CHAPTER 14.

Factors Contributing to Shore Pine *(Pinus contorta* subsp. *contorta)* Mortality and Damage in Southeast Alaska (Project WC–EM–B–12–03)

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INTRODUCTION

Recent Forest Inventory Analysis (FIA) plot remeasurements revealed a statistically significant 4.6 percent loss of shore pine (*Pinus contorta* subsp. *contorta*) biomass in Alaska despite negligible harvest, with greater losses among larger size-class trees (Barrett and Christensen 2011). Shore pine is one of four distinct subspecies of *Pinus contorta* (Critchfield 1957); it occurs on coasts and wetlands from northern California to Yakutat Bay in southeast Alaska. In Alaska, shore pine is most common on peatland sites with saturated, acidic soils (known as muskegs) and is outcompeted by western hemlock (*Tsuga heterohpylla*) and Sitka spruce (*Picea sitchensis*) on more productive sites that have better drainage and nutrient availability (Bisbing and others 2015, Martin and others 1995). Little is known about the insect and disease agents of shore pine (Reeb and Shaw 2010).

Although shore pine is not a commercial species, it serves an important structural and ecological role in forested wetlands (Lotan and Perry 1983, Martin and others 1995). Few tree species are able to survive the harsh conditions of saturated and acidic peatland bogs and fens; therefore, there is concern that the loss of shore pine from these habitats may create a void that other tree species are unable to fill. This project was initiated to better understand the decline in shore pine biomass from tree mortality in southeast Alaska. Installation of a permanent plot network will provide baseline information about the insects, disease, and other damage agents that affect the health of shore pine, and it will offer an opportunity to monitor shore pine populations over time. This information will help to determine if there is reason for heightened concern regarding the health and survival of shore pine in southeast Alaska.

METHODS

Site Selection

Sites were established at five locations in southeast Alaska (fig. 14.1). Plot locations were randomly selected from National Wetland Inventory (NWI) polygons (Cowardin and others 1979) known to reliably contain shore pine (palustrine emergent wetland and palustrine scrub-shrub wetland) that were at least 4 acres in size and located within 0.5 miles of a road or trail. Geographic Information System tools from ArcMap® 10.0 (ESRI 2011) were used to assess selected wetland polygons to ensure accessibility and shore pine forest type with satellite imagery and topographic maps.

Plot Layout and Data Collection

Forty-six plots were established using a modified FIA plot layout (USDA Forest Service 2007). Plot positioning maximized shore pine composition and captured a range of shore pine size classes. Live and dead trees ≥4.5 feet tall were tagged for long-term monitoring. Data collected from live trees included height; diameter at breast height (d.b.h.); lower crown height; crown dieback (percent, visually estimated); wound type and severity; and presence of conks, decay, or topkill. Height, d.b.h., FIA-defined decay class from 1 to 5 (USDA Forest Service 2007), and wound or damage information were collected from snags. For shore pine, we also quantified western gall rust (WGR) severity and associated dieback, and we estimated foliage retention, length of branches with foliage, and disease/insect damage type and severity. The WGR severity rating was adapted from the Hawksworth (1977) dwarf mistletoe rating system. Wound severity was determined by the relative circumference of the bole affected. Symptomatic foliage was collected from shore pine to facilitate identification of foliar pathogens. Prism counts, slope, aspect, cover percentage of vegetation types and plant species, and one dominant shore pine tree core were collected in all three subplots.

RESULTS

Data were collected in 2012 and 2013 from 5,452 trees >4.5 feet tall (table 14.1), including 1,031 trees ≥5 inches d.b.h. Tree species included shore pine, yellow-cedar (*Callitropsis nootkatentis*), mountain hemlock (*Tsuga mertensiana*), western hemlock, Sitka spruce, western redcedar (*Thuja plicata*), and red alder *(Alnus rubra)*. On average, there were 62 shore pine and 119 total trees per plot, with 19 pines and 22 total trees >5.0 inches d.b.h.

Percentage Dead and Snag Decay Classes

A higher percentage of shore pine (13 percent) and yellow-cedar (14 percent) trees were dead compared to other tree species (<5 percent). Because mountain and western hemlock were less abundant and at least 18 of 73 snags

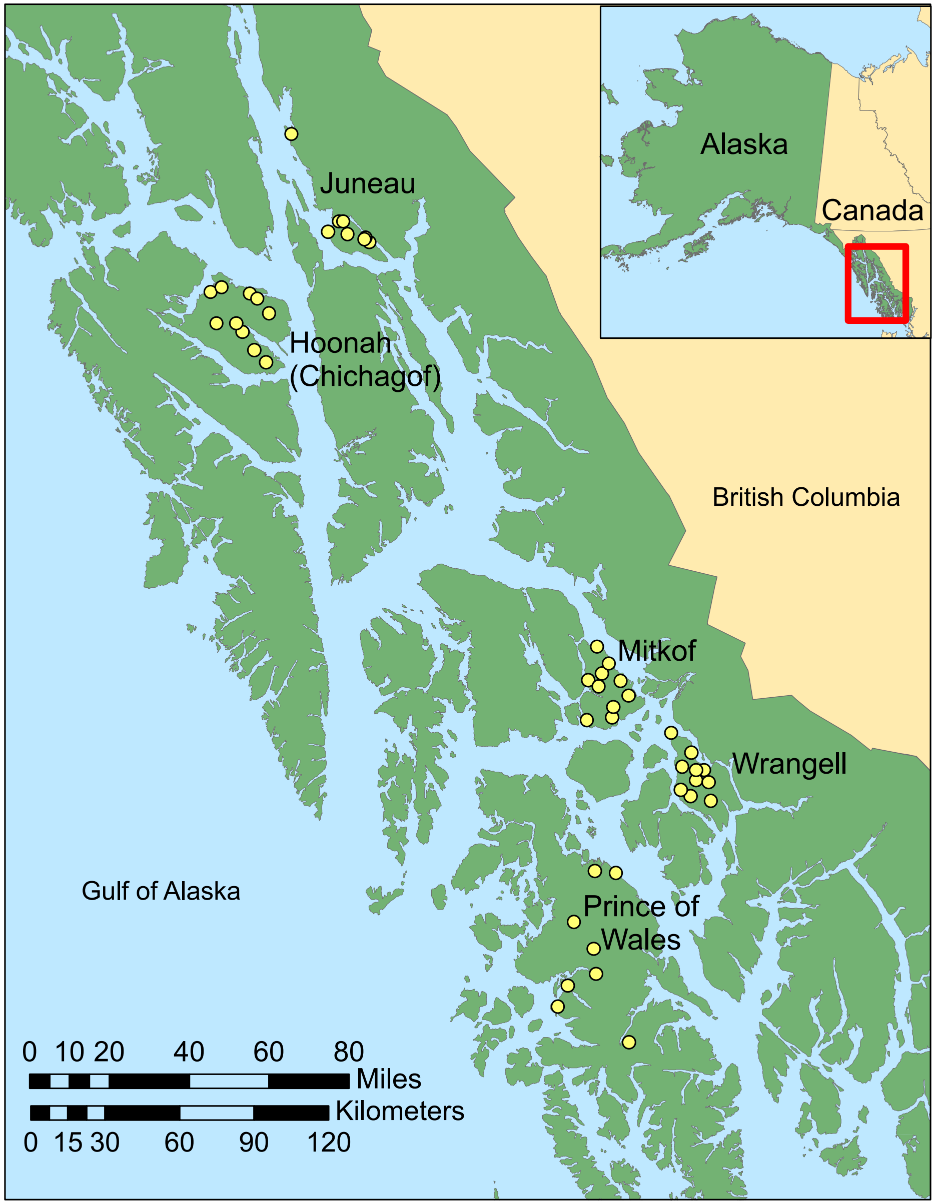

Figure 14.1—Forty-six permanent shore pine plots at five locations in southeast Alaska.

that could not be definitively identified were thought to be hemlock, percentage dead may be underestimated for these species. Among shore pine, the highest percentage of snags occurred in the largest diameter class (15.0–22.5 inches) (table 14.2). This diameter class contained just 25 trees; 5 of the 10 snags were designated decay class 2, with the remainder spread evenly among the other decay classes. There was no discernable trend for pronounced recent mortality in any particular diameter size class.

Western Gall Rust Incidence and Ratings

Western gall rust, caused by the fungus *Peridermium harknessii*, was detected in all subplots and on 85 percent of live shore pine. Among plots, infection incidence ranged from 52 to 100 percent. For snags, WGR incidence was only 32 percent and bole gall incidence was 21 percent. A greater percentage (22 percent) of small trees (0.1–2.4 inches d.b.h.) were uninfected, compared to <8 percent for all other size classes. A 0-to-6 scale quantified WGR on live trees (each vertical one-third of crown has a maximum rating of 2): 39 percent of shore pines were rated 1 to 2 (low severity), 36 percent were rated 3 to 4 (moderate severity), and 10 percent were rated 5 to 6 (high severity). The largest trees (>15 inches d.b.h.) had the lowest proportion of moderate to high severity ratings (33 percent of trees rated 3 to 6). The highest severity rating among the one-third crown portions (2) was more common in the lower crown (47 percent of live trees) than in the upper and middle crown (27 and 14 percent, respectively).

Table 14.1—Number of live and dead trees ≥4.5 feet tall and percentage of trees dead by species in 46 plots in southeast Alaska, 2013

Species	Live	Dead	Total trees	Trees dead
				percent
Shore pine	2504	361	2865	13
Yellow-cedar	1113	177	1290	14
Mountain hemlock	577	32	609	5
Western hemlock	467	20	487	4
Sitka spruce	60	3	63	5
Western redcedar	60	0	60	0
Red alder	5	0	5	0
Unknown	0	73	73	100

Table 14.2—Number of live and dead shore pine and percentage of trees dead by diameter class in 46 plots in southeast Alaska, 2013

d.b.h.[a]	Live trees	Dead trees	Total trees	Trees dead
inches				*percent*
0.1–2.4	1109	137	1246	11
2.5–4.9	655	109	764	14
5.0–6.9	289	45	334	1
7.0– 9.9	263	36	299	12
10.0–14.9	173	24	197	12
15.0–22.5	15	10	25	40
Total	**2504**	**361**	**2865**	**13**

[a] d.b.h. = diameter at breast height.

Bole galls were observed on 35 percent of live shore pine (9 to 78 percent per plot). WGR-associated topkill was observed on one-fourth of live shore pine (>70 percent of trees with bole galls). When topkill occurred, 40 percent of trees developed new leaders; however, some trees showed one or more iterations of a cycle of (1) topkill, (2) new leader development (40 percent of topkilled trees), (3) subsequent bole infection (37 percent of trees with new leaders), and (4) new topkill (7 percent of trees with new leaders). WGR-associated topkill averaged just 4.4 percent for trees without bole galls, compared to 25, 35, and 48 percent for pines with bole galls in one, two, and three crown-thirds, respectively. Similarly, mean crown dieback associated with WGR was correlated with WGR rating, ranging from 5 to 43 percent for WGR severity ratings 1 and 6 (fig. 14.2). WGR-associated crown dieback increased sharply when the WGR ratings exceeded 2. The presence of bole galls and the number of crown-thirds affected by bole galls were both significant predictors of crown dieback (analysis of variance $p < 0.001$).

Wound Incidence, Type, and Severity

Wound types recorded included mechanical injury, root exposure, porcupine feeding, antler rub, bole cankers, burls, old dead bole galls, frost cracks, bear scratch, bark rubbing from neighboring trees, sapsucker feeding, and limb or bole harvest for Christmas trees. Wounds were observed on 47 percent of live shore pine; 26 percent had moderate- to high-severity

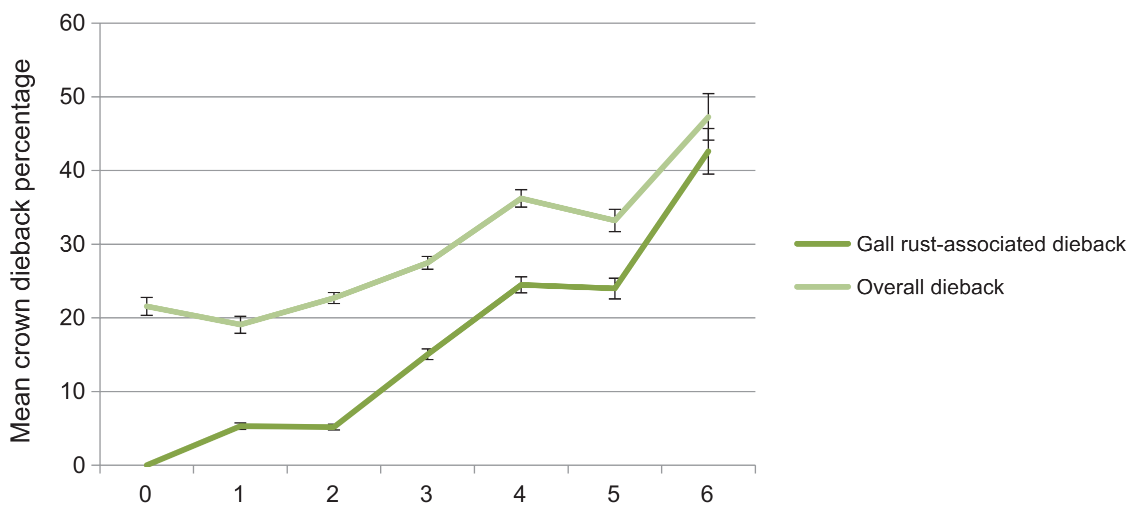

Figure 14.2—Mean crown dieback (percent) and mean crown dieback associated with western gall rust (WGR) (percent) by WGR severity rating (0 to 6) in 46 shore pine plots in southeast Alaska, 2013. Standard error bars are shown. WGR severity rating adapted from Hawksworth (1977).

wounds, and 6 percent had more than one wound type. Wound incidence was lower for dead shore pine (31 percent) than live shore pine, but the incidence of moderate- to high-severity wounds was the same. Wound severity and the proportion of live shore pine wounded increased with diameter (fig. 14.3). Shore pine had the greatest incidence of wounding among live trees, followed by western hemlock and mountain hemlock species (table 14.3).

Bole wounds were significantly more common on live shore pine (32 percent of live trees) compared to associated species (2 to 8 percent). Snow loading and animal feeding or marking are likely major sources of bole wounds, but specific causes were usually unknown. A bole canker pathogen may create diamond-shaped wounds observed on all size classes of pine, sometimes in great abundance. These cankerlike wounds were recorded as general mechanical damage in 2012. In 2013, cankers were recorded on 22 percent of live shore pine on Prince of Wales Island and 19 percent on northeast Chichagof Island, compared to 5 to 8 percent at all other locations. Moderate to high severity ratings were assigned to all canker wounds on dead trees and 74 percent of cankers on live trees.

Poor root anchorage (root exposure) in saturated soils, mossy mounds, or standing water affected 5 to 32 percent of trees (by species) and was the most common wound for nonpines. Root exposure may only harm trees when severe, as

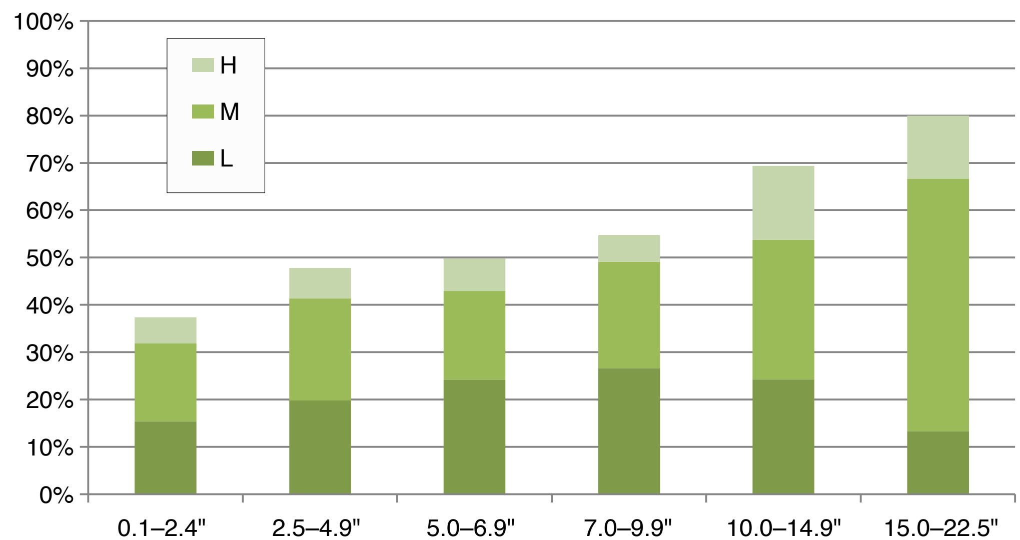

Figure 14.3—Percentage of live shore pine with low- (L), moderate- (M), and high- (H) severity wounds by diameter size class in 46 plots in southeast Alaska, 2013.

Table 14.3—Percentage of live and dead trees with bole wounds, exposed root wounds, and overall wounds by species in 46 plots in southeast Alaska, 2013

Dead/live status	Species	Trees with exposed root wounds	Trees with bole wounds	Overall trees wounded
		----------------------percent----------------------		
Dead	Shore pine	14	20	31
Dead	Yellow-cedar	9	0	9
Dead	Mountain hemlock	25	9	31
Dead	Western hemlock	40	0	40
Dead	Sitka spruce	0	0	0
Dead	Unknown	7	0	8
Live	Shore pine	17	32	47
Live	Yellow-cedar	5	2	7
Live	Mountain hemlock	23	3	26
Live	Western hemlock	32	3	36
Live	Sitka spruce	30	8	3
Live	Western redcedar	12	7	18

Note: Some trees had both wound types, and some uncommon wound types did not fall under these wound categories.

was the case in 1 percent of shore pine compared to 7 to 8 percent of spruce and hemlocks.

Foliar Damage and Retention

Foliage disease or leaf feeding insects caused low- to moderate-severity damage to 38 percent of shore pine, while <1 percent had severe foliar damage. Collected symptomatic foliage overwintered in mesh bags most often yielded fruiting bodies of *Dothistroma septosporum*. The foliar pathogens *Lophodermium seditiosum* and *Lophodermella concolor* were usually limited to scattered individual needles or the previous year's shoots. Feeding damage of the lodgepole needle miner (*Coleotechnites milleri*) and defoliating weevils (*Magdalis* sp. or *Scythropus* sp.) was occasionally observed; these tentative identifications are based on the appearance of the feeding damage. Sawflies were noted in 13 of 46 plots and at all study locations except for Juneau. Reared adults were identified as lodgepole pine sawfly (*Neodiprion nanulus contortae*). Sawfly defoliation was usually restricted to a few branches, but some small trees were heavily defoliated. On average, shore pine retained 3.3 years (standard deviation: 1.2 years) and 3.2 inches (standard deviation: 1.6 inches) of foliated branch tissue. Years of foliage retention and foliate branch length decreased as foliar damage severity rating increased (data not shown). Juneau was the location with the lowest mean needle retention (2.6 years), while Mitkof Island was the location with the highest (3.6 years), consistent with more moderate- and high-severity foliar damage in Juneau (14 percent) compared to other locations (9 to 11 percent).

Conks and Bark Beetles

Porodaedalea pini (formerly *Phellinus pini*) was the only heart rot decay fungus observed on live shore pine in study plots. *P. pini* conks were detected on 14 live trees and 6 snags. *Laetiporus sulphureus* was observed on a shore pine snag outside of study plots on Douglas Island (Juneau).

Secondary and tertiary bark beetles and galleries were observed on some large dying and recently killed pines. Detected bark beetles included *Pseudips mexicanus*, *Dryocoetes* sp., *Hylurgops porosus*, and the ambrosia beetle *Trypodendron lineatum*. *Pseudips mexicanus* beetles and galleries were most common and often occurred with a blue-staining fungus identified as *Leptographium wingfieldii* or a closely related species. Beetle galleries and staining were also noted on larger size-class shore pine snags. Bark beetle activity may be undercounted because galleries of secondary/tertiary insects (e.g., flathead borers) were common on snags and may have obscured evidence of earlier beetle activity.

DISCUSSION

Western gall rust, bole wounds, and Dothistroma needle blight were the most common forms of damage to shore pine detected in this study. All encountered biotic damage agents are presumed to be native, although some new State records were found (e.g., pine sawfly) and more work is needed to verify the causes of some forms of damage (e.g., bole cankers and other bole wounds).

Size and decay class information from snags showed that the largest diameter class of pine had the highest proportion dead (10 of 25 trees) and that much of this mortality was relatively recent (decay class 2). This pulse of mortality mirrors the loss of shore pine detected through the FIA network but is based on a small sample size. Secondary bark beetles and galleries (*Pseudips mexicanus* and *Dendroctonus murryanae*) and black fungal staining were detected on large, actively dying shore pine in our plots, and similar staining was observed on shore pine snags up to decay class 3. Shore pine occurs in a challenging environment and has a high incidence of damage; trees may succumb to injury and environmental stresses directly over time, and large weakened trees may attract bark beetles. Continued monitoring of this plot network will provide more concrete information on what conditions and damage agents are associated with mortality of trees that are currently alive.

WGR was present in all subplots and affected most trees, with variable incidence and severity. The coastal rainforest provides consistently conducive infection conditions. WGR severity was correlated with crown dieback, especially when bole galls were present, because bole galls were frequently associated with topkill. The high incidence of bole gall topkill in the upper crown meant that affected trees often survived, albeit with compromised form, reduced photosynthetic capacity from crown dieback, and a tendency for repeated injury from bole galls on new leaders. Secondary fungi (*Nectria cinnabarina*), caterpillars (Lepidoptera: Pyralidae: *Dioryctria*), and twig beetles (Coleoptera: Scolytidae: *Pityophthorus*) were detected in galls from recently killed branches.

Bole wounds were present on about one-third of live shore pine, with overall wound and bole wound incidence and severity increasing progressively with tree diameter. More than half of the trees over 10 inches d.b.h. had bole wounds, and nearly 40 percent had bole wounds of moderate to high severity. The causes of bole wounding, especially older wounds, were difficult to distinguish. More work is needed to understand the causes of bole wounding and to determine whether a fungal pathogen is responsible for the diamond-shaped cankerlike wounds observed on many shore pine. Large bole wounds can girdle and kill trees directly or increase their vulnerability to other agents.

Mild, wet summers in the coastal rainforest favor spread and infection by *Dothistroma septosporum*. Dothistroma needle blight probably limits needle retention and negatively affects growth of shore pine across the study area but was not causing mortality in study plots. Foliage disease severity varied by location and was negatively correlated with foliage retention. A localized Dothistroma outbreak observed outside the plot network near Glacier Bay caused shore pine mortality following three consecutive years of severe foliage disease. Shore pine's low needle retention in southeast Alaska may make it particularly sensitive to successive years of foliar damage. Unprecedented damage and mortality from Dothistroma needle blight has occurred in managed lodgepole pine stands of British Columbia in conjunction with recent increases in summer precipitation, demonstrating that moderate changes in local climate can significantly affect severity of native foliage diseases (Woods and others 2005). Damage from pine sawfly had not been previously noted in Alaska. The broad detection of pine sawfly across the study area, its distribution in neighboring Canadian provinces (Ciesla 1976), and its recorded occurrence on shore pine suggest that this insect is native to southeast Alaska.

Porodaedalea pini (formerly *Phellinus pini*) was the only heart rot decay fungus observed fruiting on live shore pine. Conks were uncommon, but larger size-class shore pine often had sapwood decay associated with bole wounds, bole snap at old bole galls or frost cracks, or bole swelling. Bole injuries and WGR topkill create infection points for stem decay fungi. Increment coring the largest diameter pine in each subplot often revealed otherwise undetected heart rot.

Shore pine snags, in particular, frequently had animal holes associated with decayed cavities. In light of the high incidence of other damage agents (girdling bole wounds and bole galls of WGR), stem decays appear to be relatively less important disturbance agents in shore pine stands compared to other old-growth forest types in Alaska but probably create valuable wildlife habitat for cavity nesters.

Root exposure was commonly recorded among all species and included situations in which trees were rooted in water in addition to situations in which trees were rooted in mossy mounds with apparently compromised root anchorage. Root exposure may not stress or damage trees unless severe, and <1 percent of shore pine had high-severity root exposure, usually in standing water. Sitka spruce, western hemlock, and mountain hemlock frequently grew on the relatively drier mossy mounds, microsites that these species appeared to outgrow over time. Sitka spruce was often stunted and chlorotic, an indication of nutrient deficiency or water stress. Hemlocks attained larger size and regenerated more prolifically in mixed-conifer forest on the periphery of shore pine-dominated muskegs. In contrast, shore pine more often regenerated on moderately wet microsites with high light availability and limited competition from other tree species. Yellow-cedar allocates more roots near the soil surface in saturated, nutrient-poor soils of forested wetlands, increasing its vulnerability to decline freezing injury (D'Amore and others 2009, Hennon and others 2012). Crown dieback and discoloration symptoms of yellow-cedar decline were common. Together, these observations indicate that associated conifers are not well suited to fill the niche that shore pine occupies in forested wetlands.

CONCLUSIONS

Despite the high incidence of injury to shore pine observed in this plot network, the species appears to be regenerating well in the peatland bogs and fens of southeast Alaska, as evidenced by the large number of small and medium trees in sample plots. Shore pine is well adapted to take advantage of the high light environment of forested wetlands, tolerating acidic, saturated soils better than associated conifers. We hypothesize that accumulated stress, particularly from bole wounding and bole galls of WGR, may kill trees directly or attract secondary bark beetles to weakened, larger trees. Weather conditions that support population increases of fungi or insects that attack WGR galls, cause foliar damage, or cause bole cankers may make these agents relatively more important to shore pine health in some years than others. Remeasurement of the 46-plot network every 5 years will further increase our knowledge of the causes and incidence of damage and mortality of shore pine and will help to determine whether the loss of larger diameter shore pine detected through FIA and our plot network continues and warrants concern.

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CONTACT INFORMATION

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