Chickaloon Bay area, and the Six Mile River Valley, and west shore of Turnagain Arm. Populations near the Kuskokwim River and in the Anchorage/Mat–Su areas and in southeast Alaska have remained at earlier endemic levels.

Aerial surveys in 2006 identified 7,653 acres of **engraver beetle** damage statewide. When combined with the figures for engraver–spruce beetle damage (both pests active in the same stand) the total exceeds 10,000 acres. Although there was engraver activity reported on the Kenai Peninsula this year in the Granite Creek area of the Chugach National Forest, it remains primarily a pest of interior spruce forests.

Western balsam bark beetle has moved down the Taiya Inlet and was causing mortality 1.5 kilometers south of Skagway in 2006. Mortality throughout the outbreak occurred on 498 acres in 2006.

Diseases

The most important chronic diseases and declines of Alaskan forests in 2006 were wood decay and **root rot** of live trees, **hemlock dwarf mistletoe**, and **yellow-cedar decline**. Except for yellow-cedar decline, trees affected by these diseases are difficult to detect by aerial surveys. Nonetheless, all diseases and declines are chronic factors that significantly influence the commercial value of timber resources and alter key ecological processes such as forest structure, composition, nutrient cycling, and succession.

In southeast Alaska, approximately one-third of the gross volume of forests is defective due to **stem and butt rot fungi**. Hemlock dwarf mistletoe continues to cause growth loss, top-kill, and mortality, but also provides wildlife habitat in old-growth forests.

Yellow-cedar decline has been mapped on approximately 500,000 acres across an extensive portion of southeast Alaska. Active tree mortality occurred in many of these locations in 2006, indicating an intensification of the problem on previously impacted acres. Although still not completely understood, the cause appears to be related to spring freezing injury in open canopy forests characterized by reduced snowpack.

Table 2. Affected area (in thousands of acres) for each host group and damage type over the prior five years and a 10-year cumulative sum

Host Group/ Damage Type[1]	2001	2002	2003	2004	2005	2006	Ten Year Cumulative[2]
Alder defoliation[3]	1.2	1.8	2.8	10.5	17.3	10.6	49.9
Aspen defoliation	9.4	301.9	351.4	591.5	678.9	509.5	2,243.6
Birch defoliation	3.2	83	217.5	163.9	47.5	13.2	454.1
Cottonwood defoliation	9.9	19.9	13.1	16.7	8.0	24.6	106.9
Hemlock defoliation	1.3	1.4	0.2	0.5	0.2	0.0	20.9
Hemlock mortality	0.1	0.2	0	0.0	0.1	0.0	0.6
Larch defoliation	17.8	0	0.6	14.2	16.8	2.7	1,290.8
Larch mortality	0.0	4.8	22.5	11.8	0.0	0.0	69.6
Spruce defoliation	61.1	11	61.5	93.4	31.9	68.1	699.7
Spruce mortality	104.2	53.6	92.8	145.2	93.8	130.6	2,080.8
Spruce/Hemlock defoliation	50.7	3.4	15.1	1.5	1.4	1.5	72.5
Spruce/Larch Defoliation	0.0	0.0	0.3	0.0	0.3	2.8	3.8
Subalpine fir mortality	0.1	0.2	0.0	0.2	0.8	0.5	1.6
Willow defoliation	10.9	0.3	83.9	111.2	44.5	50.7	641.7
Total damage acres	**269.9**	**481.5**	**861.7**	**1,160.5**	**941.5**	**814.8**	**7,736.50**
Total acres surveyed	22,296	24,001	25,588	36,343	39,206	32,991	
Percent of acres surveyed showing damage	1.2	2.0	3.4	3.2	2.4	2.5	

[1] Summaries identify damage, mostly from insect agents. Foliar disease agents contribute to the spruce defoliation and hemlock mortality totals. Damage agents such as fire, wind, flooding, slides and animal damage are not included. Cedar mortality is summarized in Table 10. Acres reported in thousands of acres.
[2] The same stand can have active infestation for several years. The cumulative total is a union of all areas from 1996 through 2006 and does not double count acres.
[3] This total includes defoliation on alder from alder canker, drought and insects.

Cone and other foliar diseases of conifers were generally at low levels throughout Alaska in 2006. A stem/branch **canker pathogen of alder**, continues to infect thin-leaf alder in riparian areas across thousands of acres in south-central and interior Alaska. **Canker fungi on conifers**, particularly on Sitka spruce and subalpine fir, occurred at higher than normal levels and caused branch dieback in southeast Alaska. **Canker fungi of hardwoods** were at endemic levels in south-central and interior Alaska.

In south-central and interior Alaska, **tomentosus root rot** continues to cause growth loss and mortality of white spruce in all age classes. Various stem and butt rot fungi cause considerable defect in mature white spruce, paper birch, and aspen stands.

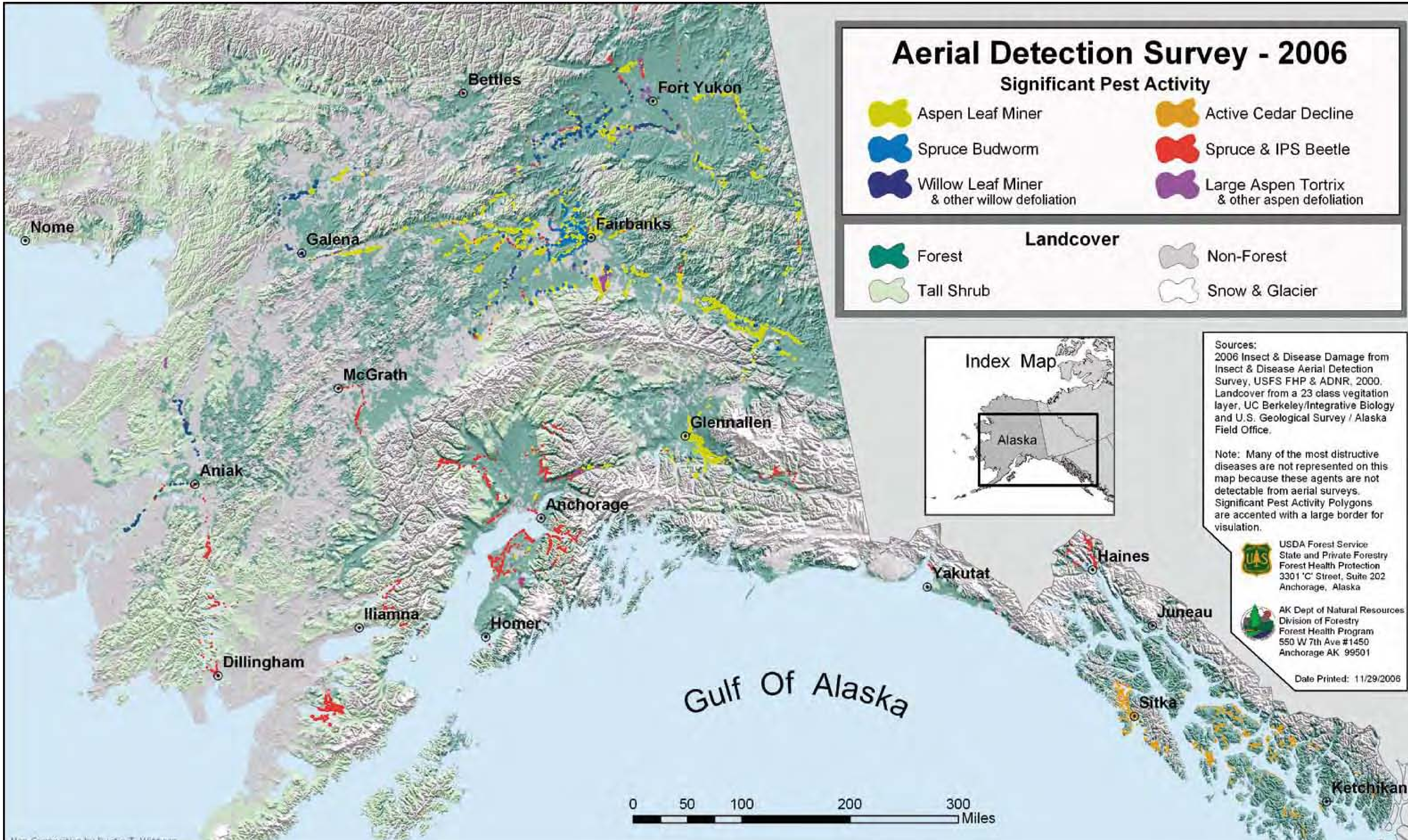
Saprophytic decay continues to degrade spruce beetle-killed trees. A deterioration study on Kenai Peninsula indicated a relatively slow overall decomposition rate (1.5 percent/year). Thus, beetle-killed trees are likely to influence fire behavior and present a hazard for over 75 years.

Invasive Plants

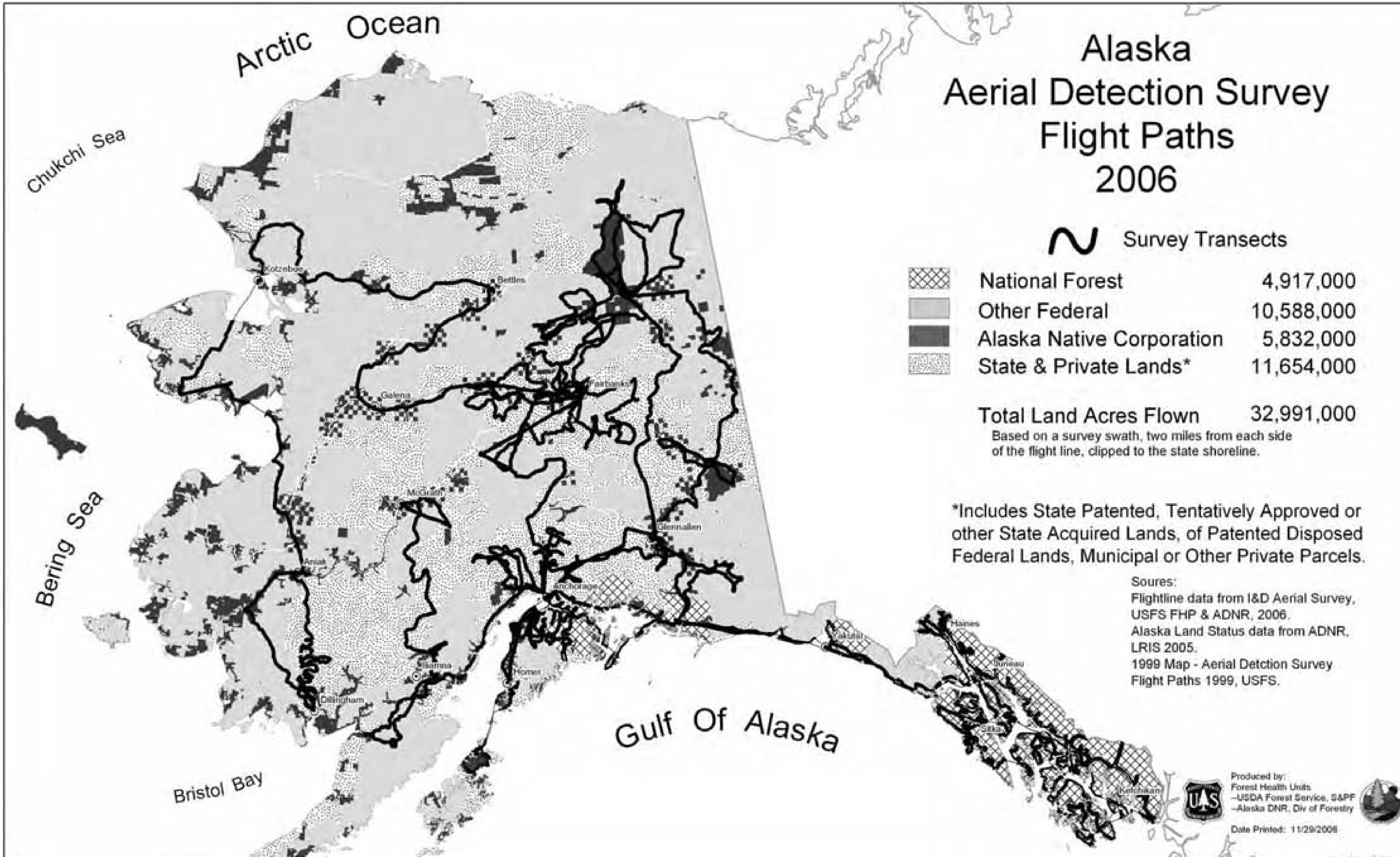
Invasive plant infestations in Alaska continue to be discovered, but an increased awareness of the threats posed by invasive plants to the state's economy and natural resources has given rise to new detection and management efforts on the part of municipal and state governments and conservation organizations. Among the newly-detected exotic invasive plant species in 2006 were **common hawkweed**, **rough hawkweed**, and **New England hawkweed**. Invasive exotic **thistles**, **spotted knapweed**, seven species of exotic **hawkweeds**, **knotweeds**, **sweetclovers, bird vetch**, and wetland invader **purple loosestrife** remain high concern, high priority species in Alaska.

Mapping and inventory of these and many other exotic invasive plant species continues around Alaska. Exotic plant data available online through the Alaska Exotic Plant Clearinghouse (AKEPIC) database rose from a total of 37,000 records in 2005 to over 43,400 points taken at over 9,900 sites in 2006. Three Cooperative Weed Management Areas (CWMA) are making progress in the areas of invasive plants public education, early detection, and management; addressing regionwide invasive plant problems across geopolitical boundaries in collaboration with the NRCS Soil and Water Conservation Districts and the Alaska Association of Conservation Districts. The UAF Cooperative Extension Service initiated the formation of the statewide Alaska Invasive Species Working Group (AISWG) in 2006, with funding from the U.S. Environmental Protection Agency.

Map 1. General forest pest activity, from 2006 aerial survey



Map 2. Survey flight paths and general ownership, 2006



Status of Insects

Willow leaf blotch miner damage seen in the Interior.

Aspen leaf miner has been so heavy that it is found infesting cottonwood as well as aspen.

Healthy larch was distinguished by the distinctive gold color in September.

Alaska Division of Forestry Entomologist Roger Burnside and APHIS Inspector Ann Ferguson inspect shipment of amber-marked birch leaf miner parasitoids for ongoing biological control project in Anchorage.

Status of Insects

The Ecological Role of Forest Insects

Insects are major components of forested ecosystems, yet very few are ever considered pests. In fact, the vast majority of insects play beneficial roles by facilitating decomposition of plant and animal materials, recycling nutrients, pollinating flowering plants, removing weak and dying plants, acting as food sources for other organisms, and serving many other ecological functions. Even those phytophagous insects that feed on trees are usually not considered pests unless they attain numbers sufficient to cause serious economic damage.

Defoliators

Of those insects that do cause injury to Alaskan forests, defoliators and bark beetles are the most significant. Defoliating insects consume the leaves or needles of forest trees. Tree responses to defoliation depend on time of season, host tree species, tree health, concurrent interacting stresses, severity of leaf damage or loss, and other biotic and abiotic factors. Responses range from no effect to outright mortality. During a defoliator outbreak, nearly every tree in a stand can be affected to varying degrees. The size of these outbreaks can be quite large, at times, exceeding millions of acres. In contrast, bark beetles bore into the bark of the stems and branches of living trees, which are usually girdled and subsequently die. Sometimes entire stands of trees die, creating striking scenes of destruction. The rate and extent of mortality varies depending partly on interacting environmental factors.

Figure 3. *John Lundquist, south-central entomologist, leads a team of land managers and decision makers in rating hazard trees near Girdwood.*

Bark Beetles

The size of beetle outbreaks can be as large as those of defoliators. What triggers bark beetle outbreaks is only partly understood. Forest insects are opportunistic in their behavior, responding quickly to changes in climate and the availability of food or breeding material. Defoliator outbreaks tend to be cyclic and strongly influenced by climatic conditions. The synchronization of larval emergence and tree bud break is closely related to population increases. The better the synchronization of insect and host throughout larval development, the more likely an epidemic will occur. Higher temperature during pupation of western black-headed budworm, for example, improves adult emergence and survival. Favorable climate for insect development resulted in a tremendous acreage of defoliated western hemlock in the early 1950s. Up to 25 percent of the western hemlock foliage was consumed by western black-headed budworm in southeast Alaska (McCambridge, 1953). At the end of this epidemic however, only 10 percent of heavily defoliated trees were top-killed and only a small number of those died. Bark beetles respond quickly to large-scale blow-downs, fire-scorched trees, and individual spruce trees impacted by seasonal flooding. Large numbers of beetles can be produced in such breeding material, leading to potential outbreaks. Drought and high temperatures for extended periods of time were at least partly responsible for the vast spruce bark beetle outbreaks on the Kenai Peninsula during the 1990s.

Impacts

Defoliator, bark beetle, and other insect infestations have a variety of biological and ecological consequences. Human perceptions of these consequences may be framed by socioeconomic considerations, depending on the forest resource in question. Some examples include:

- Wildlife may be positively or negatively affected by defoliator outbreaks. While insect larvae are a food source for fledgling chicks, avian habitat may be negatively affected by the subsequent decrease in cover.
- Populations of red squirrels, spruce grouse, Townsend warblers, ruby-crowned kinglets, marbled murrelets, and other animals that depend on live spruce forests may decline in bark beetle infestations.
- Populations of moose, small mammals and their predators, and other wildlife species that benefit from early successional vegetation such as willow and aspen may increase as stand composition changes following bark beetle caused mortality. However, thermal cover may be negatively impacted.

Figure 4. *Moose cow and calf browsing in riparian area.*

- Both defoliators and bark beetles can dramatically change the appearance of forested landscapes. A significant decline in public perception of scenic quality was shown to occur where spruce beetle impacted stands adjoin travel corridors. A similar impact to cityscapes is probably occurring in response to amber-marked birch leaf miner infestations in Anchorage.
- Fire danger in many spruce beetle impacted stands has increased. Following a spruce beetle outbreak, highly flammable species such as grasses increase, and as the dead trees break or blow down (5–10 years after an outbreak), large woody debris begins to accumulate on the forest floor. These heavy fuels do not readily ignite; however, once ignited, they burn at higher temperatures and for a longer period of time.

- Δ Aquatic systems may also be positively or negatively affected. Nutrient cycling is accelerated as foliage and insect waste enters the aquatic system, and larvae may drop into streams and serve as a food source for fish.
- Δ If all large diameter spruce trees lining salmon spawning streams are killed by spruce beetles, the future recruitment of large woody debris into the stream, which is necessary for spawning salmon, declines. Furthermore, stream temperatures may increase as a result of lost overstory shade. The removal through mortality of a large number of trees within a watershed can significantly impact the dynamics of streamflow, timing of peak flow, stream turbidity, channel morphology, etc.

Pest Management

A variety of techniques may be used to prevent, mitigate, or reduce impacts associated with forest insect infestations. Before developing pest management options, the forest manager must evaluate, in light of management objectives, resource values and the economics of management actions for each stand. The type of pest must also be considered, as this will determine the priority of management actions and the type of strategy to be implemented. Sustainable forest ecosystems are dependent on management that prioritizes retention of species diversity, both plant and animal, while providing for multiple use of resources. Healthy, diverse forests, managed using properly applied silvicultural practices and appropriate fire management, are essential for sustaining a range of natural forest products and amenities now and in the future. Suppression efforts of insect populations are usually limited to small-scale urban settings or high value recreational sites and techniques vary depending on the species of insect in question. Healthy forests experience periodic insect defoliation events. Land managers should consider the predicted duration and extent of these events and their predicted effects on the resource when considering suppression actions.

Invasive Insects

Introductions of exotic invasive insects have caused much concern and resulted in substantial control expenditures in the United States. The Asian long-horned beetle, *Anoplophora glabripennis* Motschulsky, and emerald ash borer, *Agrilus planipennis* Fairmaire, introductions in the Lower 48 are two examples of the potentially devastating effects for native ecosystems and resulting control efforts costing tens of millions of dollars.

Increasing tourism and international trade in Alaska elevates risk to forested ecosystems from exotic insect introductions (Table 3). Although geographic isolation and limited transportation corridors are thought to provide some degree of protection to Alaska ecosystems, the Forest Service in Alaska, in cooperation with other federal, state, and local organizations, monitors the populations and impacts of many invasive threats.

Table 3. Invasive insects either currently present in or thought to be coming to Alaska

Common name	Scientific name	Present in Alaska?	Invasive ranking
Pine moth	*Dendrolimus pini* (L)	No	High
European spruce beetle	*Ips typographus* L.	No	High
Asian gypsy moth	*Lymantria dispar* L.	No	High
Nun moth	*Lymantria monacha* (L.)	No	High
Western and forest tent caterpillars	*Malacosoma californicum* (Packard) and *Malacosoma disstria* (Hübner)	No	High
Larch sawfly	*Pristiphora erichsonii* (Hartig)	Yes	High
Amber-marked birch leaf miner	*Profenusa thomsoni* (Konow)	Yes	High
Brown spruce longhorn beetle	*Tetropium fuscum* (F.)	No	High
Woolly spruce aphid	*Adelges abietis* (L.)	No	Moderate
Hemlock woolly adelgid	*Adelges tsugae* Annand	No	Moderate
Asian long-horned beetle	*Anoplophora glabripennis* (Motschulsky)	No	Moderate
Larch casebearer	*Coleophora laricella* (Hübner)	No	Moderate
Spruce aphid	*Elatobium abietinum* (Walker)	Yes	Moderate
Birch leaf roller	*Epinotia solandriana* L.	Yes	Moderate
Birch leaf miner	*Fenusa pusilla* (Lepeletier)	Yes	Moderate
Larch engraver	*Ips cembrae* (Heer)	No	Moderate
European gypsy moth	*Lymantria dispar* (L.)	No	Moderate
Sitka spruce weevil	*Pissodes strobe* (Peck)	Yes	Moderate
Eastern spruce gall aphid	*Adelges piceae* (Ratzburg)	Yes	Low
Uglynest caterpillar	*Archips cerasivorana* (Fitch)	Yes	Low
Woolly alder sawfly	*Eriocampa ovata* (L.)	Yes	Low
European alder sawfly	*Hemichroa crocera* (Fourcroy)	No	Low
Birch-edge leaf miner	*Heterarthrus nemoratus* (Fallen)	Yes	Low
Currant worm	*Nematus ribesii* (Scopoli)	Yes	Low
Strawberry root weevil	*Otiorhynchus ovatus* (L.)	Yes	Low
European pine shoot moth	*Rhyacionia buoliana* (Schiffermüller)	No	Low

It is widely accepted that the most effective and lowest cost defense against exotic species introductions is to have an effective monitoring system designed to detect introductions early and allow cost effective rapid response control actions. Annual trapping for gypsy moth and other known exotic pests is carried out by our partners at UAF Cooperative Extension Service and Alaska DNR, Division of Forestry. The recent introduction of the amber-marked birch leaf miner, *Profenusa thomsoni*, along with two other birch leaf mining sawflies, has served to highlight the increasing risk to Alaskan forests and emphasize the need to develop an early warning system with a wider scope for detecting introductions.

Climate Change and Forest Health in Alaska

There seems little doubt that the climate in Alaska is changing. The mean annual temperature across Alaska has risen between 3° F to 5° F since 1950, maximum and minimum daily temperatures have increased, while growing degree days and the growing season have lengthened. Because of its unique geographic position at the northern edge of various forest types where ecosystems are notably sensitive to changing environment, Alaska has been referred to as the poster state for global warming.

Since most disturbance agents respond directly or indirectly to climate, the health of Alaska's forests will probably change in response to the changing climate. Some even believe that there has already been an unprecedented increase in forest disturbances in Alaska as a result of climate change. The 2001 North American Global Change Research Program, National Assessment, for example, attributes the infamous spruce beetle outbreak of the 1980s and 1990s on the Kenai Peninsula to climate change, and describes it as "the largest loss to insects ever recorded in North America." This outbreak has only recently been outdone by an even larger outbreak of mountain pine beetle (Dendroctonus pseudotsugae Hopkins) in British Columbia. In interior Alaska, the first recorded spruce budworm outbreak, 1993–1995, may have resulted from elevated summer temperatures that produced drought stress in the host white spruce trees. The widespread prevalence of stress related canker diseases caused by Cytospora spp. of alder and willow have become increasingly noticeable and apparently more severe throughout the state and elsewhere.

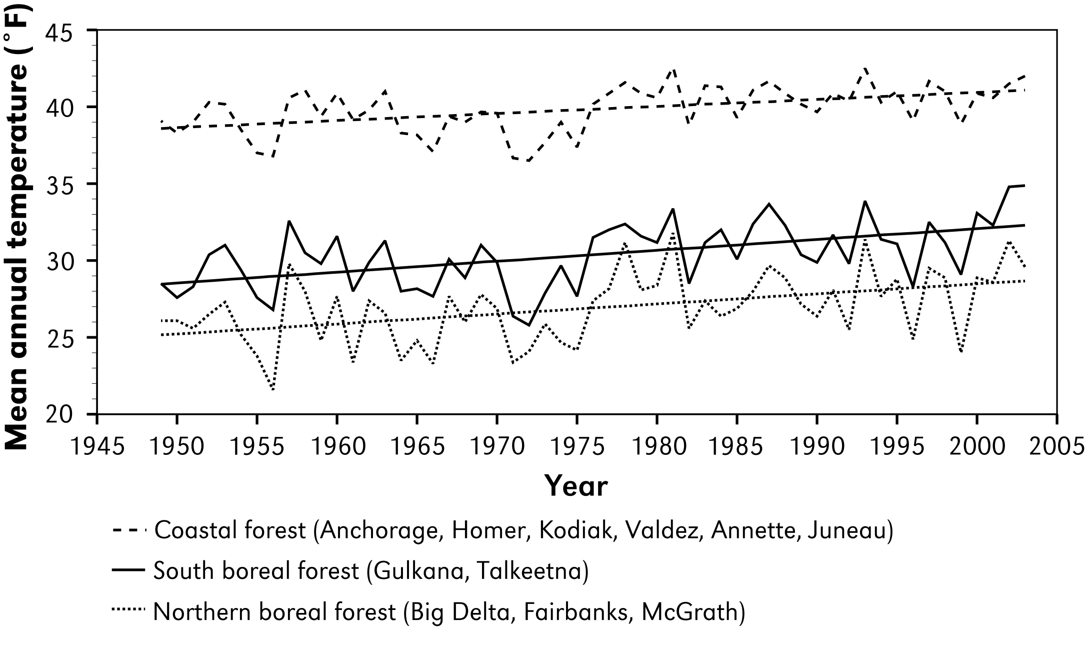


Figure 5. *Aggregate mean annual temperature, from 1949-2003, for three forested regions of Alaska with a linear regression line shown or each region. Data are from first-order weather stations and were provided by the Alaska Research Center.*

Recent wildfire seasons have been the largest on record. Increasing temperatures have been associated with both the loss of wetland habitats and increasing rates of the development of thermokarst topography, both of which result from permafrost thawing.

Forest health changes resulting from a shifting climate are expected to continue. Drought stress and reduced growth rates of some trees species are expected, possibly leading to larger and more frequent insect outbreaks. Larger and more severe fires are expected to result from a continuation of warmer, drier summers. Loss of forested acres will continue as a result of thawing of permafrost-laden soils. Also, the total number of new species in the Arctic, including Alaska, is expected to increase as a result of an influx of new species under a warmer climate. Some of these species will be invasive plants and insects that will create new forest health issues. All of the above changes will alter the composition and dynamics of Alaska's forests.

Forest health professionals in Alaska are investigating the relationships between climate and forest health on several fronts. The interactions between climate and the decline of Alaska yellow-cedar and Alaska birch forests are described in this report. A cooperative effort is currently underway by State and Private Forestry, the University of Alaska Fairbanks, and the Alaska DNR, Division of Forestry, to determine the role of climate in controlling the recent outbreaks of spruce budworm in interior Alaska. Also, a collaborative effort by the Alaska DNR, Division of Forestry, the University of Alaska Fairbanks, the Woods Hole Research Center, and State and Private Forestry, is currently underway to investigate the relationships of forest health—using aerial forest health survey data—and climate change variables across the entire forested area of Alaska from 1982–2003.

Robert Ott and John Lundquist

Defoliators

Birch Leaf Miners

***Profenusa thomsoni* (Konow), *Fenusa pumila* Leach, *Heterarthrus nemoratus* Klug**

NON-NATIVE

Three species of birch leaf mining sawflies occur in Alaska: *P. thomsoni*, *F. pumila*, and *H. nemoratus*. While *F. pumila* is still apparently rare in occurrence and *H. nemoratus* is becoming increasingly more common than in previous years, the amber-marked birch leaf miner, *P. thomsoni*, has become the most important exotic invasive insect in Alaska.

Damage was not visible from the air at the time of the 2006 surveys. However, special ground surveys were conducted along all major contiguous highways and many secondary roads south of the Yukon Flats (Map 3). These ground surveys show the extent of the current populations to be similar to that of the past two years, about 140,000 acres, with new populations found in the Fairbanks area and the Kenai Peninsula. Surveys also in-

Figure 6. *Amber-marked birch leaf miner damage was less intense in 2006 than in the previous three years. Although damage was found from Fairbanks to Haines, the largest concentration remains in south-central Alaska from Wasilla to Soldotna.*

Map 3. Amber-marked birch leaf miner populations as observed in 2006 ground surveys

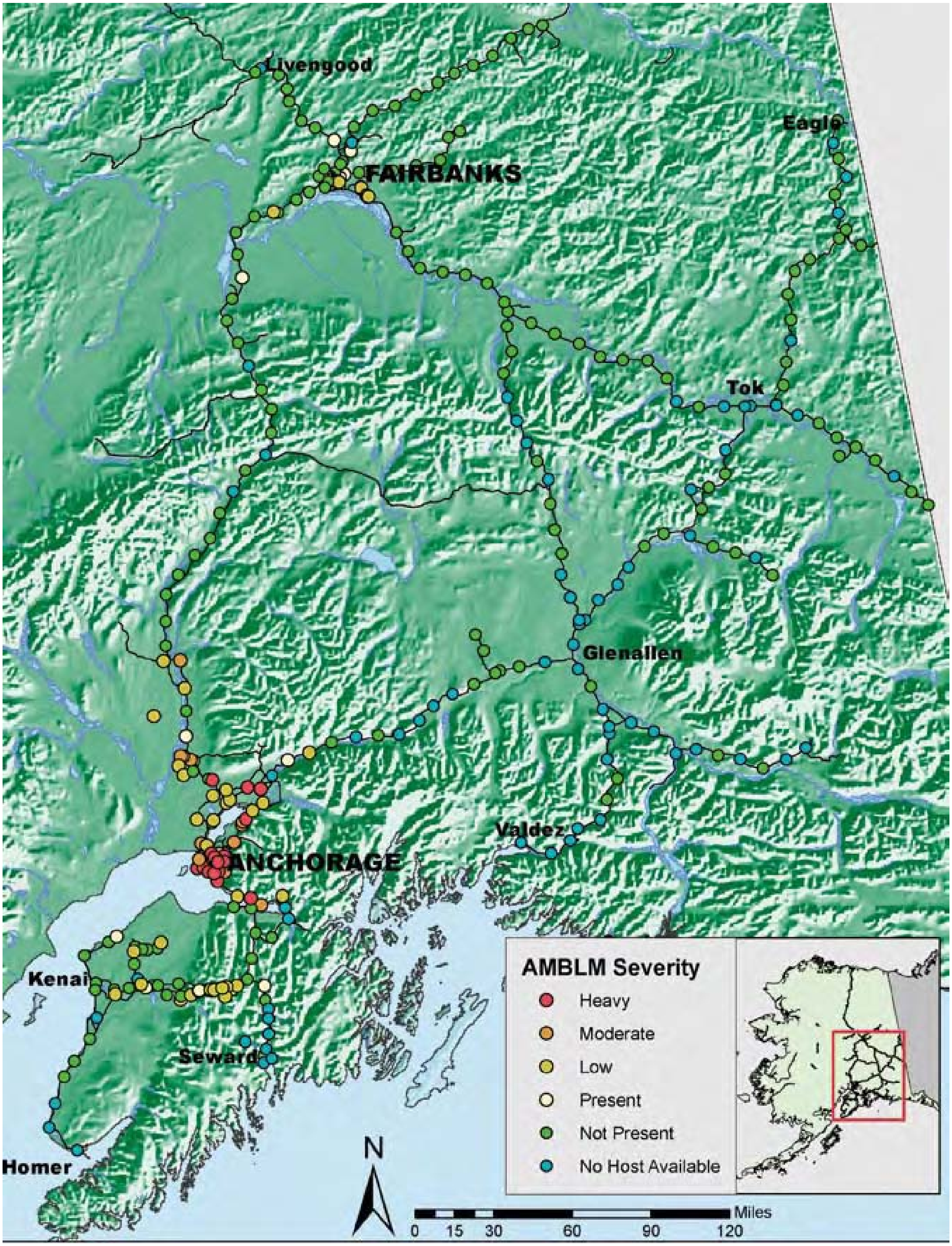


Figure 7. *Entomologists John Lundquist and Jim Kruse examine birch leaf miner larvae in a leaf.*

dicate that this insect is most likely being spread via movement of nursery–landscape stock and by “hitchhiking” on or in vehicles along road corridors. In fact, over 20 percent of the roadways surveyed had evidence of amber-marked birch leaf miner present, primarily in or near major urban centers or recreation areas.

Impacts to urban trees include decreased aesthetic values and the high cost of applying pesticides. Thousands of dollars each year are spent on pesticides to control *P. thomsoni*. The larvae of this insect eat the inside of leaves between the epidermal layers, causing leaves to die and entire urban landscapes to turn brown. Affected trees are obvious and our stakeholders commonly inquire about the damage. Mortality of affected trees after several years of continuous infestation may be possible, but has not yet been proven.

In 2003, a cooperative birch leaf miner biological control program was started in Anchorage. This biological control program entails the release of the parasitoid, *Lathrolestes luteolator* Gravenhorst (Hymenoptera: Ichneumonidae), collected in Canada. Participating agencies include: USDA Forest Service, Canadian Forest Service, University of Alberta, University of Massachusetts, USDA APHIS, Alaska DNR, Division of Forestry, and the Municipality of Anchorage.

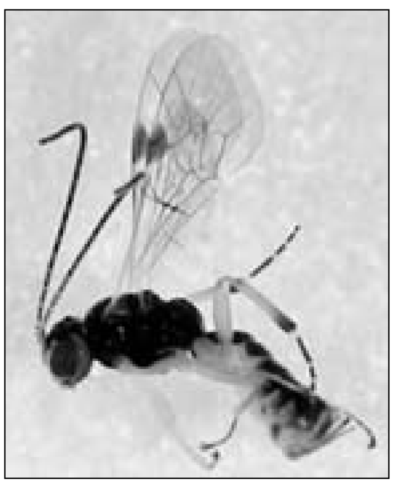


Figure 8. *Parasitoid wasps have been released as biological controls in Anchorage. From the collection of Daryl Williams, Canadian Forest Service, provided by C. MacQuarrie.*

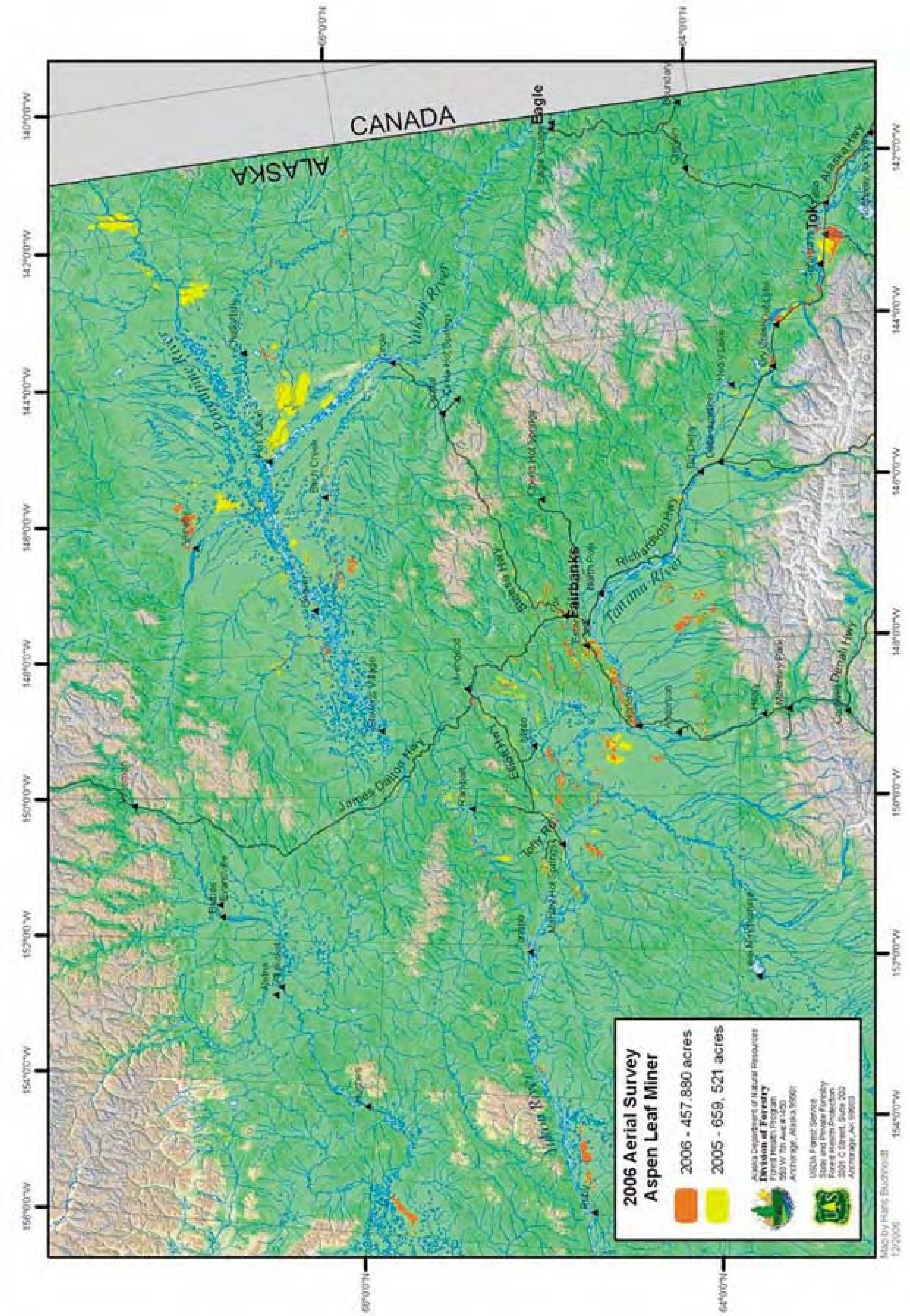
Parasitoid specimens, either reared locally from larvae imported from Canada or imported as adult wasps, have been released: 53 individuals in 2004, 158 in 2005, and 458 in 2006(C. MacQuarrie and A. Soper, Pers. Comm.). Monitoring efforts have been unable to show that the parasitoid has yet established at the release sites (C. MacQuarrie and A. Soper, Pers. Comm.). However, dissections of leaf miner larvae within the release areas show widespread parasitism(A. Soper, Pers. Comm.). This suggests that native parasitoids have the ability to parasitize the amber-marked birch leaf miner (J. Hard, Pers. Comm.).Birch leaf miners will probably continue to spread along roads throughout Alaska’s south-central and interior birch forests and access natural forests away from the road corridors.

Aspen Leaf Miner

***Phyllocnistis populiella* Chambers**

Aspen leaf miner infestations appear to have topped out in 2005 after five consecutive years of increases. In 2006, 457,882 acres were mapped by aerial surveys, the lowest acreage in two years (Map 4). In contrast, 659,536 acres were mapped in 2005, the apparent peak of the outbreak. With the exception of a few localized outbreaks found in south-central Alaska and those spread sporadically across the west of the state, the majority of the outbreak is bounded by the Alaska Range to the south and the Brooks Range to the North.

Map 4. Aspen leaf miner populations as observed in 2006 aerial surveys



This year, the Fairbanks area remained heavily infested, as well as the area between Delta and Tok, and Glennallen and Chitina.

Last year observers noticed that the intensity varied within aspen patches where intensity was highest on the edges and light in the center of each patch. This would indicate a disease outbreak in the leaf miner population as opposed to a "catch-up" of parasitoid or predator populations in response to the high leaf miner populations. The cause of outbreak crashes has often been attributed to disease or parasitoid/predator loading, and this development accurately indicated the beginning of the end of this particularly large and long lasting aspen leaf miner outbreak.

Figure 9. *Aspen leaf miner damage shows as silver during aerial surveys.*

Heavy, repeated attacks by the aspen leaf miner can reduce tree growth and may cause branch dieback, or in some cases, tree death. Many aspen trees, especially in the hills, were severely drought stressed in 2004 and continued to be in 2005, but received a tremendous amount of relief from the June rains of 2006.

Spruce Budworm

Choristoneura fumiferana (Clemens)

In 2004, indications were that a spruce budworm outbreak had begun as over 83,000 acres of spruce in interior Alaska were defoliated. Fires and smoke in 2004 and 2005 curtailed the area surveyed and may also have contributed to a decrease in the severity of the outbreak. In 2006, just over 53,000 acres of defoliation were mapped by aerial surveys. Damage was concentrated along the hills and ridges around Fairbanks (Nenana Ridge, Parks Ridge, and Chena Ridge), west along the Tanana River, north to the vicinity of Livengood, and along the northern foothills of the Alaska Range.

Ground surveys indicate that populations of spruce budworm are still expanding and that the outbreak will continue to intensify along the ridges. Defoliation of white spruce tops was observed on as much 5–10 feet resulting in some top-kill. Flight trap numbers (capturing adult moths) also increased for the fourth consecutive year.

Spruce budworm is one of the most destructive insect pests of white spruce in North America. In Alaska, budworm has only recently become a major issue. During outbreaks, budworms can be factor in spruce regeneration, and mature trees that are top-killed do not produce cones. The last budworm outbreak in the interior occurred from 1990 to 1996 along the lower Tanana River below Fairbanks and the Yukon River from the Trans–

Alaska pipeline crossing to Ruby, a 280 mile stretch. The Tanana–Yukon infestation area had expanded to 280,000 acres by 1995 with the majority of stands experiencing moderate to heavy defoliation, and scattered top and lateral branch dieback in the most heavily infested stands. Many of these trees still show the effects of this outbreak, expressed in top-kill, irregular tops, and lack of cone production. Studies will be initiated in 2007 to investigate the relationships between spruce budworm top-kill, fungi, and predisposition of trees to Ips beetle attack.

Figure 10. *Spruce budworm larvae feeding on white spruce.*

Terminal leader kill often occurs on young trees, which may be killed by repeated, severe defoliation. Current research is evaluating the efficacy of spruce budworm larvae in outbreak conditions as a mortality agent of white spruce regeneration, and quantifying the effects of spruce budworm damage of white spruce regeneration. Results should be available during the winter of 2006/7.

Large Aspen Tortrix

Choristoneura conflictana Wlkr.

Large aspen tortrix populations characteristically increase to locally epidemic proportions for two to three years, then experience significant declines as a result of adverse weather, parasites, and larval starvation. Since 2003, tortrix populations have remained at nearly undetectable levels throughout Alaska. In 2006 however, 34,431 acres of tortrix defoliation were identified. Eighty percent of the statewide tortrix activity was mapped in the central interior, nearly all concentrated in the Japan Hills, 70 miles south of Fairbanks. Other smaller, though significant, areas of activity were: the upper Matanuska River Valley (2,177 acres), south of Skilak Lake on the Kenai Peninsula (1,234 acres), 1,545 acres between Circle and Fort Yukon, and 4,181 acres north of Fort Yukon.

Willow Leaf Blotch Miner

Micurapteryx salicifolliela (Chambers)

Figure 11. *Willow leaf blotch miner damage.*

A total of 23,896 acres of willow defoliated by the leaf blotch miner were tallied during the 2006 aerial surveys. This is the 14th year in a row that this insect has been observed—a period associated with large fluctuations of leaf blotch severity. The center of this activity remains the upper Yukon River Valley and its tributaries, where this infestation was first noted in 1991, and where 67 percent of the current infested area occurs. Widely scattered populations were also found in the central interior on the Tanana and Kantishna Rivers, Bethel, Tanacross, Glennallen, and Valdez.

Sunira Moth

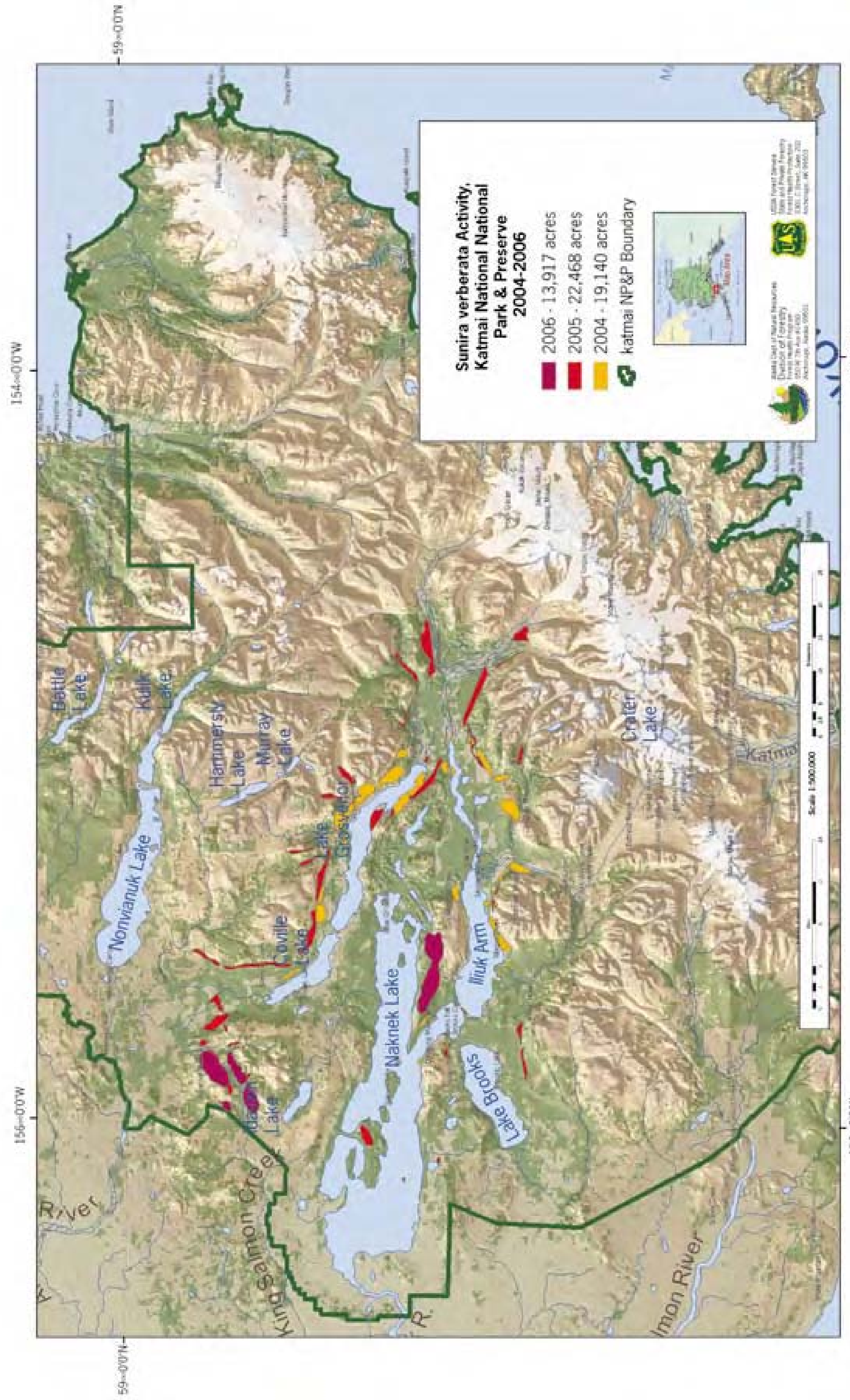
Sunira verberata (Smith)

After six years of steadily increasing populations, Sunira in Katmai National Park appears to be on the decline (Map 5). Aerial surveyors observed 13,918 acres of defoliation caused by this insect in 2006, representing a 38 percent drop in activity from the previous year. As observed in previous surveys, the majority of this moth's activity occurred near Lake Coville, Lake Grosvenor, Naknek Lake, and the Savonoski River. A considerable amount of recent (this year) alder mortality associated with Sunira was observed in these areas. The only other Sunira outbreak occurred along the shoreline of Lake Aleknagik north of Dillingham; that remains in the medium–heavy severity category and has declined to 974 acres, a 68 percent reduction from 2005 levels. Notable in 2006 are the numerous small spots of Sunira detected on Nunavaugaluk Lake, just a few miles west of the Lake Aleknagik infestation.

Cottonwood Defoliation

Defoliated cottonwood was observed over an area of 16,330 acres during the 2006 surveys. The cause of this defoliation was not determined, but presumably involved leaf feeding insects. Additional 4,341 acres and 3,946 acres of defoliation were attributed to cottonwood leaf beetles and leaf rollers, respectively. Total area showing defoliation was up considerably from previous years; 7,958 in 2005 versus 24,617 acres in 2006.

Map 5. *Sunira verberata* near Katmai National Park and Preserve



Alder Defoliation

A suite of insects are associated with alder defoliation in Alaska. These include: woolly alder sawfly (*Eriocampa ovata* (L.)), striped alder sawfly (*Hemichroa crocea* (Geoffroy)), rusty tussock moth (*Orgyia antiqua* nova Fitch), and several defoliating leaf beetles. Of these, the most significant is the woolly alder sawfly, a European invasive that is well established throughout the northern U.S. and Canada. Between Fairbanks and Anchorage, over 7,000 acres of defoliated alder stands were recorded by aerial surveyors, much of which is attributed to woolly alder sawfly.

Woolly Alder Sawfly

Eriocampa ovata (L.)

NON-NATIVE

Defoliation by woolly alder sawfly remained moderate to heavy on thin-leaf alder, *Alnus tenuifolia* Nutt., from Palmer to Seward in south-central Alaska. Based on roadside observations, many acres additional to the 7,000 in the previous section, were affected by this insect on the Kenai Peninsula. This species skeletonizes alder leaves, consuming all leaf tissue except major veins. Thin-leaf alder is the preferred host of this insect; Sitka alder, *A. sinuata* (Regel) Rydb. and green alder, *A. crispa* (Ait.) Pursh are seldom defoliated.

Figure 12. *Late instar larvae of the woolly alder sawfly have a distinctive white coating.*

Spear-marked Black Moth

Rheumaptera hastata (L.)

Although large numbers of spear-marked black moth adults have frequently been encountered in both forest and urban settings for years, no obvious signs of feeding on hardwoods have been observed until 2006. The last major outbreak of these moths occurred in the mid-1970s when nearly 3 million acres of interior Alaskan birch were defoliated. Aerial surveys in 2006 identified 7,946 acres of locally concentrated activity in a number of widely scattered areas. These areas include: 1,862 acres between Fort Yukon and Venetie, 1,734 acres along the Tanana River between Fairbanks and Manley Hot Springs, 2,258 acres along the Kantishna River, 817 acres near Skwentna, and 704 acres near McCarthy.

Figure 13. *Spear-marked black moth has a distinctive coloration pattern.*

Birch Leaf Roller

Epinotia solandriana (L.)

Figure 14. *Birch leaf rollers can be very difficult to detect aerially.*

Three thousand five hundred acres of birch leaf roller activity were observed during the survey this year. This represents a 46 percent decline from 2005 levels. Nearly 2,000 of these infested acres were located in the Yukon Flats National Wildlife Refuge northwest of Fort Yukon. Another 450 acres were found near the confluence of the Tanana and Yukon Rivers, south of Tanana. Two smaller infestations were observed at Eklutna Lake outside Anchorage, and in Resurrection Creek Valley near Hope. It is worth noting that low-level leaf roller populations are often difficult to ascertain during aerial surveys, and it is quite likely that the current cycle of leaf roller activity is considerably more extensive than it appears to be from the air. A substantial amount of leaf roller activity was observed at ground level as casual observations during road trips in numerous areas of Anchorage and on the Kenai Peninsula.

Larch Sawfly

***Pristiphora erichsonii* (Hartig)**

Larch sawfly defoliation decreased from 16,771 acres in 2005 to 2,666 acres in 2006. Nearly all of the defoliation occurred on Minto Flats west of Fairbanks. Smaller infestations were also noted east of McGrath where larch sawfly has been very active for a number of years.

Larch sawfly is an invasive defoliator in Alaska. Based on aerial survey data, it is estimated that 600,000–700,000 acres of larch forest in Alaska have been impacted by a larch sawfly infestation that began in 1999. The mortality of larch affected by the larch sawfly has been documented to reach 80 percent. As a result, concern has been expressed that the extent of the larch mortality may necessitate genetic conservation measures.

In September 2006, a special aerial survey was conducted in order to update the mapped distribution of larch in Alaska, and document the extent of healthy stands of larch. This survey was conducted while larch were exhibiting their fall foliage, making them easy to distinguish from the black spruce trees that occupy many of the same sites as the larch. Over four days, 2,572 miles were flown, with 6,067,738 acres being surveyed for healthy larch trees. The land area with healthy larch stands totaled 673,685 acres (11.1 percent of area surveyed). Outside the known range of larch, 10,651 acres of larch were identified. A second fall aerial survey to map healthy larch stands will be conducted during September 2007.

Spruce Aphid

Elatobium abietinum (Walker)

Only 9,120 acres of spruce aphid defoliation were mapped in 2006, down 60 percent from 2005. Defoliation occurred in small pockets along the beach fringe from Lincoln Island in the Lynn Canal, across from Berners Bay, to the north end of Kupreanof Island, and along the mainland from Juneau to Thomas Bay. In the southwest area of the panhandle small spots were mapped between Edna Bay, Kosciusko Island, Naukati, Prince of Wales Island, and on Long and Dall Islands. Defoliation also occurred around the towns of Craig, Juneau, Ketchikan, and Sitka.

The current outbreak started in 1998, but the worst year was in 2003, when defoliation occurred on 30,627 acres and was distributed over more of the area surveyed than in the previous five years.

In 2006, four low temperature events of approximately 20 hours total occurred in southeast Alaska, from March 14 through March 17 (Figure 15). These combined low temperature periods are thought to have killed a large number of aphids.

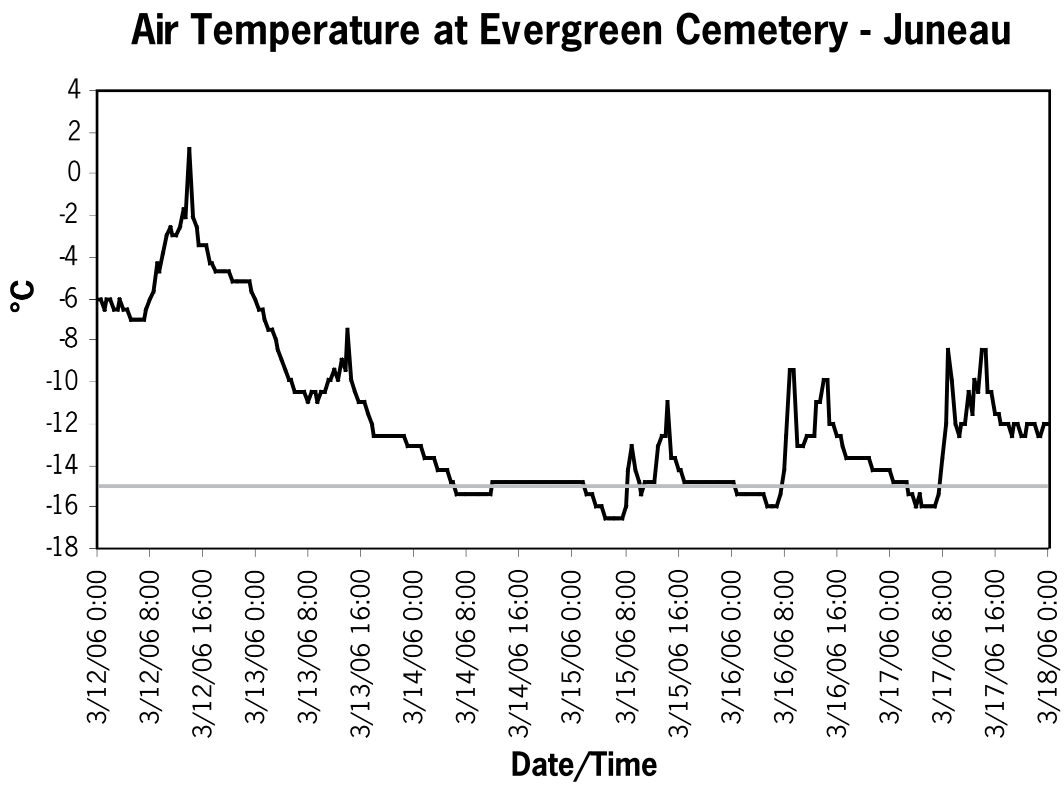


Figure 15. *Temperature plot during the coldest part of the late winter 2006, Evergreen Cemetery, Juneau.*

Spruce aphids feed on older needles of Sitka spruce, moving progressively to newer foliage. In a year with high populations of aphids this causes a significant amount of needle drop (defoliation). Spruce aphids feed primarily in the lower, innermost portions of tree crowns, but may impact entire crowns during outbreaks. Outbreaks in southeast Alaska are usually preceded by mild winters. Since the late 1960s the outbreaks have been more frequent and of more acres, except in years of significantly low spring temperatures. Defoliation by aphids reduces tree growth and can predispose the tree to bark beetles, however severe defoliation alone may result in tree mortality. Historically, spruces in urban settings and along south-facing marine shorelines are most seriously impacted.

Western Black-headed budworm

Acleris gloverana **(Walsingham)**

Western black-headed budworm populations are currently at endemic levels, with approximately 1,400 acres of defoliation mapped in Prince William Sound and southeast Alaska for the past three years.

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

Hemlock Sawfly

Neodiprion tsugae **Middleton**

No hemlock sawfly defoliation was mapped in 2006. Hemlock sawfly, a common defoliator of western hemlock, is found throughout southeast Alaska. Historically, sawfly outbreaks have been larger and of longer duration in areas south of Frederick Sound.

Unlike the larvae of the black-headed budworm, hemlock sawfly larvae feed in groups, primarily on older hemlock foliage. These two defoliators, feeding in combination, have the potential to completely defoliate western hemlock. Heavy defoliation of hemlock by sawflies is known to reduce radial growth and cause top-kill, thus may ultimately influence both stand composition and structure. The larvae are a food source for numerous birds, other insects, and small mammals.

Gypsy Moth

Lymantria dispar **(L.)**

NON-NATIVE

Alaska has maintained a detection monitoring system focused on the gypsy moth, a serious defoliator of hardwoods, for several years. Both the European and Asian gypsy moths are of concern to Alaska. To address this concern, annual gypsy moth trapping has and continues to be done in cooperation with the Animal and Plant Health Inspection Service (APHIS) in several locations across Alaska. In addition to gypsy moth in 2006, traps were placed for Nun moth, *Lymantria monacha* (L.) and Rosy Gypsy moth, *Lymantria mathura* Moore. A single male gypsy moth was found at a campground in south Fairbanks in 2006. Genetic testing revealed that it's haplotype has been present in North America for many years and therefore it is not a new foreign introduction.

European Yellow Underwing Moth

Noctua pronuba **L.**

NON-NATIVE

Since the discovery of the European yellow underwing moth in Haines and St. Lazaria Island (near Sitka), Alaska in 2005, this moth has spread as far north and west as Anchorage in 2006. Also, its presence has been confirmed throughout southeast Alaska in 2006, including Sitka, Prince of Wales Island, Thorne Bay, Juneau, and Ketchikan.

This well-known European pest was introduced in Nova Scotia in 1979, and has been rapidly spreading across the continent ever since. Based on the rapid movement of this species, it is likely to be found in the Mat–Su valley in the next year, will likely be in Fairbanks within three years, and will be quite numerous throughout most areas of Alaska by 2010. Its final distribution will likely be throughout southeast, south-central, and interior Alaska as far north as the Brooks Range. It has been recorded in tundra around northwestern Hudson's Bay, so there is the potential to impact Alaska's tundra ecosystem.

The European yellow underwing is largely an agricultural pest. The larvae are generalist feeders and have been recorded on grasses, dock and dandelions, and a wide range of wild and cultivated herbaceous plants. They also attack, tomato, potato, carrot, beet, lettuce, grape, and strawberry, and are pests on garden flowers. In British Columbia, where this species arrived about five years ago, it has become one of the most common insects, reported as "everywhere, invading cars, houses, and workplaces."

Yellow-headed Spruce Sawfly

***Pikonema alaskensis* Rohwer**

Non-native

The yellow-headed spruce sawfly has steadily spread west from its original infestation point at the Alaska Native Hospital over the past three years. Large landscape trees in the Fairview area were heavily defoliated in 2006. This defoliator is not considered a serious forest pest, but can seriously affect the aesthetic value of urban trees, and can cause mortality with repeated years of heavy defoliation.

Uglynest Caterpillar

***Archips cerasivorana* Fitch**

Non-native

Populations of uglynest caterpillar, whose presence in Anchorage has caused mostly cosmetic damage to landscape trees and shrubs, has caused much concern among Anchorage homeowners and businesses. It was introduced on ornamental plantings and remains a problem in west Anchorage on plantings of cotoneaster and mountain ash. It can also be found along roadsides near and around Anchorage on *Prunus*, *Malus*, and *Salix* spp. This insect is especially a problem for nurseries and owners of ornamental plantings because of the unsightly appearance of the larval nests. Larval feeding may also cause some branch deformity.

Miscellaneous Defoliators

Several areas of defoliation by less often noted pests were documented this year. Throughout northern, interior, and south-central Alaska from Nome to Valdez, nearly 27,000 acres of willow were defoliated, most by various species of moths, particularly noctuid moths. The noctuid moth *Anathix puta* (Grt. & Rob.) caused problems in aspen stands in the Fairbanks area. Over 4,200 acres of alder leaf roller (probably *Epinotia solandriana* L.) were also recorded in the Anchorage bowl. Also on the rise, nearly 3,000 acres were defoliated in interior Alaska by spruce/larch budmoth (*Zeiraphera* spp.).

Bark Beetles

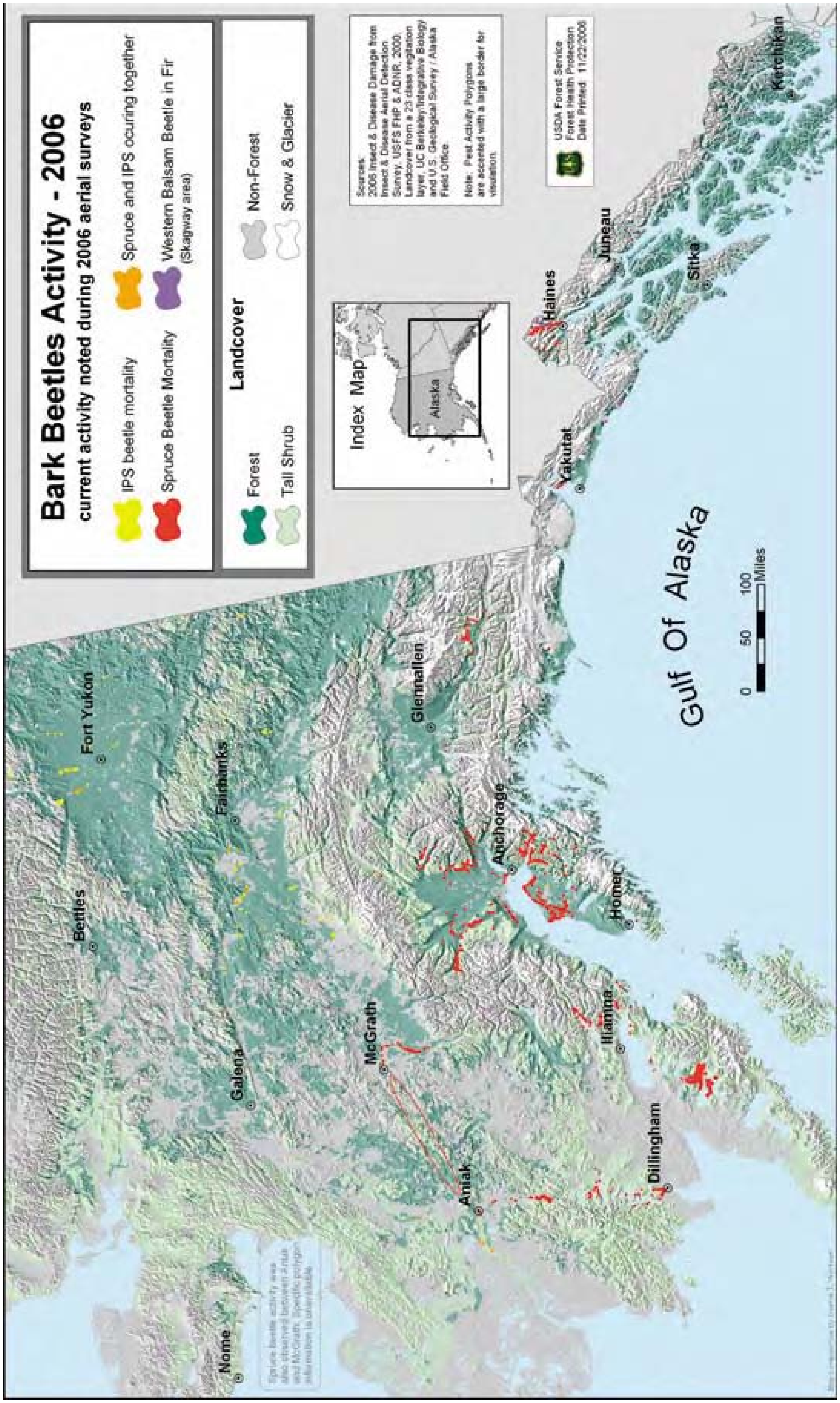
Spruce Beetle

Dendroctonus rufipennis (Kirby)

Spruce beetle activity in Alaska has increased for the third time in the past five years. A total of 119,610 acres were mapped in 2006, an increase of 68 percent since 2005 (Map 6). **Kuskokwim River:** Technical difficulties prevented the recording of acres of spruce beetle activity along the Kuskokwim River between McGrath and Sleetmute, an area of known ongoing activity. Aerial observation in 2006 indicate the activity has most likely increased slightly over the 2005 level of 13,500 acres, while the intensity of the outbreak has increased significantly in a number of those areas. This beetle activity remains confined to the river bottom stands and adjacent slopes. Had acreage estimates of infested forests been available for this area, 2006 would have been shown to be the most active spruce beetle year in the past six years. **Lake Clark:** Although only 2,100 acres of beetle activity were identified, this relatively small figure belies its potential significance. Intense beetle activity has occurred over the past 10 years in the Iliamna area to the south and the Lake Clark Pass area to the east. Throughout this period, beetle populations in the vast, mature, susceptible spruce stands around Lake Clark have remained at endemic levels. If conditions become favorable for an outbreak of spruce beetle, the forests around Lake Clark are capable of sustaining widespread activity for a number of years to come. Aerial surveys will continue in this area in 2007 to assess the progress of this activity. **Katmai National Park:** Katmai National Park has the most intense spruce beetle outbreak in the state. Populations at Katmai increased 300 percent since last year. Nearly 70,000 acres of mature spruce, primarily at the west end of Naknek Lake and Lake Brooks, are currently under attack. **Kenai Peninsula:** On the Kenai Peninsula, spruce beetle activity has doubled over the last year, increasing to over 10,000 acres. In addition to beetles moving into previously uninfested stands, trees too young and too small in stands infested earlier are now mature and large enough to be susceptible. The most active spruce beetle infestations on the Kenai Peninsula are in the Kenai National Wildlife Refuge north and east of Nikiski, the Point Possession–Chickaloon Bay area, the Six Mile River Valley, and west shore of Turnagain Arm. **Municipality of Anchorage:** Beetle populations within the two previously most active areas in the Municipality of Anchorage, Bird and Indian Creek Valleys, have remained static in 2006 at levels of approximately 2,500 acres. **Matanuska–Susitna Valley:** Spruce beetle populations in the Mat–Su Valley doubled to 14,200 acres during the past year due largely to increasing beetle activity in the Skwentna and Yentna River Valleys. In the Beluga and Judd Lakes area, where the spruce beetle was quite active in 2005, populations remained relatively

Figure 16. *Spruce bark beetle making galleries.*

Map 6. Spruce beetle activity mapped in 2006



static. **Southeast Alaska:** In Southeast Alaska, the spruce beetle outbreak from Haines to north of Skagway remains relatively static at just over 4,000 acres. Other areas of spruce beetle activity of note in 2006 are 4,800 acres of light, scattered activity just northwest of Dillingham and 3,500 acres of continuing activity in the Kennicott River Valley near McCarthy.

Engraver Beetle

Ips perturbatus (Eichhoff)

Aerial surveys in 2006 identified 7,653 acres of engraver beetle damage statewide. When combined with the figures for engraver–spruce beetle damage (both pests active in the same stand) the total exceeds 10,000 acres. Although there was engraver activity reported on the Kenai Peninsula this year in the Granite Creek area of the Chugach National Forest, it remains primarily a pest of interior spruce forests. Engraver populations can fluctuate widely from year to year as figures for the acres impacted over the past five years demonstrate: 2002, 465 acres, 2003, 1,200 acres, 2004, 16,099 acres, 2005, 2,990 acres, 2006, 7,653 acres. *Ips* infestations generally occur in areas disturbed by erosion, such as river flood plains, as a result of mechanical damage such as spruce top breakage from snow-loading, harvest activities or wind events, and in areas damaged by wildfire. As a result of extensive wildfires in the interior in both 2004 and 2005, an increase in *Ips* populations was expected to occur in 2006. Two general areas of the interior accounted for 75 percent of the *Ips* activity recorded this year. Historically, and once again this year, the major river drainages around Fort Yukon, namely the Porcupine, Christian, Sheenjek, and Chandalar Rivers, experienced the majority of this activity, accounting for 4,600 of the acres affected by *Ips* statewide. In the central interior, between Fairbanks and the Kantishna River, 3,500 acres of activity were recorded. Technical difficulties precluded recording the acres affected by *Ips* in the last area of major *Ips* activity in Alaska, that being along the Kuskokwim River between McGrath and Sleetmute, thus, the final damage figures do not reflect this activity. 2005 aerial surveys detected nearly 20,000 acres of combined engraver and spruce beetle activity along the Kuskokwim River, south of McGrath. Observations of that infestation suggest that the area affected most likely expanded somewhat in 2006, and the intensity of activity has increased in a number of those areas. Although the majority of the beetle

Figure 17. *Ips beetle is often evident by topkill of spruce.*

activity along the Kuskokwim River can be attributed to spruce beetle, *Ips* remain quite active throughout this infestation.

Western Balsam Bark Beetle

Dryocoetes confusus **Swaine**

Acreage of subalpine fir mortality is still small but this beetle has moved down the Taiya Inlet and was causing mortality 1.5 kilometers south of Skagway in 2006. Subalpine fir is easy to spot because of its conical crown. Mortality throughout the outbreak occurred on 498 acres in 2006. The outbreak will likely continue due to higher spring and fall temperatures; southeast Alaska in particular has been affected by record high maximum temperatures (see Figure 1, in "Climate and Forest Health"). Since the range of subalpine fir is very limited in Alaska, even a small outbreak has a significant impact on the resource.

Sitka Spruce Weevil

Pissodes strobii **(Peck)**

NON-NATIVE

IPM scouts for the Cooperative Extension Service reported evidence of Sitka spruce weevil in landscape trees planted at a new construction project on the Anchorage hillside. The trees had been planted in 2004 and the beetles were no longer present. The trees were to be removed and replaced with live trees by the owner and a follow-up by IPM scouts will be made in 2007.

Figure 18. *Sitka spruce weevil emergence holes.*

Eastern Larch Beetle

Dendroctonus simplex **LeC.**

Often, aerial surveys are unable to detect or separate mortality caused by larch beetle activity from mortality caused by repeated defoliation by larch sawfly. Historically, large infestations of larch beetle have been recorded in the Alaskan interior, with over 8 million acres infested from 1974–1980. *Dendroctonus simplex* generally attacks injured and recently down trees, those weakened by fire and flooding, and those trees previously defoliated by the larch sawfly.

Status of Diseases and Declines

Prolific fruiting of Inonotus tomentotus conks in a spruce forest near Skagway.

Yellow-cedar decline near Sitka.

Birch in various stages of decline in interior Alaska.

Spruce needle rust.

Status of Diseases and Declines

Managing Diseases to Achieve Forest Health in Alaska

Forest health is a concept based on human values used to judge the condition of a forest relative to resource goals. Forest lands in Alaska are managed for specific or combined purposes, including timber production, fish and wildlife habitat, recreation, and natural values. Given the strong ecological and economic effects of several diseases on forests in Alaska, the types and severity of disease must be considered when evaluating forest health (Table 4). High levels of a specific disease may be beneficial and contribute to a healthy forest in some circumstances or harm resource values creating an unhealthy forest in others. Thus, appropriate or desirable disease levels for a forest will vary dramatically by the various intended resource goals. Fortunately, several of the most important forest diseases can be manipulated silviculturally to predictably achieve a range of disease levels and impacts. Thus, disease management can be tailored to help meet simple or complex resource management goals.

Figure 19. *Collapse of a large hemlock from extensive internal heart rot. Diseases such as heart rot play key ecological roles in forests. They can be viewed as enhancing or harming forest health, depending on intended resource objectives.*

Heart rot fungi and hemlock dwarf mistletoe illustrate this point about the relationship of disease levels and forest health. Heart rot fungi consume about one-third of the volume of live trees in old-growth hemlock–spruce forests in southeast Alaska. They enhance biological diversity, provide wildlife habitat through the creation of cavities, and alter forest structure, composition, nutrient cycling, and succession in old forests. Many old-growth trees die through collapse because heart rot fungi have consumed so much of the tree's supporting wood. Hemlock dwarf mistletoe produces unique tree structures (brooms) which may serve as key habitat for some wildlife species. This disease also dramatically slows the growth of highly infected trees, and sometimes kills them standing. Thus, heart rots and dwarf mistletoe are among the primary factors that sustain the old-growth condition through individual tree death, or small-scale (canopy-gap) disturbance. Viewed as impairing forest health where timber resources are important, however, heart rot fungi and dwarf mistletoe cause enormous commercial losses through reduced tree growth, internal wood decay, or outright mortality. In addition, heart rot in live trees can lead to hazardous situations in forests managed primarily for recreation where tree fall can lead to loss of life or property.

Table 4. Suspected effects of common diseases on ecosystem functions in Alaskan forests.

Disease	Ecological Function Altered: Structure	Composition	Succession	Wildlife Habitat
Stem Diseases				
Dwarf mistletoe	●	◗	◗	●
Hemlock cankers	❍	◗	❍	◗
Hardwood cankers	◗	◗	◗	❍
Spruce broom rust	◗	❍	❍	●
Hemlock bole fluting	❍	❍	❍	◗
Western gall rust	❍	❍	❍	❍
Heart Rots				
(Many species)	●	◗	●	●
Root Diseases				
(Several species)	❍	●	●	❍
Foliar Diseases				
Spruce needle rust	❍	❍	❍	❍
Spruce needle blights	❍	❍	❍	❍
Hemlock needle rust	❍	❍	❍	❍
Cedar foliar diseases	❍	❍	❍	❍
Hardwood leaf diseases	❍	❍	❍	❍
Shoot Diseases				
Sirococcus shoot blight	❍	❍	❍	❍
Shoot blight of yellow-cedar	❍	◗	❍	❍
Declines				
Yellow-cedar decline	●	●	●	◗
Animal Damage				
Porcupines	◗	❍	❍	◗
Brown bears	◗	❍	❍	◗
Moose	◗	◗	❍	◗

Effects by each disease of disorder are qualified as:
negligible or minor effect = ❍
some effect = ◗
dominant effect = ●

Reducing Disease Levels

Forest practices can be used to alter diseases to meet resource management objectives. Where these diseases are viewed as harming forest health, both heart rot and mistletoe can be eradicated through clearcut harvesting and planned short rotation, even-aged management.

Thus, old forests with abundant levels of heart rot and dwarf mistletoe can be converted to near disease free conditions and harvested before disease levels reappear. This was the dominant view during the mid 1900s when "decadent" old forests were perceived as undesirable and were routinely converted to "thrifty" young-growth condition. Short rotations and thinning with minimal injury to residual trees effectively eliminate heart rot and dwarf mistletoe as management issues.

Maintaining Disease Levels

Where disease levels should be maintained to achieve resource goals, natural disturbance can be relied upon to sustain disease levels in most old forests. Several diseases, particularly heart rots and dwarf mistletoe, are favored by small-scale disturbance processes that prevail in old forests. Or, on more highly managed lands, various retention harvesting techniques can be used to sustain both of these diseases. Trees with heart rot or hemlock dwarf mistletoe can be retained as individual trees or in reserve patches where they will continue to contribute various ecological benefits. Levels of dwarf mistletoe can be manipulated through the distribution, size, and infection levels of residual trees that remain after harvest. These diseases will vary through time in a predictable manner by whatever silvicultural strategy is adopted. Thus, retention harvesting is a useful tool in a more complex management scenario that attempts to produce timber and also maintain ecological processes and wildlife habitat.

Figure 20. *Hemlock dwarf mistletoe mortality with distinctive "witch's brooms."*

Diseases & Declines

Enhancing disease levels

Young-growth, even-aged forests generally lack the structural diversity and many elements and processes found in old forests. Heart rot is either absent or present in only small amounts in most young-growth forests until trees reach the age of about 150 years. Porcupine feeding, logging wounds, or any other form of bole or top injury can greatly speed the time in which heart rot develops in young forests. Thus, thinning treatments that result in top and bole injuries to residual trees can be used to restore heart rots, and their associated ecological functions, to these forests. The actual decay levels can be manipulated intentionally because decay development in wounded trees is highly predictable for hemlock and spruce.

Invasive pathogens

Currently, no serious exotic tree pathogens occur in Alaska. Several exotic pathogens have been found e.g., white pine blister rust, but because of the limited number of plant species that these pathogens can attack, none present pose a serious threat to the health of Alaskan forests. We have initiated a review of worldwide literature in an attempt to identify the tree pathogens that, if introduced, could cause damage to native tree species in Alaska. Our approach is mainly based on host taxa; that is, to review scientific literature on the fungal pathogens that infect close relatives (e.g., same genus) of Alaska tree species. A number of species have been identified from Europe and Asia that are potential threats to Alaska (Table 5). Preliminary qualitative rankings are given for each of these species based on the type and severity of the disease that they cause in their native forests, their adaptability to Alaska's climate, and their likelihood of introduction.

Table 5. Invasive pathogens either currently present in, or thought to be coming to Alaska.

Common name	Scientific name	Present?	Ranking
Spruce needle rust	*Chrysomyxa abietis* (Wallr.) Unger	No	High
Rhododendron-spruce needle rust	*Chrysomyxa ledi* var. rhododendri (de Bary.) Savile	No	Moderate
Resinous stem canker	*Cistella japonica* Suto et Kobayashi	No	Moderate
Cedar shot hole	*Didymascella chamaecyparidis* (J. F. Adams.) Maire	No	Moderate
Cedar leaf blight	*Lophodermium chamaecyparissi* Shir & Hara.	No	Moderate
Poplar rust	*Melampsora larici-tremulae* Kleb.	No	Moderate
Seiridium shoot blight	*Seiridium cardinale* (Wagener) Sutton & Gibson	No	Moderate
Phytophthora root disease	*Phytophthora lateralis* Tucker & Milbrath	No	Moderate
Needle and twig blight	*Acanthostigma parasiticum* (Hart.) Sacc.	No	Low
Black knot	*Apiosporina morbosa* (Schwein.:Fr.) Arx	Yes	Low
Pine wilt nematode	*Bursaphelenchus xylophilus*	No	Low
White pine blister rust	*Cronartium ribicola* J.C. Fischer: Rabh.	Yes	Low
Fire blight	*Erwinia amylovora* (Burrill) Winslow	Yes	Low
Sudden oak death	*Phytopthora ramorum* Werres deCock Man in't Veld	No	Low
Birch leaf curl	*Taphrina betulae* (Fckl.) Johans.	No	Low
Birch witches broom	*Taphrina betulina* Rostr.	No	Low
Valsa canker	*Valsa harioti*	No	Low

Stem Diseases

Hemlock Dwarf Mistletoe

Arceuthobium tsugense (Rosendhal) G.N. Jones

Hemlock dwarf mistletoe is an important disease of western hemlock in unmanaged old-growth stands throughout southeast Alaska as far north as Haines. Although the range of western hemlock extends to the northwest along the Gulf of Alaska, dwarf mistletoe is absent from Cross Sound to Prince William Sound.

Figure 21. *Western hemlock with dwarf mistletoe and characteristic "witch's broom."*

It is difficult to detect dwarf mistletoe during aerial surveys, but new estimates of occurrence are available from Pacific Northwest Research Station, Forest Inventory and Analysis (FIA) plots. Approximately 12 percent of forest land in southeast Alaska is infested with hemlock dwarf mistletoe (Table 6). Ignoring the inaccessible wilderness not sampled, hemlock dwarf mistletoe occurs on approximately 830,000 acres. Including wilderness areas would increase this estimate to more than one million acres of forest infested with hemlock dwarf mistletoe in southeast Alaska. Most of this occurrence is in the old sawtimber classes, and both the young and old sawtimber classes have a higher proportion occurrence (19.8 and 13.5 percent, respectively) than in the smaller size classes. These values are likely conservative estimates because dwarf mistletoe may not have been recorded when other damage agents were present. Also, it is important to note that scattered larger trees may have been present in the plots designated as smaller and younger classes. This could explain, in part, the higher level of hemlock dwarf mistletoe in the young sawtimber class.

Table 6. Occurrence of hemlock dwarf mistletoe on Forest Inventory and Analysis (FIA) plots in southeast Alaska.[1]

Stand Size Class[2]	Accessible Forest Sampled[3]	Mistletoe Present	Percent of Land
Seedling/sapling	667	27	4.1
Poletimber	423	10	2.3
Young sawtimber	699	138	19.8
Old sawtimber	4,863	655	13.5
Nonstocked	217	0	0.0
All size classes	6,869	830	12.0

[1] Acres in thousands.
[2] Size classes terms from FIA and defined by plurality of stocking by live, growing stock trees. Poletimber sized trees: dbh > 5 inches and < sawtimber sized; sawtimber sized trees: dbh > 9 inches for softwoods and > 11 inches for hardwoods. Young sawtimber and old sawtimber distinguished by aging of sample trees.
[3] Includes all forest lands in southeast Alaska extending to the Malaspina Glacier northwest of Yakutat; does not include wilderness areas (i.e., inaccessible) not sampled by FIA.

Hemlock dwarf mistletoe is concentrated at low elevations in southeast Alaska (Figure 22). Productive forest land represents most of the occurrence. There is an apparent threshold at approximately 500 feet on both productive and unproductive forest lands, above which the parasite can occur, but is less common. The principle host, western hemlock is distributed well above this threshold, suggesting that some climatic factor limits the distribution of hemlock dwarf mistletoe at higher elevations.

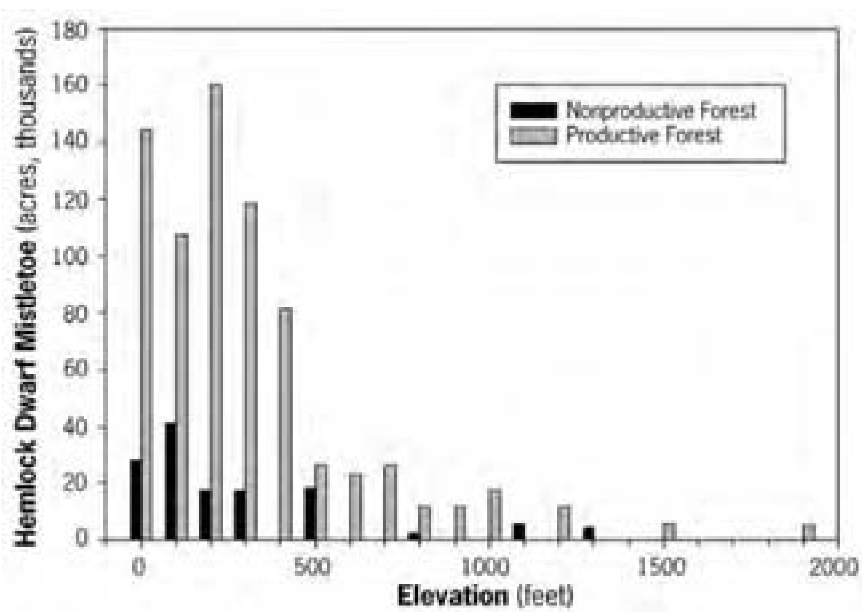


Figure 22. *Occurrence of hemlock dwarf mistletoe in southeast Alaska by elevation zones (100 foot classes) on lands supporting either "unproductive" (stocked, but not capable of producing 1.399 cubic meters per hectare per year at culmination of mean annual increment) or "productive" forests (capable of producing 1.399 cubic meters per hectare per year at culmination of mean annual increment). Data from Pacific Northwest Research Station, forest inventory and analysis (FIA) plots covering all of southeast Alaska except inaccessible wilderness areas. FIA data were collected between 1995 and 2000.*

The dominant small-scale (canopy gap) disturbance pattern in the old forests of coastal Alaska favors the short-range dispersal mechanism of hemlock dwarf mistletoe and may explain the common occurrence of the disease here. Infection of Sitka spruce is uncommon and infection of mountain hemlock is rare. Heavily infected western hemlock trees have branch proliferations or "witches' brooms," bole deformities, reduced height and radial growth, less desirable wood characteristics, and a greater likelihood of heart rot, top-kill, and death. The aggressive heart rot fungus, *Phellinus hartigii*, is associated with large mistletoe brooms on western hemlock.

These symptoms are all potential problems in stands managed for wood production. Growth loss in heavily infested stands can reach 40 percent or more. On the other hand, witches' brooms, wood decay associated with bole infections, and scattered tree mortality can result in greater diversity of forest structure and increased animal habitat for birds or small mammals, although this topic has not been adequately researched in Alaska. The inner bark of swellings and the seeds and shoots of the parasitic plants are nutritious and often consumed by small mammals (e.g., flying squirrels). Stand composition is altered when mixed-species stands are heavily infected; growth of resistant species such as Sitka spruce and cedar is enhanced.

Spread of the parasite into young-growth stands that regenerate following clearcutting is typically by: 1) infected nonmerchantable hemlock trees (residuals) which are sometimes left standing in cut-over areas, 2) infected old-growth hemlocks on the perimeter of cut-over areas, and 3) infected advanced reproduction. Residual trees may play the most important role in the initial spread and long-term mistletoe development in young stands. Managers using alternative harvest techniques (e.g., large residuals left standing in clearcuts, small harvest units, or partial harvests) should recognize the potential reduction in timber volume and value from hemlock dwarf mistletoe under some of these silvicultural scenarios. Substantial reductions to timber are only associated with very high disease levels, however. High levels of hemlock dwarf mistletoe will only result if numerous large, intensely infected hemlocks are well distributed after harvest. Selective harvesting techniques will be the silvicultural method for maintaining desirable levels of this disease if management intends to emphasize structural and biological diversity along with timber production.

Heart Rots of Conifers

Numerous species

Heart rot decay causes enormous loss of wood volume in all major tree species in Alaskan forests (Table 7). Approximately one-third of the old-growth timber volume in southeast Alaska is defective largely due to heart rot fungi. These extraordinary effects occur where long-lived tree species predominate, such as old-growth forests in southeast Alaska where fire is absent and stand replacement disturbances are infrequent. The great longevity of individual trees allows ample time for the slow-growing decay fungi to cause significant amounts of decay. By predisposing large old trees to bole breakage, these fungi serve as important disturbance factors that cause small-scale canopy gaps.

In the boreal forests, large-scale disturbance agents, including wildfire, insect outbreaks (e.g., spruce beetle), and flooding, are key factors influencing forest structure and composition. Although small-scale disturbances from the decay fungi are less dramatic, they have an important influence on altering biodiversity and wildlife habitat at the individual tree and stand level. In south-central and interior Alaska, heart rot fungi cause considerable volume loss in mature white spruce forests.

Table 7. Common wood decay fungi on live conifer trees in Alaska.

Heart and butt rot fungi[1]	Tree Species Infected Western hemlock	Sitka spruce	Western redcedar	White/Lutz spruce	Mountain hemlock
Laetiporus sulphureus	X	X		X	X
Phaeolus schweinitzii	X	X		X	
Fomitopsis pinicola	X	X		X	X
Phellinus hartigii	X				
Phellinus pini	X	X		X	X
Ganoderma sp.	X	X		X	
Coniophora sp.				X	X
Armillaria sp.	X	X	X	X	X
Inonotus tomentosus				X	
Heterobasidion annosum	X	X			
Ceriporiopsis rivulosa			X		
Phellinus weirii			X		
Echinodontium tinctorium					X

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

Heart rot fungi enhance wildlife habitat indirectly by increasing forest diversity through gap formation and more directly by creating hollows in live trees or logs for species such as bears and cavity nesting birds. The 'white rot' fungi can be responsible for actual hollows because these fungi degrade both cellulose and lignin, leaving a void. The lack of hollows caused by 'brown rot' fungi, which leave lignin largely intact, would appear to lead to less valuable habitat for some animals, although primary excavators can create cavities in this soft wood. Wood decay in both live and dead trees is a center of biological activity, especially for small organisms. Wood decay is the initial step in nutrient cycling of wood substrates and, in the case of brown rot, contributes large masses of stable carbon structures (e.g., partially modified lignin) to the humus layer of soils.

Figure 23. *Heartrot and bole breakage.*

The importance of decay fungi in managed young-growth conifer stands is less certain. Wounds on live trees caused by logging activities provide decay fungi with entrance courts to potentially invade and cause appreciable losses. Heart rot in managed stands can be manipulated to desirable levels by varying levels of bole wounding and top breakage during stand entries. In some instances, bole breakage is sought to occur in a specific direction (e.g., across streams for coarse woody debris input). Artificially wounding trees on the side of the bole that faces the stream can increase the likelihood of tree fall in that direction. Generally, larger, deeper wounds and larger diameter breaks in tops result in a faster rate of decay. Wound-associated heart rot development is much slower in southeast Alaska than areas studied in the Pacific Northwest.

Figure 24. *The red belt conk,* Fomitopsis pinicola. *This fungus is an important heart rot agent of live trees and the dominant decomposer of dead conifers.*

Wood decay fungi decompose branches, roots, and boles of dead trees; therefore, they play an essential role in recycling wood in forests. This is particularly the case in southeast Alaska where fires are rare and thus do not contribute to carbon recycling.

In south-central and interior Alaska, sap rot decay routinely and quickly develops in spruce trees attacked by spruce beetles. Significant volume loss occurs within 3 to 5 years after tree death. Thus, large amounts of potentially recoverable timber volume are lost annually following the massive spruce beetle outbreak of the 1980s and 90s that killed over 3.4 million acres of spruce on the Kenai Peninsula. Research indicates that the most common and conspicuous sap rot fungus associated with dead spruce is *Fomitopsis pinicola*, the red belt fungus. However, over 70 taxa have been detected in dead and down beetle-killed trees.

A deterioration study of beetle-killed trees on the Kenai Peninsula assessed the rate at which beetle-killed trees decompose. Results indicate an overall decomposition rate of 1.5 percent per year, which is slow compared to other spruce ecosystems worldwide. Beetle-killed trees are, therefore, likely to influence fire behavior and present a hazard for over 75 years. Estimates indicate it would take over 200 years for beetle killed trees to completely decompose.

Stem Decay of Hardwoods

Numerous Species

Figure 25. *Stem decay of paper birch caused by the cinder conk,* Inonotus obliquus.

Stem decay causes substantial volume loss and reduces wood quality in Alaskan hardwood species. The incidence of stem decay is high by the time most hardwood forests reach maturity. The most reliable sign of decay is the presence of fruiting bodies (mushrooms or conks) on the stem. Frost cracks, broken tops, dead–broken branches, and poorly healed trunk wounds all provide entrance courts for decay fungi.

Stem decay fungi alter stand structure and composition and appear to be important factors in the transition of even-aged hardwood forests to mixed species forests. Bole breakage of hardwoods creates canopy openings, allowing release of understory conifers. Trees with stem decay, broken tops, and collapsed stems are preferentially selected by wildlife for cavity excavation. Several mammals, including the northern flying squirrel, are known to specifically select tree cavities for year-round nest and cache sites. In south-central and interior Alaska several fungi are the primary cause of wood decay in live paper birch and aspen (Table 8).

Table 8. Common wood decay fungi on live hardwood trees in Alaska.

	Tree Species Infected	
Heart and Butt-rot Fungi	**Paper Birch**	**Trembling Aspen**
Phellinus igniarius	x	
Inonotus obliquus	x	
Phellinus tremulae		x
Pholiota sp.	x	x
Armillaria sp.	x	x
Ganoderma applanatum	x	x

Spruce Broom Rust

***Chrysomyxa arctostaphyli* Diet.**

Broom rust is common on spruce throughout south-central and interior Alaska, but is found in only localized areas of southeast Alaska (e.g., Halleck Harbor area of Kuiu Island and Glacier Bay). Infections by the rust fungus result in dense clusters of branches or witches' brooms. The actual infection process may be favored during specific years, but the incidence of the perennial brooms changes little from year to year.

The disease may impair spruce growth, and witches' brooms may serve as entrance courts for heart rot fungi, including *Phellinus pini*. Ecologically, the dense brooms provide important nesting and hiding habitat for birds and small mammals. In interior Alaska, research on northern flying squirrels suggests that brooms in white spruce are an important habitat feature for communal hibernation and survival in the coldest periods of winter.

Western Gall Rust

***Peridermium harknessii* J.P. Moore**

Infection by gall rust fungus causes spherical galls on branches and main boles of shore pine. The disease was common throughout the distribution of pine in Alaska in 2006. Infected pine tissues are swollen but not always killed by the rust fungus. Another fungus, *Nectria macrospora*, colonized and killed many of the pine branches with rust fungus galls this year. The combination of the rust fungus and *N. macrospora* frequently caused top-kill. The disease, although abundant, does not appear to have a major ecological effect in Alaskan forests.

Shoot Blights and Cankers

Alder Canker

Valsa melanodiscus Otth.

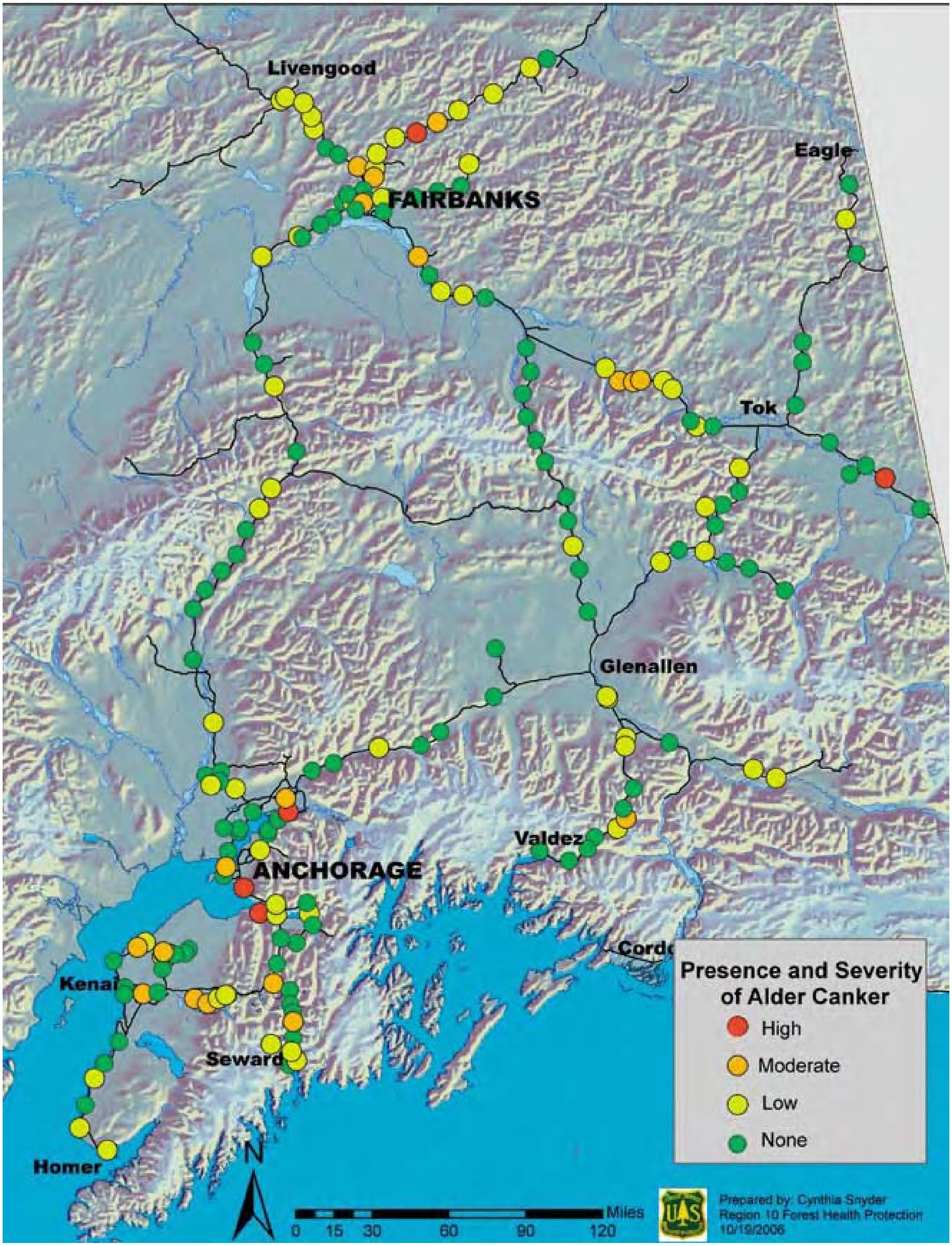
For the fourth consecutive year, cankers caused by *Valsa melanodiscus* were found girdling and killing branches, stems, and genets of alder. This pathogen is the primary agent associated with riparian thin-leaf alder, *Alnus tenuifolia*, dieback and mortality across thousands of acres in south-central and interior Alaska. While the primary host affected is thin-leaf alder, dieback and mortality is occurring and intensifying on Sitka alder, *A. sinuata*, and to a lesser degree on green alder, *A. crispa*. Road surveys in 2006 in south-central and interior Alaska detected the canker at over 100 locations (Map 7). Although presence of *V. melanodiscus* was noted on all three species of alder, 75 percent of sites with *A. tenuifolia* as the dominant species had canker, while only 25 percent of the *A. crispa* and *A. sinuata* dominated sites were infected. An outbreak of alder canker near Council on the Seward Peninsula in 2004 appeared closely tied to sudden intense spring freeze–thaw events, indicating that stress factors play a role in reducing host defenses and/or favoring the pathogen's infection process.

Figure 26. *The margin of a* Valsa melanodiscus *canker is exposed revealing the dead vascular tissue under the canker on the left side of the photo and healthy bark and vascular tissue on the right.*

Monitoring of 16 sites in 2006 revealed that dieback and mortality is intensifying within affected sites and is expected to continue in the near future. Recovery of the alder is not certain as less than half of the dead genets appear to be recovering with live sprouts at the base. Since alder is a keystone successional species, alder mortality may have important long-term ecological consequences. Researchers from the University of Alaska Fairbanks are assessing the impact of dieback and mortality on nitrogen fixation.

Figure 27. *South-central and Interior Pathologist Lori Trummer, explores pervasive alder canker with visiting UAF researchers.*

Map 7. Presence of alder canker, *Valsa melanodiscus* during road surveys of south-central and interior Alaska



Sirococcus Shoot Blight

Sirococcus conigenus (D.C.) P.F. Cannon & Minter

The shoots of young western hemlock were killed in moderate levels by *Sirococcus conigenus* in southeast Alaska during 2006. Mountain hemlock appears to be more susceptible to this pathogen than western hemlock. Several small mountain hemlock trees were severely affected each year from 2003 to 2006. A fungal specimen from a small mountain hemlock in Juneau was sent to pathology colleagues in Wisconsin as part of a study on the taxonomy of North American *Sirococcus* species. There is evidence that the *Sirococcus* affecting hemlock in southeast Alaska is morphologically and genetically distinct from the *Sirococcus* affecting pine throughout much of North America. The *Sirococcus* infecting conifers in Alaska will soon be formally named as *S. tsugae*.

Thinning may be of some value in reducing damage by the fungus as thinned stands have fewer infections than unthinned stands. Ornamental trees can be protected by the application of fungicides in the spring just after bud break when the pathogen produces its infectious spores. This disease is typically of minimal ecological consequence as infected trees are not often killed and young hemlock stands are usually densely stocked. However, species composition in a given area may be altered to some degree where other trees may be favored by the disease.

Shoot Blight of Yellow-cedar

Apostrasseria sp.

The shoot blight fungus, *Apostrasseria* sp., in southeast Alaska infected yellow-cedar regeneration in 2006. The disease does not affect mature cedar trees. Infection by the fungus causes terminal and lateral shoots to be killed back 10 to 20 centimeters on seedlings and saplings during winter or early spring. Entire seedlings up to 0.5 meters tall are sometimes killed. The fungus that causes the disease, *Apostrasseria* sp., is closely related to other fungi that cause disease on plants under snow. The severe late spring frosts in recent years affected so many small yellow-cedar trees that new cases of shoot blight were difficult to detect this year.

The fungus *Herpotrichia juniperi* is often found as a secondary invader on seedling tissues that die from any of these causes. This shoot blight disease probably has more ecological impact than similar diseases on other host species because by killing the leaders of yellow-cedar seedlings and diminishing their ability to compete with other vegetation, the pathogen reduces the regeneration success of yellow-cedar and thereby alters species composition. However, freezing injury and browsing by deer are probably more serious factors limiting yellow-cedar regeneration.

Canker Fungi of Hardwoods

Cryptosphaeria populina **(Pers.) Sacc.**
Cenangium singulare **(Rehm.) D. & Cash**
Ceratocystis fimbriata **Ell. & Halst.**
Cytospora chrysosperma **Pers. ex Fr.**
Nectria galligena **Bres.**

Canker-causing fungi of aspen and other hardwoods were at endemic levels in 2006. Most of these fungi cause perennial target-shaped cankers except for *C. singulare*, which causes a long diffuse stem canker. The vascular tissue beneath the cankers is killed. Although most are considered weak parasites, *C. singulare* can girdle and kill an aspen in three to ten years. Bole breakage typically occurs at the canker sites because of stem weakening at that point.

Figure 28. Ceratocystis fimbriata *on aspen.*

Diseases & Declines

Hemlock Canker

Unknown fungus

The hemlock canker disease was at endemic levels in 2006, although the outbreak from several years ago was still evident as dead stems and branches persisted in several areas in southeast Alaska. The most recent outbreak was especially noticeable in young forests on Prince of Wales Island and Etolin Island. One notable outbreak was in thinned, young western hemlock crop trees near Polk Inlet that were subsequently killed. In past outbreaks, the disease has been common along unpaved roads and roadless areas on Prince of Wales Island, Kuiu Island (Rowan Bay road system), Chichagof Island (Corner Bay road system), and near Carroll Inlet on Revillagigedo Island. Modification of stand composition and structure are the primary effects of hemlock canker. Other tree species, such as Sitka spruce, are resistant and benefit from reduced competition. Wildlife habitat, particularly for deer, may be enhanced where the disease kills understory hemlock which tends to outcompete the more desirable browse vegetation.

White Pine Blister Rust

Cronartium ribicola **J.C. Fischer ex Rabh.**

NON-NATIVE

A single ornamental eastern white pine tree was found to be infected by white pine blister rust in Ketchikan several years ago. The rust fungus was also found sporulating on leaves of the alternate host, an ornamental black currant, at the same location. This was the first report of white pine blister rust in Alaska. The fungus is not native to North America and, while causing devastating mortality in native white pines in some areas of the US and Canada, it does not pose a threat in Alaska because no native trees are susceptible. The ornamental tree is about 20 years old and is being repeatedly reinfected, as evidenced by small young infected branches. Removal of the alternate host may eliminate any new infections. The pathway of the original introduction into Ketchikan is not certain. The tree has received surgical treatment, with infected shoots removed and infected cambial tissue carved away. The health of the tree will be monitored into the future.

Black Knot

Apiosporina morbosum (Schwein.:Fr.) Arx

NON-NATIVE

Black knot, introduced in the early to mid 1980s, is now established in the Anchorage Bowl. Reports of damage continued in 2006. *Prunus padus* and *P. virginiana* are the most commonly affected ornamental trees, while the Amur chokecherry (*P. maackii*) does not appear to be susceptible. Control efforts have been modestly successful.

Figure 29. *Black knot causes unsightly swellings on branches resulting in dieback.*

Infected trees develop perennial black corky swellings or "knots" on branches or the main stem, occasionally resulting in dieback. The primary impact from this disease is loss of aesthetic and economic value of ornamental *Prunus* plantings. Black knot is costly to landscape contractors, nurserymen, businesses, local government, and homeowners due to the dismissal of infected stock and/or the removal and replacement of infected trees.

Fire Blight

Erwinia amylovora (Burrill) Winslow et al.

NON-NATIVE

Fire blight, caused by a bacterium, is an introduced pathogen detected annually in Alaska on various ornamental trees and shrubs. Reports of infection continued in 2006. The bacterium causes leaves and blossoms near the tips to turn brown and die. Infections can move to older portions of the plant causing cankers and branch dieback. Cankers may weep a cloudy, bacteria-laden sap. The disease is not likely established but introduced repeatedly from imported plant material. A concern is the possibility of an outbreak of fire blight on mountain ash (*Sorbus* sp.) trees.

Root Diseases

In Alaska, there are three important tree root diseases: tomentosus root rot, annosus root disease, and armillaria root disease. The laminated root disease caused by a form of the fungus *Phellinus weirii*, important in some western forests of British Columbia, Washington, and Oregon, is not present in Alaska. A form of the fungus that does not cause root disease is present in southeast Alaska. There it causes a white rot in western redcedar, contributing to the very high defect levels in this tree species.

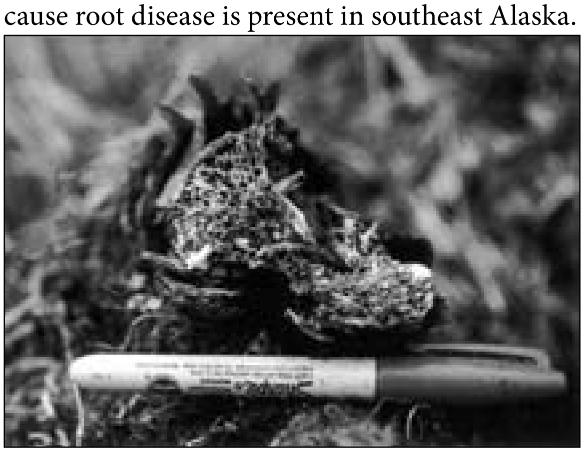


Figure 30. *Uprooting results when root diseases severely compromise the root systems of infected trees.*

Tree infected with root diseases are prone to uprooting, bole breakage, and outright mortality due to the extensive decay of root systems and the lower tree bole. Volume loss attributed to root disease can be substantial, up one-third of the gross volume. In managed stands, root rot fungi are considered long-term site problems because they can remain alive and active in large roots and stumps for decades, impacting the growth and survival of susceptible host species on infected sites.

Root diseases are considered natural, perhaps essential, parts of the forest. They alter stand structure, composition, and increase plant community diversity through canopy openings and scattered mortality. Resistant tree species benefit from reduced competition within infection centers. Wildlife habitat may be enhanced by small-scale mortality centers and increased volume of large woody downed material.

Tomentosus Root Disease

Inonotus tomentosus (Fr.) Teng.

Inonotus tomentosus is the most important root and butt-rot of spruce and may also attack lodgepole pine and tamarack. The disease appears to be widespread across the native range of spruce in south-central and interior Alaska. Recently, tomentosus root rot was found for the first time in southeast Alaska, infecting Sitka spruce near Dyea. Surveys in the Dyea area in 2006 indicated a high level of tomentosus root disease with over 27 percent of surveyed trees infected. Uprooting of root diseased trees at the Dyea site is a concern for public safety.

Figure 31. *Fruiting body of* Inonotus tomentosus.

Inonotus tomentosus will remain alive in colonized stumps for at least three decades, and successfully attack adjacent trees through root contacts. Thus, spruce seedlings planted in close proximity to infected stumps are highly susceptible to infection through contacts with infected roots.

Recognition of this root disease is particularly important in managed stands where natural regeneration spruce is limited and adequate restocking requires planting. The incidence of this root rot is expected to increase on infected sites that are replanted with spruce.

Annosus Root & Butt Rot

Heterobasidion annosum (Fr.) Bref.

Annosus commonly causes root and butt-rot in old-growth western hemlock and Sitka spruce forests in southeast Alaska. The form present in Alaska is the "S type," which causes internal wood decay, but is not typically a tree killer. The high rate of heart rot in old-growth hemlock that was attributed to *H. annosum* by Kimmey in 1956 by examining the appearance of wood decay should probably be reevaluated using modern methods. *Heterobasidion annosum* has not yet been documented in south-central or interior Alaska.

Elsewhere in the world, spores of the fungus are known to readily infect fresh stump surfaces, such as those found in clearcuts or thinned stands. Studies in managed stands in southeast Alaska, however, indicate limited stump infection and survival of the fungus. Thus, this disease poses minimal threat to young managed stands from stump top infection. Reasons for limited stump infection may be related to climate. High rainfall and low temperatures, common in Alaska's coastal forests, apparently hinder infection by spores.

Armillaria Root Disease

Armillaria sp.

Several species of *Armillaria* occur in the coastal forests of southeast Alaska, but in general, these species are less aggressive saprophytic decomposers that only kill trees that are under some form of stress. Studies in young, managed stands indicate that *Armillaria* sp. can colonize stumps, but will not successfully attack adjacent trees. *Armillaria* may be an important agent in the death and decay of red alder. A few red alder trees were found apparently killed by *Armillaria* in 45-year old mixed hardwood–conifer forests in the Maybeso Valley of Prince of Wales Island. Many more affected red alders were found in 100+ year-old mixed forests on Baranof Island and Chichagof Island, indicating that the disease may be important in the senescence of alder as these stands age.

Figure 32. *Armillaria mushrooms.*

Several species of *Armillaria* occur in south-central and interior Alaska where some invade conifers and others invade hardwoods. Most species appear to be weak pathogens invading trees under stress. Mature stands of paper birch and trembling aspen are particularly susceptible to attack by *Armillaria*.

Foliar Diseases

Spruce needle rust occurred at low to moderate levels statewide. This needle rust was particularly evident from the Glen Highway east to the Canadian border. All of the other needle diseases occurred across the state at low levels in 2006 (Table 9).

Table 9. Common foliar diseases of trees in Alaska.

Common Name	Scientific Name	Conifer Hosts
Spruce Needle Rust	*Chrysomyxa ledicola* Lagerh.	All spruce species
Weir's Spruce Cushion Rust	*Chrysomyxa weirii* Jacks.	Sitka spruce
Spruce Needle Blights	*Lirula macrospora* (Hartig) Darker *Lophodermium picea* (Fuckel) Hhn. *Rhizosphaera pini* (Corda) Maubl.	All spruce species
Hemlock Needle Rust	*Naohidemyces vaccinii* (Wint.) Sato	Western hemlock
Pine Needle Blight	*Lophodermium seditiosum* Min., Sta. & Mill.	Native Shore Pine

Declines

Along with insects and diseases, many other contributing factors affect forest health. Predisposing factors, those which result in stresses that remain in a relatively fixed state, include forest age, genetic potential, climate change, urban disturbances, poor soil fertility, and drainage. Factors with relatively short duration periods but severe impacts, known as inciting factors, include not only insects and disease but also abiotic factors such as drought, frost, wind, and fire. The combination of predisposing and inciting factors may function as agents of decline affecting vast acreages. This section describes the most important declines mapped, monitored, or surveyed in 2006.

Yellow-cedar Decline

Yellow-cedar decline is one of the most prominent forest health issues in Alaska. The principal tree species affected, yellow-cedar, is an economic and culturally important tree. An abnormal rate of mortality to yellow-cedar began in about 1900, accelerated in the mid 1900s and continues today. These forests generally now have mixtures of old dead, recently dead, dying, and living trees. The extreme decay resistance of yellow-cedar results in trees remaining standing for about a century after death and allowed for the reconstruction of cedar population dynamics through the 1900s.

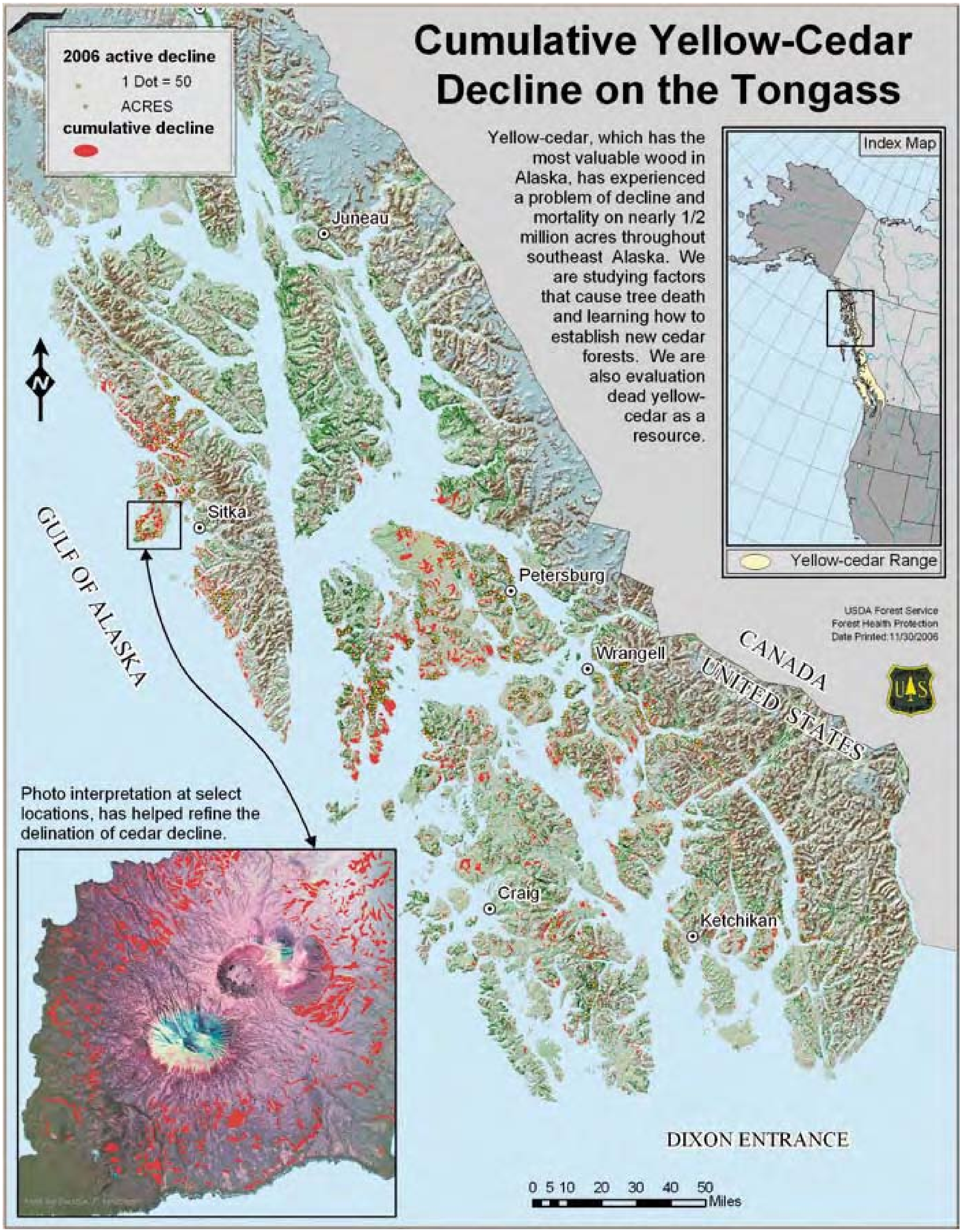
Approximately 500,000 acres of decline have been mapped during aerial detection surveys. The extensive mortality occurs in a wide band from western Chichagof and Baranof Islands to the Ketchikan area (Table 10). During the 2006 annual aerial detection survey, actively dying trees were noted in many locations including Peril Strait, south of Sitka on western Baranof Island, southern Kuiu Island, the mainland near Wrangell Island, and various areas on Kupreanof Island. Several years ago, we discovered that yellow-cedar decline extend approximately 100 miles south into British Columbia, where mapping efforts continued in 2006 (Map 8).

The entire distribution of yellow-cedar decline suggests climate as a trigger for initiating the forest decline. Our current state of knowledge suggests that yellow-cedar decline may by a form of freezing injury. Trees may be predisposed by growing on wet sites where roots are shallow and temperature fluctuations are extreme. Soil warming in these exposed growing conditions may cause premature dehardening and contribute to spring freezing injury. Our collaborative research with experts from Vermont on cold tolerance testing of cedar supports this hypothesis, as yellow-cedar trees are quite cold hardy in fall and mid winter, but are susceptible to spring freezing. Snow appears to be the key environmental factor in yellow-cedar decline; where snow is present in spring, yellow-cedar trees appear to be protected from this presumed freezing injury.

Table 10. Acreage affected by yellow-cedar decline in southeast Alaska by ownership

National Forest	**488,154**	**Native Land**	**19,690**
Admiralty National Monument	**5,363**	Admiralty Island	55
Craig Ranger District	**32,246**	Baranof Island	305
Dall & Long Islands	1,111	Chichagof Island	954
Prince of Wales Island	31,135	Dall and Long Island	1,361
Hoonah Ranger District	**1,350**	Kruzof Island	143
Chichagof Island	1,350	Kuiu Island	579
Juneau Ranger District	**951**	Kupreanof Island	4,055
Mainland	951	Mainland	877
Ketchikan Ranger District	**35,861**	Revillagigedo Island	2,301
Annette & Duke Islands	1,770	Prince of Wales Island	9,060
Gravina Island	1,113	**Other Federal**	**472**
Mainland	15,846	Baranof Island	33
Revillagigedo Island	17,132	Chichagof Island	3
Misty Fjords National Monument	**27,928**	Prince of Wales Island	88
Mainland	18,700	Etolin Island	35
Revillagigedo Island	9,228	Kuiu Island	175
Petersburg Ranger District	**163,269**	Kupreanof Island	138
Kuiu Island	70,347	**State & Private Land**	**23,460**
Kupreanof Island	76,315	Admiralty Island	40
Mainland	8,178	Baranof Island	3,801
Mitkof Island	6,026	Mainland	3,120
Woewodski Island	2,403	Chichagof Island	1,164
Sitka Ranger District	**118,574**	Dall and Long Island	53
Baranof Island	52,761	Etolin Island	22
Chichagof Island	38,269	Gravina Island	1,260
Kruzof Island	27,544	Heceta Island	66
Thorne Bay Ranger District	**50,045**	Kosciusko Island	179
Heceta Island	1,379	Kruzof Island	299
Kosciusko Island	12,827	Kuiu Island	658
Prince of Wales Island	35,839	Kupreanof Island	1,542
Wrangell Ranger District	**52,567**	Mitkof Island	1,467
Etolin Island	21,153	Prince of Wales Island	4,235
Mainland	15,562	Revillagigedo Island	4,186
Woronofski Island	536	Wrangell Island	1,368
Wrangell Island	9,832		
Zarembo Island	5,484	**Total Land Affected**	**531,776**

Map 8. Occurrence of yellow-cedar decline in southeast Alaska



Mapping yellow-cedar decline at three different spatial scales also is consistent with this climate-freezing scenario. At the broadest scale, the distribution of yellow-cedar decline is associated with parts of southeast Alaska that have mild winters with little snowpack. At the mid-scale, we are finding elevation limits to yellow-cedar decline, above which cedar forests appear healthy. This elevation limit is consistent with patterns of snow persistence in spring. For example, the mortality problem is found up to 1,000 feet or slightly higher on some southern aspects, but only to about 500 feet on nearby northern aspects in a study area at Peril Strait and Mount Edgecumbe. Our studies at the fine scale help us define the role of wet soils in creating exposed conditions for trees. Here, we also measure the influence of exposure on soil warming and rapid air temperature fluctuations, as well as snow deposition and persistence.

Figure 33. *Healthy yellow-cedar dominates high elevations on Mount Edgecumbe.*

Throughout most of its natural range, yellow-cedar is restricted to high elevations. We speculate that yellow-cedar trees became competitive at low elevation in southeast Alaska during the Little Ice Age (approximately 1500 to 1850 AD) when there were periods of heavy snow accumulation. Our information on tree ages indicates that most of the trees that died during the 1900s, and those that continue to die, regenerated during the Little Ice Age. Trees on these low elevation sites are now susceptible to exposure-freezing injury due to inadequate snowpack during this warmer climate.

The primary ecological effect of yellow-cedar decline is to alter stand structure (i.e., addition of numerous snags) and composition (i.e., yellow-cedar diminishing and other tree species becoming more abundant) that leads to eventual succession favoring conifer species such as western hemlock and mountain hemlock (and western redcedar in many areas south of latitude 57). Also, in some stands where cedar decline has been ongoing for up to a century, large increases in understory biomass accumulation of shrubby species is evident. Nutrient cycling may be altered, especially with large releases of calcium as yellow-cedar trees die. The creation of numerous snags is probably not particularly beneficial to cavity-using animals because yellow-cedar wood is less susceptible to decay. Region-wide, this excessive mortality of yellow-cedar may lead to diminishing populations (but not extinction) of yellow-cedar, particularly when the poor regeneration of the species is considered. Planting of yellow-cedar is encouraged in harvested, productive sites where the decline does not occur to make up for these losses in cedar populations.

The large acreage of dead yellow-cedar and the high value of its wood suggest opportunities for salvage. Cooperative studies with the Wrangell Ranger District, the Forest Products Laboratory in Wisconsin, Oregon State University, Pacific Northwest Research

Station, and State and Private Forestry are investigating the mill-recovery and wood properties of snags of yellow-cedar that have been dead for varying lengths of time. This work includes wood strength properties, durability (decay resistance), and heartwood chemistry.

Figure 34. *Yellow-cedar decline at lower elevation on Mount Edgecumbe. This mortality problem probably has a link to climate change, particularly with low snowpack. Dead yellow-cedar forests represent a considerable resource for salvage recovery as wood properties are maintained long after tree death.*

We are working with managers to devise a conservation strategy for yellow-cedar in southeast Alaska. The first step in this strategy is partitioning the landscape into areas where yellow-cedar is no longer well adapted (i.e., declining forests), areas where yellow-cedar decline does not now occur but is projected to develop in a warming climate, and areas where decline will not likely occur. Salvage recovery of dead standing yellow-cedar trees in declining forests can help produce valuable wood products and offset harvests in healthy yellow-cedar forests. Yellow-cedar can be promoted through planting and thinning in areas suitable for the long-term survival of this valuable species on sites at higher elevation with adequate spring snow or on sites with good drainage that support deeper rooting.

Drought Stress of Birch Stands in South-central Alaska

Beginning in 2003, numerous scattered Alaska birch (*Betula neoalaskana*) trees in urban and suburban landscapes exhibited symptoms commonly associated with drought stress (e.g. scorched leaf margins, beginning in the tops of tree crowns, early leaf fall, and mortality of individual trees and small groups of trees). Then in 2005, following the record hot, dry summer of 2004, birch trees in hardwood and mixed conifer forests in south-central and interior Alaska were observed for the first time to exhibit signs of drought stress similar to trees in urban and suburban landscapes. Also in 2005 during Forest Health Monitoring (FHM) aerial surveys, stands of Alaska birch trees were observed to have thin crowns that were attributed to defoliating insects, although the defoliation signature was suspect. Several site visits and anecdotal reports indicated that these birch stands produced leaves a fraction of their normal size or none at all—suggestive of acute drought stress.

Further site visits were necessary to determine to what extent stands of Alaska birch were exhibiting symptoms of drought stress, to characterize the response of the birch stands to drought stress, and to identify site characteristics that could potentially assist FHM aerial surveyors to discriminate between insect defoliation and drought stress.

Aerial surveys were conducted along the road system in interior and south-central Alaska during the early spring of 2006, after full leaf-out, but before insect defoliator damage was prevalent. Birch (and some quaking aspen) forests that had thin canopies or that were not

Figure 35. *Birch in interior Alaska showing signs of decline.*

leafing out were mapped. In total, 1,140,824 acres were surveyed. In the Interior, 518,416 acres were surveyed, of which 6,253 (1.21 percent) acres were mapped as being potentially drought-stressed (mostly quaking aspen). In south-central, 622,408 acres were surveyed, of which 3,788 (0.61 percent) acres were mapped as being potentially drought-stressed (mostly Alaska birch).

Site visits to unhealthy and adjacent healthy birch stands (for comparative purposes) were conducted from mid-July through August 2006. This sampling effort was conducted in the Anchorage Bowl, from Anchorage to Palmer, where the majority of the unhealthy birch stands were located. A total of 18 birch stands (10 in decline, 8 healthy) were sampled.

Site characteristics (slope, aspect, soils) were similar between the unhealthy and healthy birch stands. However, most declining birch stands were classified as open canopy birch forest, while healthy birch stands were classified as closed canopy birch forests. Compared to the healthy birch stands, unhealthy birch stands tended to have larger diameter trees, lower tree densities, smaller total basal areas, and less canopy cover. Unhealthy birch stands were older than the healthy birch stands, and many of the trees has indicators (e.g. fungus conks) of extensive internal decay. In the unhealthy birch stands, 86 percent of the overstory trees were in decline, and the average mortality of those tree crowns was 46 percent. In contrast, in the healthy birch stands, 30 percent of the overstory trees were in decline, and the average mortality of those crowns was 6 percent. A tree crown was defined as being in decline if at least 5 percent of the crown was dead.

Understory vegetation was dominated by blue joint grass (*Calamagrostis canadensis*) in 80 percent of the unhealthy birch stands. Green alder (*Alnus crispa*) dominated the remaining 20 percent of the unhealthy birch stands. In contrast, blue joint grass only dominated the understory vegetation in 37.5 percent of the healthy birch stands. High-bush cranberry (*Viburnum edule*) and oak fern (*Gymnocarpium dryopteris*) each dominated the understory vegetation in 25 percent of the healthy birch stands. Understory vegetation in the declining birch stands was very healthy. No unusual insect problems were associated with the declining birch stands.

The unhealthy birch stands that were sampled are in decline, with drought stress as a likely abiotic stressor, but stand age and history are also a factor in the decline of these forests.

The Status of Abiotic Factors and Animal Damage

Fireweed blooming in areas affected by the fires of 2005.

Abiotic & Animal

The Status of Abiotic Factors and Animal Damage

The forest ecosystems of Alaska are in a constant state of adjustment within their successional development following some form of disturbance. Disturbances influence forest structure and function; from the falling of a single tree due to stem decay to physical forces such as drought that affect vast acreages. Disturbance in Alaska is often created by insects and diseases, but geologic processes, climatic forces, and the activities of animals and humans also have a role. This section describes the most important abiotic agents and animal damage mapped, monitored or surveyed in 2006.

Abiotic Damage

Hemlock Fluting

Hemlock fluting is characterized by deeply incised grooves and ridges extending vertically along boles of western hemlock (Figure 36). Fluting is distinguished from other characteristics on tree boles, such as old callusing wounds and root flaring, in that fluting extends near or into the tree crown and fluted trees have more than one groove. This condition, common in southeast Alaska, reduces the value of hemlock logs because they yield less saw log volume and bark is contained in some of the wood. The cause of fluting is not completely understood, but associated factors include: increased wind-firmness of fluted trees, shallow soils, and a triggering mechanism during growth release (e.g., some stand management treatments or disturbance). The asymmetrical radial growth appears to be caused by unequal distribution of carbohydrates due to the presence of dead branches. After several centuries, fluting sometimes is no longer outwardly visible in trees because branch scars have healed over and fluting patterns have been engulfed within the stem. Bole fluting has important economic impact, but may have little ecological consequence beyond adding to wind firmness. The deep folds on fluted stems of western hemlock may be important habitat for some arthropods and the birds that feed upon them (e.g., winter wren).

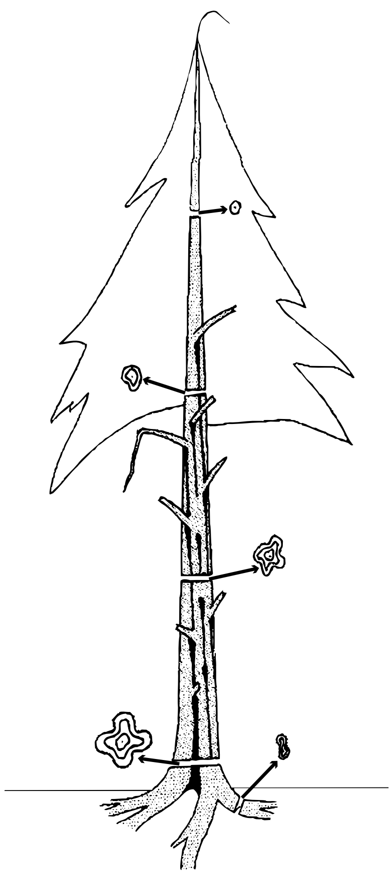


Figure 36. *Hemlock fluting branches disrupt the vertical flow of carbohydrate in the stem causing annual rings to become asymmetrical. Flutes originate beneath decadent branches and extend downward, forming long grooves where other branches are intersected. (Figure and caption from Julin, K.R.; Farr, W.A. 1989. Stem Fluting of Western Hemlock in Southeast Alaska.).*

Windthrow

While in most years, several hundred acres of windthrow are detected, in 2006, only two areas totaling approximately 150 acres about 31 miles southeast of Delta Junction were noted.

Wildfire

The 2006 fire season was marked by a reduction in activity from the past two years in Alaska. Both 2004 and 2005 were record fire years for the state (4.66 million and 6.6 million acres burned, respectively). There were 307 fires totaling 266,268 acres reported at the end of 2006 by the Alaska Interagency Coordination Center.

Animal Damage

Porcupine feeding

Porcupines represent one of the only disturbance agents in the young-growth forests of southeast Alaska. Feeding on the boles of spruce and hemlock leads to top-kill or mortality, reducing timber values but enhancing stand structure. This form of tree mortality leads to a thinning in these forests; however, the largest, fastest growing trees are frequently killed. Porcupines are absent from several areas of southeast Alaska, most notably Admiralty, Baranof, Chichagof, Prince of Wales, and nearby islands. Feeding appears most severe on portions of Mitkof and Etolin Islands in the center of southeast Alaska. There, feeding is intense in stands that are about 10 to 30 years of age and on trees that are about 4 to 10 inches in diameter. As stands age, porcupine feeding typically tapers off, but top-killed trees often survive to form forked tops and internal wood decay as a legacy of earlier feeding. Thinning plans are being modified in these areas. Western redcedar and yellow-cedar are not attractive to porcupines as a source of food; thus, young stands with a component of cedar provide more thinning options.

Figure 37. *Porcupine feeding damage in southeast Alaska.*

Status of Invasive Plants

Infestations of spotted knapweed along Turnagain Arm.

Volunteers remove dense mats of bird vetch from a riparian area.

While purple loosestrife control work is underway in Chester Creek, this species is still grown in surrounding home gardens.

Second year of purple loosestrife control work in Chester Creek.

Status of Invasive Plants

Partnering is Key in Invasive Plants Program

While 2005 was marked by an increase in public awareness of the threats posed by invasive plants to the state's forests, subsistence resources, wildlife, agriculture, land values, and diverse ecosystems, 2006 witnessed the largest number of organizations involved in invasive plant prevention and management in Alaska to date. Media coverage and public involvement in 2005 spurred municipalities, nongovernmental organizations, and state government to address invasive plants on the lands they manage. Some are adopting invasive plant prevention policies, while others have initiated volunteer weed management programs. At the state level, the Alaska Department of Natural Resources is currently soliciting public input on a proposal to add orange hawkweed (*Hieracium aurantiacum* L.) and purple loosestrife (*Lythrum salicaria* L.) to the state's Prohibited Noxious Weed list.

Figure 38. *UAF Cooperative Extension and Forest Health Protection provide technical training in invasive plant ID workshops.*

A new Integrated Vegetation Management position within the Alaska Department of Transportation will help to address highway roadside seeding as a vector for invasive plant introductions, and the spread of invasives along some of the most problematic disturbance corridors—the state's road system. A statewide interagency Alaska Invasive Species Working Group (AISWG) was developed through the University of Alaska Cooperative Extension Service (UAF-CES) with funding from the U.S. Environmental Protection Agency. At the local level, the Municipality of Anchorage "Citizens Weeds Warriors" logged many hours engaged in manual invasive plant removal projects in city parks, forests, wetlands, and greenbelts throughout the summer of 2006.

The increasing diversity and abundance of invasive plant species in Alaska may be attributed to a wide range of opportunities for invasive plant introductions, coupled with warming temperatures and longer growing seasons in recent years. 2006, however, was characterized by a cool spring with lower average temperatures than in recent years, followed by above average rainfall in August. Although Alaska's native flora may be better adapted to these cooler and wetter growing conditions, established populations of invasive plants continued to expand. Spotted knapweed (*Centaurea stoebe* L. ssp. micranthos (Gugler) Hayek) has spread to five locations along the Turnagain Arm in south-central Alaska, and is present on Prince of Wales Island, Haines, and Ketchikan in southeast Alaska. On-going survey work on Prince of Wales Island found that 79 species of non-native plants, including spotted knapweed, Japanese knotweed (*Polygonum cuspidatum* Sieb. & Zucc.), and Scotch broom (*Cytisus scoparius* (L.) Link), have spread to over 16,000 infestations along roads and other disturbance corridors. Purple loosestrife, a notorious wetland invader first detected in an Anchorage-area wetland in 2005, is now known to occupy three locations along the Chester Creek drainage. Newly-detected exotic plant species of concern in 2006 include greater burdock (*Arctium lappa* L.), Maltese star-thistle (*Centaurea melitensis* L.) found in nursery stock, common hawkweed (*Hieracium lachenalii* K.C. Gmel.), rough hawkweed (*H. scabrum* Michx.), and New England hawkweed (*H. sabaudum* L.).

Figure 39. *Natural Heritage Program staff assist USFS and UAF Cooperative Extension with public education at a Weed ID Workshop.*

The Forest Service, Alaska Region, State and Private Forestry collaborated with a wide range of partner agencies and organizations on research, survey, and public education projects in 2006, providing planning and oversight, funding, staffing, and other resources.

Over 25 years of successful collaboration between Alaska Region, State and Private Forestry and the University of Alaska Cooperative Extension Service (UAF-CES) Integrated Pest Management Program continues to emphasize invasive species prevention and early detection in Alaska. Acting as a bridge to the Alaskan public, UAF-CES provides statewide invasive plants public education as well as scouting and inventory work for the AKEPIC database. New publications generated by Alaska Region Forest Health Protection in collaboration with UAF-CES include an informational flier on preventing the spread of invasive plants into the backcountry, and an 8-page color guide for gardeners, listing invasive horticultural plants and providing noninvasive alternatives.

In addition to publications, UAF-CES fosters public invasive plants awareness through conferences, lectures, workshops, site visits, and individual client contacts. UAF-CES sponsored workshops include the "Invasive Plants ID Workshop," where live specimens are brought into a classroom setting and participants learn to identify the invasive plants of concern in their region. UAF-CES organized and hosted the seventh annual Alaska Committee for Noxious and Invasive Plant Management (CNIPM) conference in 2006. Over 100 participants from around the state took part in two days of invasive plant workshops and presentations by state and national speakers. The Forest Service and UAF-CES cofacilitated the reorganization of CNIPM in 2006, facilitating the creation of a new Charter and Board of Directors for the organization.

UAF-CES invasive plant inventory work continued in 2006, with Anchorage-based technicians collecting data from across the state's population center for the Alaska Exotic Plants Information Clearinghouse (AKEPIC) statewide database. UAF-CES survey data and data from several other Forest Service-funded surveys in 2006 was submitted to the AKEPIC

The Significance of Invasive Organisms in Alaska

Invasive pests (introduced exotic plants, animals, insects, and microbes which spread aggressively and displace native species) are a serious threat to biological diversity, and consequently have gained increased publicity both nationally and within Alaska. For example, the amber-marked birch leaf miner has spread from Anchorage to much of south-central and interior Alaska, and the Alaska Department of Natural Resources is currently asking for public input on whether to add two invasive plants, orange hawkweed and purple loosestrife to the state's Prohibited Noxious Weeds list.

Of primary concern for Alaska is the introduction of organisms from the continental United States, Canada, and the Russian Far East. As global climate change drives warming trends in arctic regions, the probability increases that organisms introduced into Alaska, either accidentally or intentionally, will become established and begin to spread. Alaska's soaring tourism industry and strategic location as an international trade and travel hub elevate the risk of introduction dramatically. Many newly initiated and ongoing invasive species prevention, early detection, and management programs specific to Alaska are described in this report.

Once established, invasive pest populations can be extremely difficult to manage. In general, invasive organisms are not subject to the complement of parasites and predators that served to check their population sizes in native habitats. Further, Alaska's forests are fairly homogenous, largely characterized by one of six canopy-dominant species. This relative lack of biodiversity makes the state's forests much more susceptible to large-scale, severe disturbance, were an invasive insect, disease, or noxious weed to become established.

Figure 40. *Invasive non-native organisms such as white pine blister rust, uglynest caterpillar, and purple loosestrife are found in Alaska. Forest Health Protection works with a variety of cooperators on projects to reduce the impacts of invasive organisms.*

Ecologists now recognize that it is far easier and more economical to prevent the introduction of invasive species and respond quickly to small, incipient populations than to wait until they have become widely established. The recent introduction of the amber-marked birch leaf miner, for instance, has served to highlight the increasing risk to Alaskan forests and emphasize the need to further develop an early warning system with a wider scope for detecting introductions. The USDA Animal & Plant Inspection Service (APHIS), the State of Alaska Divisions of Agriculture and Forestry (AK DOA, AK DOF), the University of Alaska Cooperative Extension Service (UAF-CES), and the Forest Service, Forest Health Protection have programs in place to monitor and detect potential insect, disease, or invasive plant introductions. For further information about invasive species of concern in Alaska, or to report an invasive species, contact UAF-CES, APHIS, or AK DOF. Alaska residents, resource professionals, and land managers all have roles and responsibilities to address exotic invasive species prevention, early detection, and management.

- Michael Shephard and Jamie Nielsen

database, which now contains 43,472 data points taken at 9,931 sites across the state, all accessible online (http://akweeds.uaa.alaska.edu). The AKEPIC database is hosted and maintained by another Forest Service collaborator; the UAA Natural Heritage Program. Treatment options for problematic invasive plants in Alaska will be available to land managers and the general public by spring 2007, at a new Forest Service-funded, UAF-CES based website (http://www.akipm.org).

In an effort to provide comprehensive, science-based information on which exotic plant species have the greatest potential to spread aggressively and negatively impact natural systems, Forest Health Protection had provided three years of funding for the UAA Alaska Natural Heritage Program's Invasive Plant Ranking Project. Forest Health Protection has actively participated in the ranking process, along with the UAF Cooperative Extension Service, the USDI National Park Service, the USDA Agricultural Research Service, and the US Geological Survey. In 2006 the Natural Heritage Program completed the process of researching and assigning invasiveness rankings to 112 exotic plant species, with assessments and summaries available online (http://akweeds.uaa.alaska.edu/index.htm).

Based on the existing structure of the NRCS Soil and Water Conservation Districts in Alaska, several Cooperative Weed Management Areas (CWMAs) have been formed and are actively addressing invasive plants prevention and management in their regions of the state. In Alaska there are currently three functioning CWMAs: in Fairbanks, the Matanuska-Susitna Valley, and the Kenai Peninsula. Although not officially a CWMA, the Kodiak Soil and Water Conservation District functions as one, and there is interest in forming a CWMA in Anchorage. Currently there is funding available to CWMAs for invasive plants education and outreach, inventory, and treatment through the Invasive Plant Program (IPP) administered by the Alaska Association of Conservation Districts (AACD). Alaska Region State and Private Forestry provided funding to AACD in 2006 to support a statewide "CWMA Coordinator" position. This position has provided valuable assistance with CWMA formation, grant applications, reporting, and CWMA-sponsored invasive plant pubic education and management projects. The Coordinator also represents the state's CWMAs as a member of the newly-formed interagency Alaska Invasive Species Working Group.

Figure 41. *Tiphanie Henningsen, season technician with Forest Health Protection, helped map white sweet clover infestation across the state.*

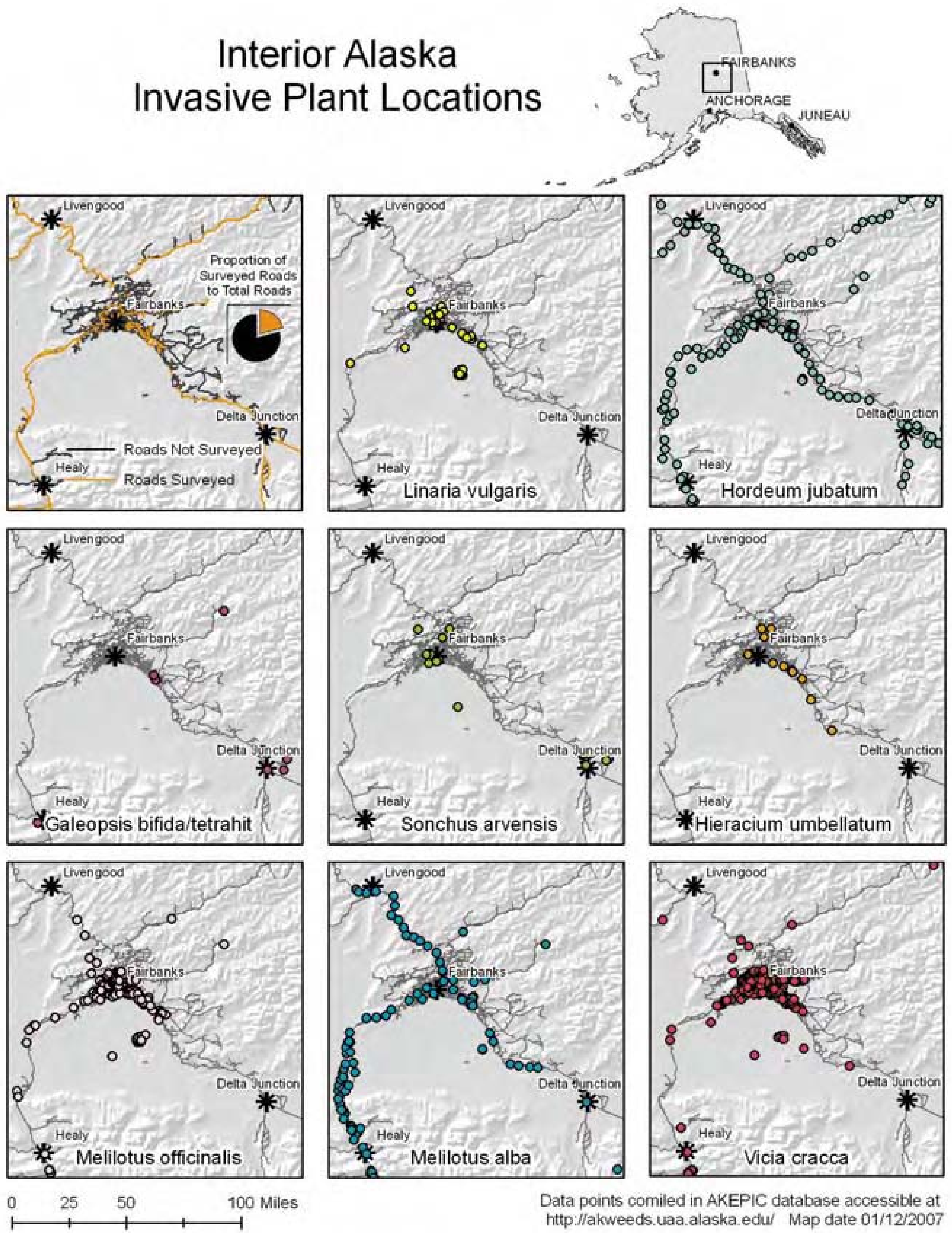
Throughout 2006 Forest Health Protection also collaborated on and provided support for research and survey projects including USDA Agricultural Research Service (ARS) research on hay and straw from both local and out-of-state sources as vectors for weed seed introductions, and University of Alaska Fairbanks/Pacific Northwest Research Station research documenting the current distribution of white sweetclover (*Melilotus alba*) on roadsides and river flood plains near bridges and subsequent examination the spatial relationships between roads, river, and public lands of high conservation value. Forest Health Protection-funded invasive plant survey work in 2006 included an Alaska Natural Heritage survey of 900 miles of roads in the Fairbanks region of interior Alaska, and extensive exotic plant surveys on four previously unsurveyed islands in southeast Alaska (Ketchikan (Revillagigedo Island), Kupreanof Island, Mitkof Island, and Wrangell Island). For complete summaries of these research and survey projects.

2006 Spotlight: Invasive Plants in Interior Alaska

The following section highlights invasive plants of concern in subarctic interior Alaska (Map 9), the vast central portion of the state which extends north to the Brooks Range, and encompasses the Alaska Range and Wrangell Mountains. Interior Alaska is home to the state's longest river, the Yukon, and vast tracts of boreal forest and forest–tundra transitional zones. The climate in the interior is characterized by seasonal temperature extremes—long cold winters and short, relatively warm summers. Most of the annual precipitation falls as snow, and the region is underlined by pockets of permafrost to the south, transitioning to continuous permafrost in the northern interior.

The largest city in the interior is Fairbanks, located within the Fairbanks North Star Borough, which is home to roughly 12 percent of Alaska's estimated 663,661 residents. Other population centers include the communities of Delta Junction, Tok, and Glennallen. Invasive plants, plant seeds, and propagules are introduced to these population centers via contaminated agricultural seed and livestock feed, roadside seed mixes, nursery, landscaping and greenhouse stock, construction materials and heavy equipment, and on recreational equipment and vehicles. Once established in areas of human disturbance, there is strong potential for movement into surrounding natural areas; the mountains, river valleys, forests, and plateaus of Alaska's pristine interior.

Map 9. Locations of selected invasive plants in interior Alaska



Species of Concern in Interior Alaska

Bird vetch

Vicia cracca L.

NON-NATIVE

Bird vetch is a climbing vine-like perennial with three coiling tendrils at the terminus of each stem. By climbing and covering surrounding vegetation, this species is able to monopolize sunlight, leaving underlying vegetation stunted and chlorotic. Infestations of bird vetch can cause branch dieback on conifers, suppress seedlings, and potentially negatively impact forest regeneration in forest openings and along forest edge.

Figure 42. *A volunteer works to remove bird vetch (*Vicia cracca*) from forest understory.*

Intentionally introduced in the early 1900s, bird vetch has spread along road corridors from Fairbanks to the Kenai Peninsula. Dense mats of this species can be found overtopping young trees, shrubs, meadow vegetation, riparian vegetation, roadsides, and landscaping in the Fairbanks area.

Infestations of bird vetch in the Fairbanks area are reported to be rapidly expanding, not only in the typical disturbed sites but also in shaded areas, moving up trails and into wooded areas. Small, incipient populations have been documented on roadsides in and around Delta Junction, increasing in density and frequency with proximity to Fairbanks. In 2006 Fairbanks region roadside surveys found bird vetch at 8 percent of the sites visited. However, where it did occur bird vetch created extremely dense infestations, climbing native trees and shrubs, suppressing surrounding vegetation, and in one case spreading into a closed alder-willow tall shrub community (Lapina et al. 2006).

Canada thistle

Cirsium arvense (L.) Scop.

NON-NATIVE

This perennial thistle is characterized by spiny stems, sometimes growing to 4 feet tall, which sit atop an extensive network of horizontal and lateral roots. Canada thistle spreads by seed and root fragments, rapidly colonizing areas of disturbance. Dense patches also move along forest edge and into meadows. Canada thistle clones can expand up to 2 meters in diameter in a single growing season,

Figure 43. *White flowers on typically purple-flowered stands of Canada thistle (*Cirsium arvense*).*

creating spiny barriers to human and animal traffic and out-competing seedlings and native grasses and forbs.

In the late 1970s an infestation of Canada thistle was discovered in Delta Junction, distributed over 160 acres of agricultural land. UAF Extension Agents, later joined by the Delta Chapter of the Alaska Farm Bureau, and the Salcha–Delta Soil and Water Conservation District, treated this infestation repeatedly over the course of 18 years. The Canada thistle in Delta Junction has been completely eradicated since 1997. The focus of weed control efforts in Delta Junction have now shifted to split-lip hempnettle and perennial sowthistle (see below).

European bird cherry

***Prunus padus* L.**

NON-NATIVE

European bird cherry is a small ornamental tree with cylindrical spikes of showy white flowers in the spring. Long a staple of nursery and landscape industries, European bird cherry or "mayday tree" has escaped and colonized parks, greenbelts, and riparian areas in Anchorage, and is beginning to exhibit the same behavior in Fairbanks and Delta Junction. The seeds of this species are bird-dispersed, and bird cherry seedlings are capable of dominating the understory of riversides, streamsides, and forested areas—replacing native woody vegetation such as alder, willow, birch, and spruce. The Alaska Chapter of the American Society of Landscape architects no longer recommends this species as a landscape tree.

Figure 44. *Early spring flowers on European bird cherry (*Prunus padus*).*

A popular landscaping species in Fairbanks, there is little information on whether bird cherry is spreading into natural areas as it has in Anchorage. Volunteer seedlings have been observed spreading from mature trees along the downtown Fairbanks stretch of the Chena River. Volunteer seedlings are reported to be spreading from horticultural plantings and along ATV trails in the Delta region. A single individual sapling was found this summer, growing on imported road fill along the Elliot Highway, northwest of Fairbanks (Lapina et al. 2006).

Foxtail barley

***Hordeum jubatum* L.**

NON-NATIVE

Although native to western North America, the nativity of foxtail barley in Alaska is currently under debate. Further research is needed to determine whether the invasive genotypes present in Alaska today are the same as those believed to be present in eastern interior Alaska prior to European settlement. In Alaska it has spread rapidly and aggressively in areas of human disturbance.

A perennial bunch grass, the hollow stems of foxtail barley arise from a mass of fibrous roots. The leaf blades of foxtail barley are rough, grey-green, and ribbed. Its nodding open spike inflorescence has long awns, which are green tinged with pink or purple in early summer, fading to a straw color in late summer and fall. While palatable to grazing animals in early summer, the sharp awns develop backward-pointing barbs which can lodge in the eyes, nose, mouth, ears, and stomachs of animals, causing infection.

Foxtail barley is found across the interior, prolific in areas of human disturbance. This species is considered a pest in pastures, hay fields, and grain crops, and is expanding into natural areas via logging roads and the Alaska oil pipeline.

Hempnettle

Galeopsis bifida **Boenn.**

NON-NATIVE

An annual in the Mint Family, hempnettle has square-sided stems with swollen nodes. The entire plant is covered with bristly hairs. Hempnettle leaves are oval to lance-shaped and sharply toothed, and its flowers range in color from white to pink or purple, clustered in the axils of upper stem leaves. Fused flower petals with an upper and a lower lip give this plant its common name "split-lip hempnettle." Although this plant does not spread vegetatively, hempnettle produces prolific amounts of seed. This weedy invader of disturbed areas quickly expands to create a dense layer which monopolizes soil moisture and nutrients, and is likely to delay the establishment of native species.

Figure 45. *Split-lip hempnettle (*Galeopsis bifida*).*

Hempnettle control work is currently underway in Delta Junction.

Narrowleaf hawkweed

Hieracium umbellatum **L.**

NON-NATIVE

Considered native to regions of North America, narrowleaf hawkweed is steadily expanding its range in Alaska. This yellow flowered hawkweed species was not historically present in Alaska, but has been spreading aggressively in recent years. Narrowleaf hawkweed is known to have become established in the Matanuska–Susitna Valley, throughout Anchorage, and south into the Kenai Peninsula. Several incipient populations were recently detected along roadsides in the vicinity of Delta Junction. One of these populations is located along a powerline right-of-way, which has the potential to function as a corridor for the spread of this species along forest edge and into natural forest openings. Surveys in 2006 found narrowleaf hawkweed in two roadside locations along the Elliot Highway, along one section of the Richardson Highway, and at multiple sites along the Dalton Highway, north of the Yukon river. Infestations under alder and willow, covering up to 90 percent of the understory were reported (Lapina et al. 2006).

Unlike the other invasive hawkweed species in Alaska, narrowleaf hawkweed does not form a basal rosette of leaves, and has no stolons. Narrowleaf hawkweed is the tallest non-native hawkweed in Alaska, with linear to lance-shaped stem leaves covered in short, stiff, star-like hairs.

Narrowleaf hawkweed is one of seven exotic hawkweed species now present in Alaska, the other six being orange hawkweed (*Hieracium aurantiacum*), meadow hawkweed (*H. caespitosum*), common hawkweed (*H. lachenalii*), mouseear hawkweed (*H. pilosella*), New England hawkweed (*H. sabaudum*), and rough hawkweed (*H. scabrum*).

Perennial sowthistle

***Sonchus arvensis* ssp. uliginosus (Bieb.) Nyman**

NON-NATIVE

Perennial sowthistle is a deep-rooted plant with loose clusters of yellow, dandelion-like flowers. The leaves of perennial sowthistle vary in shape, and have prickly margins and leaf bases which clasp the stem. This plant has a milky sap-like resin and can grow up to five feet tall. With its extensive horizontal root system, perennial sowthistle is able to monopolize soil moisture and form dense stands. Along with white sweetclover (see below) perennial sowthistle is a colonizer of open, gravelly, early-successional areas, and has the potential to spread into riparian areas and glacial outwash plains.

Figure 46. *A stand of perennial sowthistle (*Sonchus arvensis*).*

Widespread across south-central Alaska, perennial sowthistle has become established in both Fairbanks and Delta Junction. Two roadside infestations of perennial sowthistle were detected in Fairbanks during the 2006 surveys, both associated with recent road construction (Lapina et al. 2006). Perennial sowthistle is now the focus of control efforts by UAF Extension in Delta Junction, the Delta Chapter of the Alaska Farm Bureau, and the Salcha–Delta Soil and Water Conservation District.

Siberian peashrub

***Caragana arborescens* Lam.**

NON-NATIVE

A shrub or small tree in the pea family, Siberian peashrub is multistemmed with erect to spreading branches originating from a dense, spreading root system. The leaves of this plant are pinnately compound, with 8 to 12 leaflets. Narrow stipules at the base of leaf petioles persist as sharp spines. Its pea-like yellow flowers are approximately one inch long, and are borne singly or in small groups. The pods of Siberian peashrub are linear, green, and strongly flattened, becoming more cylindrical and brown at maturity. Mature pods disperse seeds by opening explosively.

Siberian peashrub has long been promoted in Alaska as a hardy landscaping plant, which can withstand the harsh climate with little to no maintenance. In the interior Siberian peashrub is often planted as a windbreak or hedge between residential properties.

Figure 47. *Siberian peashrub (*Caragana arborescens*).*

Invasive plant surveys in 2004 detected several sites in south-central Alaska where volunteer seedlings are spreading into undisturbed forest understory. UAF Cooperative Extension Service technicians report having witnessed the same behavior in the Fairbanks region. Escaped populations of Siberian peashrub have the potential to modify forest structure and composition. In some instances seedlings are found in close proximity to residential plantings, and in other cases isolated plants in forest understory are thought to have originated from bird-dispersed seed.

White sweetclover

Melilotus alba **Medikus**

NON-NATIVE

Yellow sweetclover

M. officinale **(L.) Lam.**

NON-NATIVE

Some of the fastest spreading exotic plants in Alaska, the sweetclovers have infested highways, roadsides, and waterways throughout the state. The sweetclovers are tall, branching members of the pea family, with fragrant white or yellow flowers. Both white and yellow sweetclover are described as biennial, but have been found to flower and produce seed after one growing season in Alaska, possible due to the long hours of daylight during summer months. The sweetclovers alter soil chemistry through nitrogen fixation and contain coumarin, a chemical that is toxic to grazing animals and livestock.

Frequently established along roadsides, white sweetclover is now moving from the road system into river corridors and flood plains, via road–river interfaces. Sweetclover seeds float, and are therefore spreading rapidly down river and stream corridors. White sweetclover, more abundant in Alaska than yellow sweetclover, infests riverbanks on the

Nenana River in the interior, the lower sections of the Matanuska River in south-central Alaska, and the Stikine River in southeast Alaska.

Yellow toadflax

Linaria vulgaris **P. Mill.**

NON-NATIVE

Yellow toadflax or "butter and eggs" is a multiple-stemmed perennial, growing to 2 feet, with pale green lanceolate or linear leaves and racemes of bright yellow "snapdragon like" flowers with orange palates (nectar guides). Producing up to 30,000 seeds per plant and spreading by creeping rhizomes, yellow toadflax forms dense colonies and suppresses surrounding vegetation. Its horizontal roots, which can grow to several meters long, develop adventitious buds which give rise to new plants.

Figure 48. *Flowers and seed capsules of yellow toadflax (*Linaria vulgaris*).*

This species is adapted to a wide range of conditions, and has become widespread along Alaska's rail systems, road systems, and in areas of human disturbance. In addition to aggressively colonizing meadows and other natural forest openings, this species contains a glucoside toxic to grazing animals.

Yellow toadflax is considered one of the most problematic invasive plant species in population centers throughout the Alaskan interior. However, 2006 surveys of highway right-of-ways in the interior detected toadflax in only three locations: in western Fairbanks, outside of Fairbanks near the community of North Pole, and at the end of the Elliot highway. This limited number of sightings is not reflective of the fact that yellow toadflax is commonly found in residential areas of the interior.

Other Species of Concern in Interior Alaska

Ornamental jewelweed

Impatiens gladulifera Royle

NON-NATIVE

Cheatgrass

Bromus tectorum

Non-native

Rough hawkweed

Hieracium scabrum Michx.

NON-NATIVE

Ornamental jewelweed, also known as "policeman's helmet" or "Washington orchid," is listed as noxious in the state of Washington and in British Columbia. This herbaceous annual can grow to 5 feet tall, and has hollow stems with swollen nodes, and flowers that range from white to pink, red, or purple. Ornamental jewelweed thrives in moist areas, and is capable of forming dense stands in streams, lowlands, and drainage areas. Popular with unwary gardeners in southeast and south-central Alaska, this garden ornamental has found its way to home gardens in Fairbanks.

Figure 49. *Ornamental jewelweed (*Impatiens glandulifera*) flowers.*

One of the most problematic invasive plants in the western United States, cheatgrass or "downy brome" is well-adapted to harsh climates, limited moisture, and temperature extremes; a species well-suited to establishment and spread in interior Alaska. Widespread infestations of cheatgrass across the western US have had a devastating influence on landscapes by altering wildfire regimes. A one-acre infestation of cheatgrass has been identified at a high-traffic area northeast of Fairbanks, in Chena (Lapina et al. 2006). Immediate management of this infestation is essential, as there is high risk of seeds being transported from the site. Cheatgrass is an annual cool season grass which can be identified by its drooping panicles and soft white hairs on leaves and stems, which give this grass a "downy" appearance.

Another hawkweed species to add to the list of exotic hawkweeds in Alaska, rough hawkweed was discovered at a popular recreation area outside of Fairbanks. This is the only known infestation of rough hawkweed in Alaska, and is estimated to occupy less than one-tenth of an acre (Lapina et al. 2006), making it a high priority site for treatment and eradication. Rough hawkweed is considered native to eastern regions of the United States, but as is the case with narrowleaf hawkweed, it is not considered native to Alaska.

Other Exotic Species of Note in Southeast and South-central Alaska

English holly

Ilex aquifolium L.

NON-NATIVE

Greater burdock

Arctium lappa L.

NON-NATIVE

Maltese star-thistle

Centaurea melitensis L.

NON-NATIVE

Paleyellow iris

Iris pseudacorus L.

NON-NATIVE

English holly is an introduced evergreen shrub or small tree with irregularly-toothed, glossy, dark green leaves and bright red berries. This widely-cultivated ornamental species is spreading into natural areas in California, Oregon, Washington, and on Hawaii and portions of the west coast of Canada. To date English holly is not known to be problematic in Alaska, but may be a species to monitor. Volunteer seedlings were observed around a mature English holly tree in Ketchikan in 2006.

Greater burdock is one of four exotic burdock species now present in North America. The burdocks are biennial weeds, present across most of the United States, known for their rounded flowerheads with hooked spines (burs) which easily attach to clothing or animal fur. Greater burdock has long been cultivated in Asia as a root vegetable and medicinal plant. It is sometimes called "giant burdock" because it can grow to two meters in height, with broad heart-shaped leaves and prickly flowerheads (burs) over an inch in diameter. The only known infestation of greater burdock is located in Anchorage, where it has spread from landscaping at a commercial site into surrounding fragments of open forest.

Figure 50. *Greater burdock (*Arctium lappa*) flowers and broad leaves.*

Figure 51. *Spiny flowerhead on Maltese star-thistle (*Centaurea melitensis*).*

Similar in appearance to yellow starthistle (*Centaurea solstitialis*), **Maltese starthistle** or "to-calote" is highly competitive for soil moisture, and forms dense monotypic stands that displace native vegetation. Maltese starthistle is an introduced winter annual with spiny, yellow flower heads and elongated leaf bases which give the stem a "winged" appearance. This species is known to be invasive in the western and southwestern states, and is dispersed by birds, in contaminated crop seed or hay, and on hikers, animals, vehicles, and equipment. Maltese starthistle is known to be introduced to Alaska as a weed in nursery stock from the lower 48 states. Although it has not yet been detected outside of the nursery environment, a single individual was able to flower and produce seed during the 2006 growing season in south-central Alaska.

A popular ornamental species, **paleyellow iris** or "yellow-flag iris" is an introduced perennial forb, native to Europe. Across North America paleyellow iris has spread into riparian, lowland, and wetland areas. Fast growing and poisonous to grazing animals, paleyellow iris spreads by seed and rhizomes, forming almost impenetrable thickets. This species is now listed as "noxious," "banned," or "prohibited" in five states, including Washington and Montana. Paleyellow iris is now present in Craig, Petersburg, and Ketchikan, and has the potential to spread aggressively across southeast Alaska, where wetlands, rivers and streams are valued as salmon spawning areas. Paleyellow iris can be identified by its showy yellow flowers and erect, flat, swordlike leaves. Individual plants can grow from two to three feet tall.

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2006 Cooperative Projects

Following is a list of some of the projects funded by Forest Health Protection through grants and contracts.

Insect Projects in 2006

Evaluation of systemic insecticide technologies for control of spruce aphid infestations in Sitka spruce

Chris Fettig. USDA Forest Service, Pacific Southwest Forest Research Station, Davis, CA

Roger Burnside, AKDNR, Anchorage, AK.

In cooperation with Pacific Southwest Research Station and the state of Alaska we explored treatments available for protecting Sitka spruce from spruce aphid infestations in addition to the use of Acecaps. Unfortunately, there is a limit to the number of times that an infested tree can be treated with Acecaps as the procedure requires the drilling of a hole for every 10 centimeters of tree circumference to facilitate treatment. The Arborjet injection system requires (according to manufacturer's instructions) fewer and small holes to facilitate injection. The system has been shown to be effective in controlling hemlock woolly adelgid populations on eastern hemlock (Fidgen et al. 2002). The Kioritz soil injection systems also hold promise for this important use. In this study, we demonstrated that Acecaps were the most effective means of control. However, during most evaluations relatively few aphids were encountered overall (Tables 1–4). The results concerning the Arborjet and Kioritz treatments may simply be an artifact of the large variation observed and should be interpreted with caution. A percent crown cover change was calculated from vertical crown picture taken before and several months after treatment. Control trees lost on the average one and one-half percent of their needle cover each in 2005 and 2006 and, this includes the gain in needle cover by new growth after leaf-out in June. The AceCap treated trees had an average of about a two percent gain in needle cover; the gain in needle cover for Arborjet and Kioritz was somewhat less than for AceCap treatments.

Tree Injury of Lack of Injury with the use of ACECAPS to control spruce aphids in Sitka spruce.

Roger Burnside, AKDNR, Anchorage, AK.

In cooperation with the state of Alaska we are testing the possible reduction in xylem conductance and fungal infection of ACECAP wounds in Sitka spruce. We will fell several trees each year over a time-frame of four years and use uptake of dyes and fungal isolation techniques to study the effects of injury. There are two installations, one in Juneau and one near Thorne Bay.

Diseases and Declines Projects in 2006

Enhancing the stand visualization software (SVS) to visualize and communicate the effects of forest diseases, insects, and decline syndromes at the stand level.

James McCarter, Rural Technology Initiative, College of Forest Resources, University of Washington, Seattle, WA.

Robert McGaughey, USDA Forest Service, PNW, University of Washington, Seattle, WA.

In collaboration with Region 10 State and Private Forestry, a new user-friendly software program was developed, the Stand Visualization Add-in for Excel, as an interface to the Stand Visualization System (SVS). The Add-In tool streamlines the process of creating forest images because it works directly from Excel using a standardized worksheet and simple menu commands. Also, the Add-In supports new tree form definitions to depict dwarf mistletoe infections in live trees and a range of mortality structures including uprooted, broken, and standing dead trees. These new tree forms were used to create time-series images of Alaskan forests depicting yellow-cedar decline, dwarf mistletoe spread and intensification, and various forest health and management treatments scenarios. The images can be used for a variety of purposes including publications, poster presentations, and web pages. The Stand Visualization Add-In software can be downloaded from: http://silvae.cfr.washington.edu/standviz-addin/ .

Comparing the Alaskan Alder Cytospora Pathogen to isolates from other regions of the United States

Gerard Adams, Department of Plant Pathology, Michigan State University, East Lansing, MI.

This project, in cooperation with Region 10 State and Private Forestry, is examining the plant pathogen associated with extensive dieback and mortality of *Alnus tenuifolia*. Long narrow cankers that were girdling branches and trunks were sampled from infected *Alnus* from Seward to Fairbanks. From the canker margins, strains of a plant pathogenic fungus were routinely isolated. DNA sequence data, morphology and phylogenetic analysis confirmed the identity of the fungus as *Valsa melanodiscus* based on a one gene tree. This pathogen is common on Alnus species throughout North America, and yet, never has it been observed to cause such extensive and widespread damage. Research is continuing to determine whether the Alaskan strains of the pathogen represent a unique genetic population distinct from populations in other parts of the United States that cause little damage.

Testing pathogenicity of fungi associated with cankers on Alnus tenuifolia (syn. Alnus incana subspecies tenuifolia) in Alaska

Glen R. Stanosz, Departments of Plant Pathology and Forest Ecology and Management, University of Wisconsin-Madison

This project, in cooperation with Region 10 State and Private Forestry, is conducting greenhouse inoculation trials and pathogenicity testing of several canker causing fungi on vegetative cuttings of *Alnus tenuifolia* from Alaska and Colorado. Propagation of the Alaska alder cuttings has been slower than anticipated. In preliminary inoculation trials with a scalpel wound, *V. melanodiscus* was consistently recovered from the bark under the sunken margin and from the wood beneath the wound. The pathogen was less consistently recovered from stained wood. A similar full scale trial will be used as propagated plants develop using both Colorado and Alaskan plants, as well as isolates of *V. melanodiscus* from each state. That propagation is proceeding as the growth of the Alaskan stock plants allow. Enough plants for this trial should be available to allow this trial to proceed in early 2007.

Invasive Plants Projects in 2006

The USDA Forest Service, Region 10 State and Private Forestry collaborated with partner agencies and organizations on the following research and survey projects, providing planning and oversight, funding, staffing, and other resources.

Hay and Straw as Vectors for Weed Seed in Alaska

Jeffrey Conn. Research Agronomist, USDA Agricultural Research Service, Fairbanks, AK. (Publication in press)

As ecologists and land managers work to prevent the introduction of invasive plants into Alaska, there is a need for information on how plant seed and propagules are transported into the state. Many different vectors or "pipelines" have been identified as sources of weed seed, among these hay and straw imported from Canada and the lower 48 states. In Alaska, small pockets of agriculture interface directly with pristine forests and riparian areas, and invasive plants can make inroads into intact ecosystems via logging roads, fire lines, roads, trails, and rivers.

In a 2005–2006 research project funded by Region 10 State and Private Forestry, the USDA Agricultural Research Service (ARS) surveyed suppliers and importers of hay and straw, collected representative samples, and propagated the "fines" (small seeds and particles which can be sifted out of a unit of forage or agricultural seed) in Fairbanks greenhouses. This study focused on determining species presence and numbers of weed seed in hay and straw from both local and out-of-state sources. The number of weed seeds per bale of hay was nearly 3.2 times greater in Washington and Oregon hay than in hay produced in-state. Invasive plant species found in locally produced hay and straw included foxtail barley, and narrowleaf hawksbeard (*Crepis tectorum*). Among the invasive plants found in imported hay and straw were common sowthistle (*Sonchus oleraceus*), stickywillie or "cleavers" (*Galium aparine*), and downy brome or "cheatgrass" (*Bromus tectorum*). Based on ARS data it is estimated that one 20-ton truckload of hay from Washington could contain over 60 million weed seeds. This research will serve as an important tool in the development and strengthening of a fledgling Alaska Weed Free Forage program.

Spread of Invasive Plants from Roads to River Systems in Alaska: A Network Model

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Macander, Matt J. Remote Sensing & GIS Specialist, ABR Inc.—Environmental Research & Services, Box 80410, Fairbanks AK

Spellman, Blaine T. Graduate Student, School of Natural Resources and Agricultural Sciences, University of Alaska Fairbanks, Fairbanks, AK

(Publication in press)

In 2006 Region 10 State and Private Forestry had the opportunity to support a team of scientists and students conducting road surveys and doing modeling work focused on white sweetclover (*Melilotus alba*) in south-central and interior Alaska. Study objectives included documenting current distribution of *Melilotus* on roadsides and river flood plains near bridges, and developing a network model to examine the spatial relationships between roads, river, and public lands of high conservation value. In cooperation with the Pacific Northwest Research Station and the University of Alaska Fairbanks, State and Private Forestry provided staffing for survey work, and funding for the mapping components of this project. A total of 1,780 miles of eight major highways in interior and south-central Alaska were surveyed, including 192 road–river interfaces. *Melilotus* was present at 64 of these road–river interfaces. At 17 interfaces *Melilotus* had spread to the river flood plain. Currently under development, the network model will be an important tool for land managers seeking to prevent the introduction of new invasive plants to the lands they manage by helping to identify critical upstream river–road interface control points.

Non-Native Plant Species of the Fairbanks Region, 2006 Surveys

Irina Lapina. Botany Research Associate, Alaska Natural Heritage Program, University of Alaska Anchorage. Anchorage, AK 99501.

Klein, Susan. Ecology Research Associate, Alaska Natural Heritage Program, University of Alaska Anchorage. Anchorage, AK 99501.

Carlson, Matthew. Program Botanist, Alaska Natural Heritage Program, University of Alaska Anchorage. Anchorage, AK 99501.

Region 10 State and Private Forestry has collaborated with the Natural Heritage Program to evaluate roadside invasive plant populations in Anchorage, the Matanuska–Susitna Valley, the lower Kenai, several regions of southeast Alaska, and now in the Fairbanks region of interior Alaska. In 2006 survey work by the Natural Heritage Program covered a total of 900 miles of interior roads within an area bounded by Stevens Village to the north, Circle Hot Springs to the east, Paxson and Talkeetna to the south, and Manley Hot Springs and Rampart to the west. Survey sites were located at five mile intervals along primary roadways, data was collected at 191 sites, and 1,187 records of non-native species were submitted to the AKEPIC database.

The most frequently encountered exotic plant species were common dandelion (*Taraxacum officinale* ssp. officinale), foxtail barley (*Hordeum jubatum*), common plantain (*Plantago major* var. major) and disc mayweed or "pineapple weed" (*Matricaria discoidea*). These species were recorded at more than 50 percent of all survey sites. White sweetclover was widely-distributed as well, occurring at 33.3 percent of all sites. No infestations of orange hawkweed, reed canarygrass (*Phalaris arundinacea*), or Canada thistle (*Cirsium arvense*) were recorded. Sites within the survey area which harbored large numbers of non-native species or highly invasive species were recommended for monitoring and control. This survey work will provide critical baseline information on which invasive plant species have expanded their range to regions outside of the Fairbanks metropolitan area.

Non-Native Plant Species Inventory of Southeast Alaska: Ketchikan, Wrangell, Mitkof, Kupreanof

Katie Arhangelsky, Turnstone Environmental Consultants, Inc., Portland, Oregon.

During the 2006 field season the Tongass National Forest and Region 10 State and Private Forestry funded extensive exotic plant surveys on four previously unsurveyed islands in southeast Alaska: Ketchikan (Revillagigedo Island), Kupreanof Island, Mitkof Island, and Wrangell Island. Utilizing two field crews, the invasive plant inventory began on Ketchikan and Kupreanof concurrently, and then concentrated on Wrangell and Mitkof. Field data on non-native plants was collected on road right-of-ways on state and local lands, and Forest Service controlled road rights-of-way on private land. An estimated 468 miles of road right-of-way were inventoried, as well as the areas around each road intersection, recreation site, pull-out, rock pit, and parking area. A total of 2,026 sites were surveyed, each of these sites was inventoried using AKEPIC protocol, and all points entered into the AKEPIC database. In addition, two voucher specimens of each exotic species identified were collected and submitted for use in the Forest Service and UAF-CES herbarium teaching collections.

The surveys recorded 92 non-native species along roads and adjacent disturbed areas, which represents approximately 47 percent of the 197 known exotic species in Alaska. The locality with the highest diversity of non-native species was Ketchikan, which harbored 72 exotic plant species, while the locality with the lowest diversity was the Portage Bay road system on Kupreanof Island, with only 27 non-native species.

The roads in and around the residential areas of Ketchikan, Wrangell, Petersburg, and Kake contained the highest diversity of non-native species and also had more extensive invasions. Exotic species of highest concern included: Scotch broom (*Cytisus scoparius*), poison hemlock (*Conium maculatum*), English ivy (*Hedera helix*), Himalayan blackberry (*Rubus discolor*), Queen Anne's Lace (*Daucus carota*), common hawkweed, meadow hawkweed (*H. caespitosum*), orange hawkweed, white sweetclover, Japanese knotweed (*Polygonum cuspidatum*), Hairy catsear (*Hypochaeris radicata*), creeping bentgrass (*Agrostis stolonifera*), common tansy (*Tanacetum vulgare*), common St. Johnswort (*Hypericum perforatum*), Canada thistle, bull thistle (*C. vulgare*), reed canarygrass, tansy ragwort (*Senecio jacobea*), perennial sowthistle (*Sonchus arvensis*), and spotted knapweed.

To assist local land managers in these regions of southeast Alaska, specific survey populations were selected as "high priority populations recommended for immediate control" based on their invasiveness potential, distribution, and abundance.