2015 Update: Forest Health Assessment of Yellow-cedar Young-growth on Zarembo Island

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2015 Update

Two adjacent young-growth stands with confirmed yellow-cedar decline symptoms in 2013 (4570000070 and 4570000024) were revisited in 2015. Of 60 trees monitored in 2013, 53 live trees were reassessed for live/dead status, crown symptoms, and signs of bark beetle attack and *Armillaria* root disease. Seven dead trees were not reassessed. We wanted to increase monitoring of asymptomatic trees close to declining trees. A dozen live yellow-cedar trees were added to the monitoring effort, intermixed with the other monitored trees. Eight of these trees were healthy (crown fullness ratings ≥85% and green foliage in ≥75% of the crown), while the other four were relatively stressed. Distance and bearing location information was collected for these trees rather than waypoints.

More comprehensive and repeatable methods were used to rate crown symptoms compared to the methods implemented in 2013. The new protocol is to give one rating for percent crown fullness (i.e., crown fullness compared to a healthy tree) and another rating for the percent crown discoloration (i.e., the percentage of persistent foliage that is green, yellow, and red-brown). The previous system assigned a single percent crown chlorosis/dieback rating, not distinguishing between crown thinness and discoloration. Although imperfect, we compared percent crown fullness in 2015 to the inverse of percent crown dieback in 2013 (100 - crown dieback/chlorosis in 2013).

The crown condition of 19 out of 53 trees worsened between 2013 and 2015 (Table 1). One tree died and three were nearly dead. The dead tree was colonized by *Armillaria* and had been attacked by *Phloeosinus* bark beetles, but lacked extensive, girdling larval galleries. Examination of a tree core from the dead tree showed growth loss over approximately 5 years; the roots were not excavated to look for necrotic lesions. *Phloeosinus* bark beetle attack was associated with two out of three dying trees. Our largest (10.2in dbh), healthy monitoring tree in 2013 had been attacked by bark beetles and was dying rapidly, as indicated by a full but discolored tree crown. Another dying tree lacked bark beetle galleries, but root excavation revealed necrotic lesions on coarse roots at the root collar consistent with yellow-cedar decline. A third dying tree had recently been attacked by bark beetles, but lacked extensive, girdling larval galleries. We did not remove bark or excavate roots unless trees were obviously dying because we did not want to further damage live trees, and this limited our detection of *Armillaria*.

Overall, crown symptoms of monitored trees increased in severity but only a small number of trees died. Sixty percent of trees with moderate dieback (15-45%) in 2013 were more symptomatic in 2015, whereas trees with negligible dieback tended to remain healthy, and trees with substantial dieback remained stressed but alive. In old-growth forests with yellow-cedar decline, it is common for affected trees to die gradually over +15 years. The process is more rapid when stressed trees are attacked by bark beetles; an increase in bark beetle populations in these stands could increase the mortality rate of monitored trees. We did not observe an expansion of decline symptoms into new or higher elevation parts of these stands. However, road surveys identified two nearby stands (4570000026 and 4570000020, harvested in 1975 and thinned in 2002 and 2008) with apparently extensive decline symptoms. Trees and site factors in these newly-identified stands will be evaluated in 2016.

Table 1. Summary of 53 live yellow-cedar trees monitored since 2013, categorized by 2013 crown ratings, and counts of how many had lost vigor (≥15% decrease in crown fullness), died, been attacked by bark beetles, or had discolored tree crowns when reassessed in 2015.

2013 % Chlorosis/Dieback	No. Trees	Lost Vigor Since 2015	Dead*/Almost Dead in 2015	Signs of Phloeosinus Attack	Discolored Tree Crown (<80% Green)
0-10%	29	6	1	1	3
15-30%	11	7	1*	1	10
35-45%	9	5	1		9
55-70%	4	1	1	1	4
Total	**53**	**19 (36%)**	**4 (8%)**	**3 (6%)**	**25 (47%)**

2013 Report

Introduction

Greg Roberts, Silviculturist on the Wrangell Ranger District, contacted Juneau Forest Health Protection in 2012 regarding damage observed to yellow-cedar in two adjacent naturally regenerated young-growth stands on Zarembo Island (Figure 1). The first stand (4570000070; 35 acres) was logged as a blowdown salvage in 1975 and pre-commercially thinned (PCT) to a 14-ft-spacing in 2005. The second stand (4570000024; 139 acres) was clearcut in 1973, partially PCT in 1983, and PCT in 2005. Tree species include western hemlock, Sitka spruce, western redcedar, and yellow-cedar, and minor amounts of mountain hemlock, shore pine, and red alder. Variable spacing was implemented based on best crop trees, according to health and vigor, to result in 222 trees per acre. Although thinning preference was not intended to favor any specific species, a daily diary from the thinning noted that "in some cases, too much emphasis was placed on species selection instead of tree size. We found this regarding cedar and spruce." Following the thinning, which left a significant yellow-cedar component in the stands, scattered cedars began to develop discolored tree crowns. Some trees slowly developed yellow-red crown symptoms, while other crowns turned red more rapidly as trees were killed. Many healthy yellow-cedar trees remain in the stand.

Yellow-cedar decline is typically absent from young-growth stands because most harvested stands have relatively high productivity, with better drained and deeper soils that promote deeper growth of fine roots to avoid the freezing injury. Productive stands also tend to have dense canopies that provide shade to buffer soil temperature extremes.

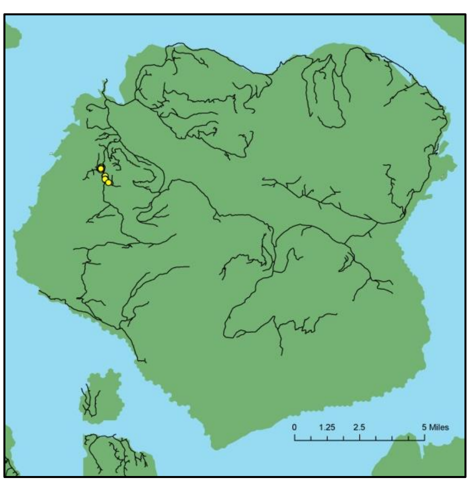

Figure 1. Location of affected stands (4570000070 and 4570000024) on Zarembo Island, elevation 300-800ft. The aerial photo shows the 35 acre blowdown and 139 acre clearcut stands.

Methods and Observations

Monitoring trees

From July 29-30 2013, we examined 60 yellow-cedar trees in the stand that ranged from healthy (no crown symptoms) to recently-dead (Figures 2 and 3). Information collected from trees included: GPS coordinates, live/dead status, diameter at breast height (DBH), estimated height, percent yellow-red crown discoloration (chlorosis), and the presence of *Phloeosinus* bark beetles and/or *Armillaria* fungus. In a subset of sample trees, we excavated a portion of the root system to observe below-ground symptoms or took an increment core near breast height.

Figure 2. Healthy (left), declining (middle) and dead (right) yellow-cedar trees were flagged and mapped for long-term monitoring. 9 live trees and 7 recently-killed trees were excavated at the base to look for necrotic lesions at the root collar, *Phloeosinus* bark beetle galleries, and signs of *Armillaria* fungal infection.

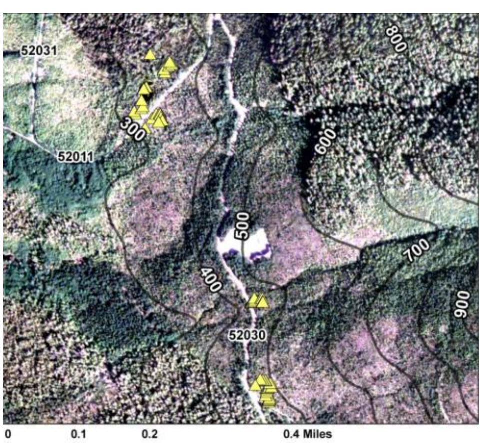

Figure 3. A stem map of yellow-cedar trees selected for long-term monitoring on Zarembo Island.

Of the 60 trees selected for monitoring, half were relatively healthy (≤10% crown discoloration), 7 were dead (100% crown discoloration/dieback), and the remaining trees ranged from 15-70% crown discoloration (Table 2). Note that yellow-cedar trees were not selected at random, so these trees do not necessarily represent the condition of yellow-cedar throughout these stands. Other data collected from selected trees are summarized in Table 2. *Phloeosinus* bark beetle galleries and mycelial fans of *Armillaria* root rot fungus were common on dead trees (Table 3, Figure 4), but were uncommon on live excavated trees. This is consistent with the paradigm that these secondary agents attack trees already stressed by other factors and are common in stands experiencing cedar decline. Signs of failed bark beetle attacks were observed on healthy trees, and live beetles (Figure 5) were only found in recently-killed trees. Necrotic lesions moving up the bole from coarse roots, fine root mortality, low density of fine roots, and mottled discoloration of phloem tissue were observed on several excavated trees, including recently-killed trees and trees with >65% crown discoloration (Figure 6).

Table 2. Crown discoloration and dieback of 60 yellow-cedar trees selected for monitoring on Zarembo Island.

% Crown Discoloration/Dieback	No. Trees
0-10%	29
15-30%	11
35-45%	9
55-70%	4
100% (dead)	7

Table 3. Summary statistics of 60 yellow-cedar trees selected for monitoring on Zarembo Island.

	No. Trees	Avg. Ht	Avg. DBH (in)	DBH range (in)	Ht range (ft)	Armillaria	Phloeosinus	Core Collected	Excavated
Live	53	26.8	5.5	2.3-10.2	16-45	1	0	9	9
Dead	7	26.3	6.3	4.1-9.0	18-40	5	7	3	7

Figure 4. Mycelial fans of *Armillaria* (left) and galleries of *Phloeosinus* bark beetles (right) are common signs of these secondary agents on yellow-cedar trees stressed by root-freezing injury.

Figure 5. Adult *Phloeosinus* beetle (left) and larvae (right) actively feeding in a recently killed yellow-cedar.

Figure 6. Necrotic phloem (brown surrounded by white) emerging from the coarse roots to the root collar and lower bole of symptomatic yellow-cedar trees. These symptoms provide compelling evidence that freezing injury to roots is occurring in these young-growth stands on Zarembo Island.

Site Observations

Stand notes describe this site as low elevation with a site index of 33-49. It is in the mixed-conifer series, with blueberry, blueberry/skunk cabbage and blueberry/deer cabbage associations. The soil is Kaikli mucky peat.

In general, trees of all species in this stand were small for 38-40 years old, indicating relatively low site productivity. This was particularly apparent in comparison to nearby stands of approximately the same age. We observed larger and more vigorous yellow-cedar trees in presumably more productive portions of the stands (Figure 7). The average DBH of live yellow-cedar was 5.5", while the maximum size recorded was 10.2"; therefore, we might infer that on productive microsites, yellow-cedar can attain 10" of growth by age 40. Wet site indicator species, such as bearberry (*Vaccinium vitis-idea*), Labrador tea (*Ledum groenlandica*), fernleaf and trifoliate golden thread (*Coptis* spp.), and skunk cabbage (*Lysichiton americanus*) provide additional evidence of low site productivity and poor soil drainage. Observations of yellow-cedar snags in the uncut area immediately outside the stand boundary indicate that there may have been a history of decline in the cut unit before it was harvested, but this information could not be ascertained directly from old stumps in the stand or from stand records.

Figure 7. Healthy and vigorous yellow-cedar trees were present in more productive portions of the units.

Conclusions and Management Implications

Overall, classic signs and symptoms of yellow-cedar decline were observed in this young-growth stand. These include necrotic lesions on the roots, root collars and lower boles of trees with pronounced crown symptoms, yellow-cedar trees with varying amounts of crown discoloration, secondary agents *Armillaria* and *Phloeosinus* beetles on freshly-killed trees, and a lack of damage to associated tree species. In addition, yellow-cedar crop trees were found to be dying and dead on wet, unproductive microsites, but appeared vigorous on more productive portions of the unit. Along with snowpack, soil drainage is a major risk factor of yellow-cedar decline in unmanaged landscapes.

This report documents the first finding of yellow-cedar decline in young-growth stands. At this time we do not know how widespread the problem is; possibly it is limited since most harvested sites are at least moderately productive with relatively deeper soils. However, this lower productivity stand on a poorly-drained site would be expected to be vulnerable to cedar decline, because saturated soils translate to shallow fine roots that are sensitive to freezing injury. Although it is unknown whether yellow-cedar trees were dead or dying in these the stands when they were harvested in 1973 and 1975, we imagine that this was the case based on cedar snags surrounding the cut unit. It is possible that thinning exacerbated or triggered the onset of decline in this young-growth stand through its impacts on canopy density and insulating snowpack. Otherwise, it is unclear why symptoms of decline would have been absent from the stand before thinning. Cored trees did not show growth release following thinning; some trees showed growth slowdown at the time of thinning eight years ago, while most trees with crown symptoms showed slowed growth over the last 3-5 years (Table 4, p9). It will be important to watch for these issues in stands that contain yellow-cedar and have wet site indicators, as logging occurred on a broad range of productivity classes in the mid-1970s. We may begin to see the effects of this shift in forest management as these second-growth stands are thinned. We will continue to monitor this stand over time to determine the rate of tree mortality and whether damage continues or worsens. Monitoring trees that are currently healthy will be particularly interesting, since these trees may be asymptomatic because they are on better microsites, because they have better tolerance to freezing injury, or because crown symptom development generally requires recurring freezing injury over time and may take many years to develop.

Completion of the Regional Yellow-cedar Strategy is anticipated in 2014. The last section of this document will focus on using GIS modeling to partition the landscape into areas where yellow-cedar is expected to thrive, and areas where it is expected to be maladapted based on soil drainage and snowpack. Our models may corroborate yellow-cedar being maladapted to this site due to wet soils and inadequate snow. Continued monitoring of this site and others like it will help determine the extent and intensity of this problem of mortality to yellow-cedar in young-growth forests. A permanent plot established for the study *Tree Growth on Forested Wetlands Following Clearcutting* is located approximately 5 miles from affected stands on Zarembo (56°19'N, 132°59'W; Figure 8; Julin and D'Amore 2003), and revisiting this plot may provide a longer-term view of yellow-cedar in marginally productive young-growth. As we gain more knowledge about decline in young stands, it is possible that we can provide management recommendations about specific situations in which yellow-cedar should not be favored during thinning (e.g., wet portions of stands). At this point we lack information to make such broad statements and look forward to accumulating more information to support a recommendation.

Figure 8. The approximate location of the permanent plot established by Julin and D'Amore (2003) relative to the stands that we examined on Zarembo Island. The permanent plot is located at higher elevation (~800ft); therefore, snowpack may afford yellow-cedar relatively greater protection from freezing injury.

Julin, K.R. and D.V. D'Amore. 2003. Tree Growth on Forested Wetlands of Southeast Alaska Following Clearcutting. Western Journal of Applied Forestry 18(1): 30-34.

Table 4. Tree core information collected from select yellow-cedar trees on Zarembo Island. Trees ordered by crown health (percent chlorosis).

Tree	DBH (in)	Ht (ft)	Chlorosis (%)	Rings	Core Length (in)	Mean in/yr	0-10 in/yr	11-20 in/yr	21-30 in/yr	31-40 in/yr	Core Notes	Crown/foliage notes
Zar12	5.9	35	0	20	3.39	0.17	0.18	0.16			minimal growth slowdown last 3 years; no obvious release; only 20, so possible that bark end of core broken and pith not hit	healthy
Zar13	10.2	34	0	30	4.96	0.17	0.22	0.19	0.09		no evidence growth slowdown; possible subtle release post-thin	healthy; close to rd; large, super tree!
Zar20	4.4	23	5	25	1.73	0.07	0.08	0.07	0.06		no evidence of growth change; very consistent	
Zar34	10.1	45	5	34	4.76	0.14	0.14	0.18	0.28	0.12	good hit of pith; good growth	
Zar8	4.5	20	15	31	2.05	0.07	0.05	0.11	0.05	0.04	direct hit of pith; evidence of growth slowdown with thin	live cambium at root collar; cored through
Zar4	6.0		20	21	2.95	0.14	0.13	0.15	0.16		some growth loss last 3 years; not as severe as other samples	relatively full crown
Zar32	8.7	36	25	25	4.33	0.17	0.19	0.19	0.10		poor growth last 3 years; young age may indicate missed pith?	
Zar5	6.8	35	30	28	3.19	0.11	0.08	0.13	0.14		poor growth last 5 years; pith not hit	chlorotic and brown; cored through
Zar7	5.9	27	40	29	2.95	0.10	0.13	0.11	0.07		good hit of pith; consistent good growth	
Zar23	6.0	30	45	27	2.80	0.10	0.07	0.15	0.09		poor growth last 4 years	top recently dead, upper 4 ft, and thin, scraggly crown; nearest "fader" to clump of healthy; very close to Zar 3, 2, 1
Zar1	7.6	28	100	29	3.54	0.12	0.10	0.14	0.13		recovery after poor growth following thinning 2-8 years ago	rapid crown dieback
Zar10	5.0	22	100	28	2.64	0.09	0.11	0.10	0.07		poor growth last 5 years; pith not hit	recently killed; Phloeosinus beetle larvae and adult collected, first attack 1-2 years ago; necrotic lesion from roots to 3 ft; Armillaria mycelial fan overlaps lesion