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Yellow-cedar (*Chamaecyparis nootkatensis*) at the Northwest Limits of Its Natural Range in Prince William Sound, Alaska

Abstract

Little is known about yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) in Prince William Sound, Alaska; even the northwest limit of the range of this valuable tree has been unresolved. Mapping the occurrence of yellow-cedar from aircraft, boat, and by foot revealed two general locations: small populations on or near Hawkins Island and larger and more extensive populations from Glacier Island to Cedar Bay, Wells Bay, and Unakwik Inlet. A population of yellow-cedar on the eastern shore of Unakwik Inlet represents the furthest known northwest extent of the natural range. Results from plots located in the eastern and north-central areas of Prince William Sound indicate that yellow-cedar is common in all diameter classes, but is younger than the associated western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and mountain hemlock (*T. mertensiana* (Bong.) Carr.). The tree is reproducing prolifically in the north-central portion of the sound. Reproduction, growth, and the vigorous appearance of trees suggest that yellow-cedar is currently thriving and increasing in abundance near the edge of its range. Direct human use of these forests has been limited to the harvesting of small diameter trees and the common occurrence of bark removal on the larger yellow-cedar trees.

Introduction

Yellow-cedar, *Chamaecyparis nootkatensis* (D. Don) Spach, is a commercially and ecologically important tree that grows throughout the Pacific coastal regions of British Columbia and Alaska. In the southern portion of its natural range, yellow-cedar occurs in a number of disjunct populations through the Cascade and Siskiyou Mountains to just south of the Oregon-California border (Mason 1941). Two other populations are known from central Oregon (Frenkel 1974) and southeastern British Columbia (Mason 1941, Griffin and Critchfield 1972), both some distance east of the main portion of the range.

Yellow-cedar is well known locally in coastal British Columbia and Southeast Alaska (i.e., panhandle) where it is an important timber-producing species, often yielding the most valuable wood of any tree. In these areas, yellow-cedar is the subject of research on regeneration ecology and, in Southeast Alaska, on a widespread forest decline and mortality (Hennon and Shaw 1997). Along with commercial uses of yellow-cedar, Native people have historically harvested its bark and wood for a number of purposes (Stewart 1984).

Surprisingly little is known about yellow-cedar near the northwest limits of its natural distribution, where even the limit of its range is not clear. Several historical observations report the occurrence of yellow-cedar in this area of Alaska, most frequently mentioning populations on Hawkins and Glacier Islands. Bandegee (1910) noted that yellow-cedar is known to grow near sea level on Hawkins and Glacier Islands and can be found on the northeastern tip of Hinchinbrook Island. He assumed that the species had a sporadic occurrence in Prince William Sound. Fernow (1910) did not make direct observations of yellow-cedar trees, but did report that fur traders had observed the species growing on Hawkins Island, 10 or 11 km from Orca (near Cordova), and on Glacier Island opposite Columbia Glacier. He may have been citing Sudworth (1908), who described these locations and added the stretch of mainland from Long Bay (north of Glacier Island) to "Unganik Bay." It is possible that Sudworth was referring to Unakwik Inlet. The wood and bark of yellow-cedar were seen being used at the Native village of Tatitlek at the foot of Copper Mountain early in the century (Fernow 1910). Cooper (1942) observed yellow-cedar growing on Glacier Island and assumed this was the edge of the range. He described it here as "locally abundant and thrifty" and mentioned that a fox farmer had seen trees up to one meter in diameter on the island (Cooper 1942) .

Further to the southeast along the Gulf of Alaska, Coville and Funston (1895) reported a lone yellow-cedar tree growing on Khantaak Island "near the Native Village," several kilometers northwest from the city of Yakutat. At Lituya Bay, Mertie (1931) described yellow-cedar on benches where it grows to one meter in diameter and Heusser (1960, Plate IX) included a photograph of a mature yellow-cedar tree in the same area. Heusser (1983) reported on the historic abundance of vegetation in Prince William Sound by using pollen profile analysis, but yellow-cedar was overlooked in pollen profiles because of the "absence of recognizable [pollen] grains."

Hultén (1941) stated that yellow-cedar was present in a few, very isolated groves in Prince William Sound. Editions of his Flora of Alaska (Hultén 1941, 1968) did not give location names for occurrence and the distribution map used has a scale that is too small to determine precise locations or the range limits.

Viereck and Little (1972) gave the northwest limits of yellow-cedar at Glacier Island and Wells Bay. Several years later, however, the same authors showed the range of yellow-cedar in Alaska with a series of large dots that depict known or suspected locations (Viereck and Little 1975, Figure 12). One dot was placed on Latouche Island, which would extend the western limits of the range to near the 148°W longitude and considerably to the south of other known locations in Prince William Sound. Page 10 of that report mentioned yellow-cedar "from Cordova to Glacier Island, Port Wells, and Latouche Island." Port Wells should not be confused with Wells Bay (see Figure 1). Heusser (1983) incorrectly cited Viereck and Little (1972), indicating that their book reported yellow-cedar growing in Port Wells. We also have an unverified report of yellow-cedar growing on Esther Island, which is located near Port Wells and north of Latouche on about the same longitude.

Except for these brief observations on occurrence, there are no descriptions in the scientific literature on the ecology of yellow-cedar in Prince William Sound. This paper has two objectives. First, we hope to clarify the occurrence of yellow-cedar at the northwest limits of its natural distribution. Second, we attempt to describe the age structure, reproduction, associated vegetation, and human use of yellow-cedar in these areas.

Methods

Several methods were used to document the occurrence of yellow-cedar in Prince William Sound. We consulted all available scientific literature from a large bibliography on the tree species (Hennon and Harris 1997) as summarized above in the introduction. Several people with extensive local knowledge concerning vegetation in Prince William Sound shared maps with locations of yellow-cedar. We requested information on Forest Inventory plots that contained any yellow-cedar from the Pacific Northwest Research Station, USDA Forest Service. We also received information on vegetation sampling transects from the Chugach National Forest, USDA Forest Service.

During our field visits to Prince William Sound in 1997 through 1999, we attempted to map locations of yellow-cedar from small aircraft, boats, and the ground. We used binoculars to scan trees from boats and the ground and searched for the characteristic bright green color and droopy foliage of yellow-cedar.

Once yellow-cedar forests were found, we installed four intensive permanent plots. Two plots were located on Hawkins Island and two at Cedar Bay to represent the eastern and north-central portions of Prince William Sound, respectively. We selected sites to exemplify forests where yellow-cedar was a common component of the larger trees. Three of these permanent plots were 0.25 hectare in size, the fourth measured 0.125 hectare. Data collected from each tree over 5 cm diameter included: species, diameter at breast height (to the nearest mm), height (to the nearest dm measured with a Criterion Laser), canopy crown class, and any evidence of human use (i.e., bark harvesting). Increment cores were taken at 1 m above ground from trees with a range of sizes for each species. Cores were transported back to our laboratory, mounted, sanded, and ring-counted using a dissecting microscope where needed. Data collected from dead trees included: species, diameter, mode of tree death (i.e., uprooted, dead standing, broken bole), decay class, and evidence of tree harvesting (i.e., stump). Stumps with a flat surface, indicating human use, were distinguished from trees that died naturally by bole breakage. The locations of all live and dead trees were mapped using a Criterion Laser, from which stem maps were constructed. Plot location was documented using a GPS device.

The abundance of understory vegetation was recorded from four $1m^2$ plots on each of the larger overstory plots; nomenclature follows Hultén (1968). These four plots were located half way between the center and corners of the overstory plot. Five cover classes for each of the taxa were: absent, uncommon (<5%), common (5 to 24%), very common (25 to 49%), and dominant (≥50%) for each understory cover stratum. Scores for each species were averaged for the four understory plots to calculate an overall abundance class for the larger permanent plots. Tree seedlings were also counted in these understory plots. Those of yellow-cedar were counted by annual age class (e.g., emergent, 1-year-old, etc.) based on our experience with the appearance of yellow-cedar seedlings.

In 1999, we visited the population of yellow-cedar that represented the furthest northwest extension of the range that we could find. There, we mapped the population from the ground, noted regeneration, and measured and aged the largest 12 yellow-cedars found.

Results

Natural Range of Yellow-cedar in Prince William Sound

Our observations on the distribution of yellow-cedar are displayed in Figure 1. Yellow-cedar was restricted to small populations in a few locations in the eastern portion of Prince William Sound. We encountered the tree at Windy Bay on Hawkins Island, where we mapped the distribution on 59 ha and installed two permanent plots. We did not find yellow-cedar 2.5 km to the southwest at nearby Cedar Bay on Hawkins Island. Yellow-cedar also grows at Point Gravina, Bomb Point and Alice Cove on the mainland and at Mud Bay on Hawkins Island (Stephen Bodnar, Pers. Comm.) (Figure 1). A small population occurs on the northeast portion of Hinchinbrook Island at Yelper Cove adjacent to Hawkins Island (John Hard, Pers. Comm.) (Figure 1).

Yellow-cedar is not known to grow in the large expanse of approximately 70 km between the Wells

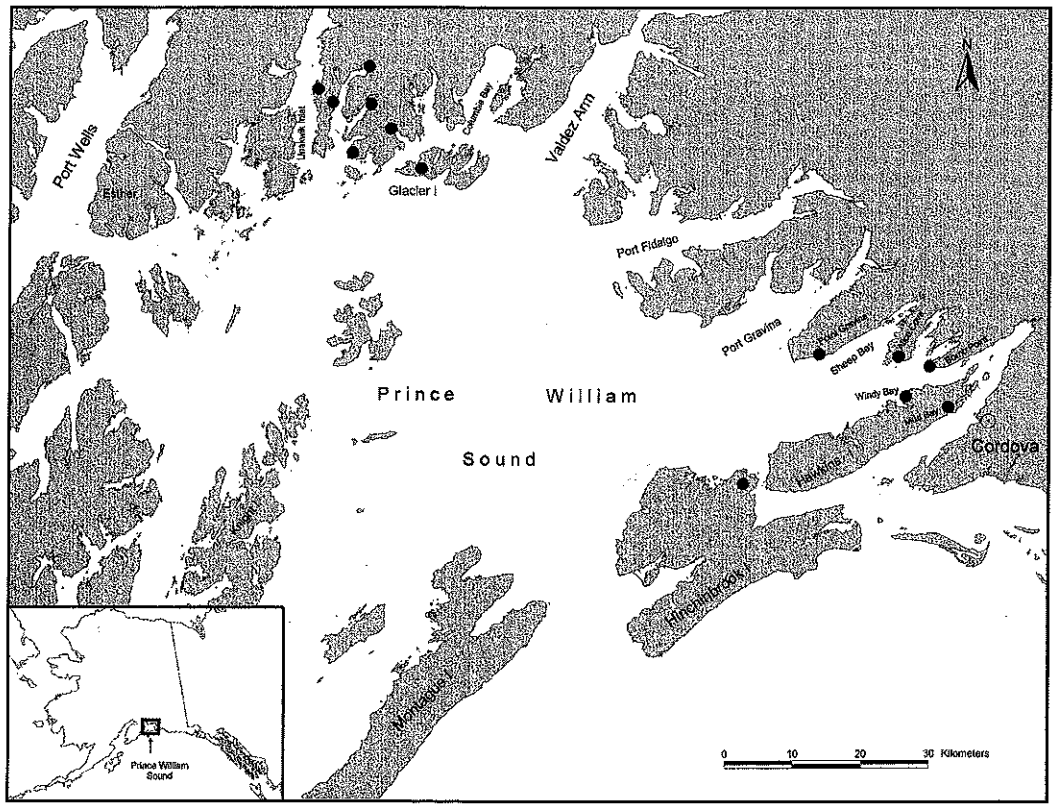

Figure 1. Known distribution of yellow-cedar in Prince William Sound, Alaska. Each dot represents a confirmed population of yellow-cedar.

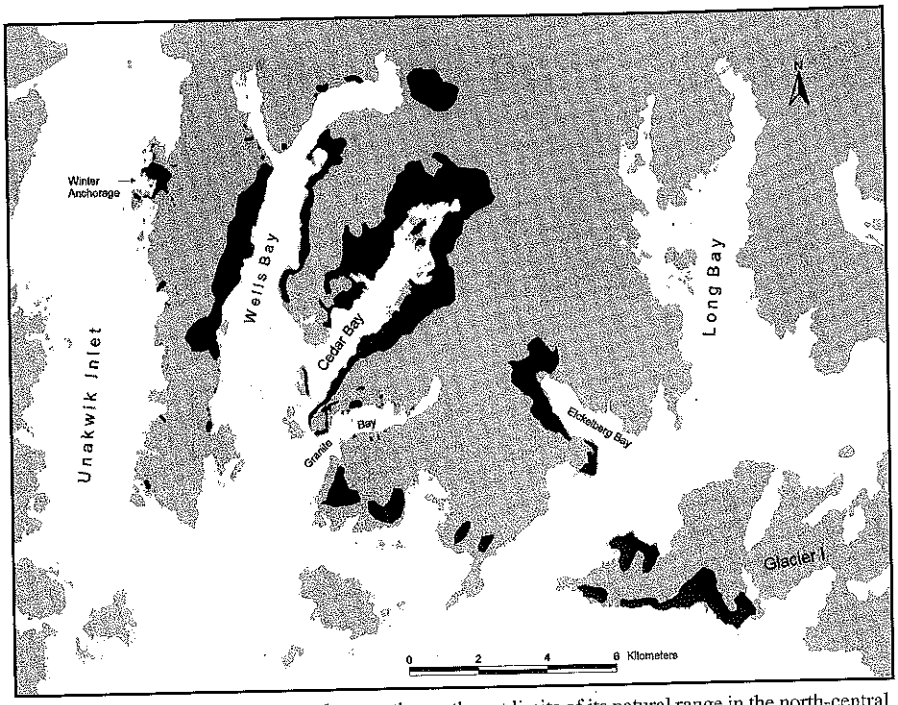

Figure 2. Distribution of yellow-cedar near the northwest limits of its natural range in the north-central portion of Prince William Sound, Alaska.

Bay-Glacier Island area and the locations on or near Hawkins Island mentioned above. We searched for yellow-cedar by boat and aircraft and mapped its occurrence on Glacier Island and several locations to the northwest leading to Granite Bay, Cedar Bay, Wells Bay, and Unakwik Inlet (Figure 2) for a total of about 2500 ha. Granitic bedrock geology is common in these areas. The 1978 Forest Inventory (USDA FS, Pacific Northwest Research Station, Forest Inventory and Analysis) documented yellow-cedar at three specific locations: Granite Bay (plot 066), Cedar Bay (plot 184), and the west side of Wells Bay (plot 050). Yellow-cedar was extremely common in the Cedar Bay area where we observed it growing from sea level to near timberline in all parts of the bay. Cedar Bay appeared to have the largest contiguous yellow-cedar population of any area in Prince William Sound. We found one stand with many dead yellow-cedar trees, all of which died several decades ago, located on an exposed hillside with thin soils on the western side of Cedar Bay. Generally, however, the mortality of yellow-cedar appeared low in Prince William Sound, especially contrasted with the large-scale forest decline of the species that occurs in Southeast Alaska (Hennon and Shaw 1997).

Yellow-cedar was also abundant along the eastern and western shore of Wells Bay and at the head of the eastern arm of Wells Bay (Figure 2.). The tree also occurred in numerous smaller populations along the eastern shore of Unakwik Inlet. The largest population in that area was near Winter Anchorage on about 41 ha. A small stand of about 2.5 ha was found on a peninsula at Winter Anchorage; this location represents the furthest known western extent of yellow-cedar's natural range at Longitude W147°32'50". Populations along the eastern arm of Wells Bay represent the furthest north that yellow-cedar has been found at Latitude N61°00'49". Several trees found 2 km north of Winter Anchorage along Unakwik Inlet extend almost that far north.

Yellow-cedar probably does not occur at several other rumored locations. Mark Stahl and Rick Rogers, land manager and forester, respectively of Chugach Alaska Native Corporation, have never encountered yellow-cedar on Latouche Island and assume that it does not grow there. A verified account of yellow-cedar on Latouche Island would extend the distribution of the species approximately 100km to the southwest of the Cedar Bay-Wells Bay population.

In 1998, we explored the possibility of yellow-cedar's occurrence on Esther Island in the Esther Passage area where others reported it. In three days of observing forests and individual trees and stands by boat and foot, we did not find any yellow-cedar. We did observe a number of western hemlock trees with bright green, droopy foliage that may have been mistaken for yellow-cedar.

The lone yellow-cedar observed on Khantaak Island near Yakutat may no longer exist. Those familiar with the island have never encountered yellow-cedar (Vince Harke, Yakutat Ranger District, USDA Forest Service, Pers. Comm).

Permanent Plots

The locations of the four permanent plots are given in Table 1. In density (stems/ha), yellow-cedar was the most frequent tree species on three of the four plots (Table 2). Western hemlock and mountain hemlock were also common, but Sitka spruce

TABLE 1. Plots used to describe the composition and age structure of yellow-cedar forests in Prince William Sound. Latitude and longitude values are averages from GPS measurements taken at the four corners of each plot. Plots 1 and 2 are on Hawkins Island and plots 3 and 4 are in Cedar Bay in the eastern and north-central portions of Prince William Sound, respectively.

Plot	Latitude	Longitude	Elevation (m)	Slope (%)	Aspect (°)	Landscape position
1	N60°34' 9.66"	W145°57' 15.13"	35	30	270	Between upper and lower bog
2	N60°34' 22.03"	W145°57' 6.12"	85	40	240	Well drained slope
3	N60°56' 42.85"	W147°24' 48.82"	38	25	250	Downslope from bog
4	N60°57' 59.10"	W147°23' 14.76"	33	30	160	Upslope from bog

TABLE 2. Characteristics of stands and canopy-level trees[1] in four forest stands in Prince William Sound.

	Hawkins Island		Cedar Bay	
Stand Characteristic by Species	Plot 1	Plot 2	Plot 3	Plot 4
Density[1] (no. stems/ha)				
Yellow-cedar	220	228	396	352
Western hemlock	164	252	160	64
Mountain hemlock	132	44	120	216
Sitka spruce	24	40	12	8
Total	540	564	688	640
Basal Area[2] (m^2/ha)				
Yellow-cedar	12.6 (0.1)	20.3 (2.0)	18.1 (5.5)	11.4 (0)
Western hemlock	5.4	20.3	5.2	0.9
Mountain hemlock	8.0	5.4	4.6	12.4
Sitka spruce	0.5	0.6	0.5	0.1
Total	26.5 (2.1)	46.6 (6.5)	28.4 (12.5)	24.8 (5.4)
Diameter[3] (cm)				
Yellow-cedar	13.1-60.1	20.7-75.5	17.2-71.7	18.6-44.0
Western hemlock	15.4-51.6	23.3-61.3	28.5-50.9	—
Mountain hemlock	23.8-49.4	25.4-67.5	24.3-49.0	25.7-54.2
Sitka spruce	—	21.8	—	—
Height[3] (m)				
Yellow-cedar	11.5-23.7	14.2-28.8	13.4-27.6	13.3-20.9
Western hemlock	9.0-19.1	14.1-28.9	14.3-24.4	—
Mountain hemlock	9.1-17.9	13.1-35.1	14.1-21.3	9.3-21.7
Sitka spruce	—	16.7	—	—
Age[3] (years)				
Yellow-cedar	71-215	139-250	138-388	95-277
Western hemlock	208-377	217-400	226-447	—
Mountain hemlock	260-406	379-385	340-551	228-432
Sitka spruce	—	410	—	—

[1] Stems ≥ 5cm in diameter

[2] Basal area given for live trees; for yellow-cedar, basal area dead given in parentheses. Species other than yellow-cedar are difficult to identify when dead.

[3] Ranges of diameter, height, and age given for codominant and dominant trees

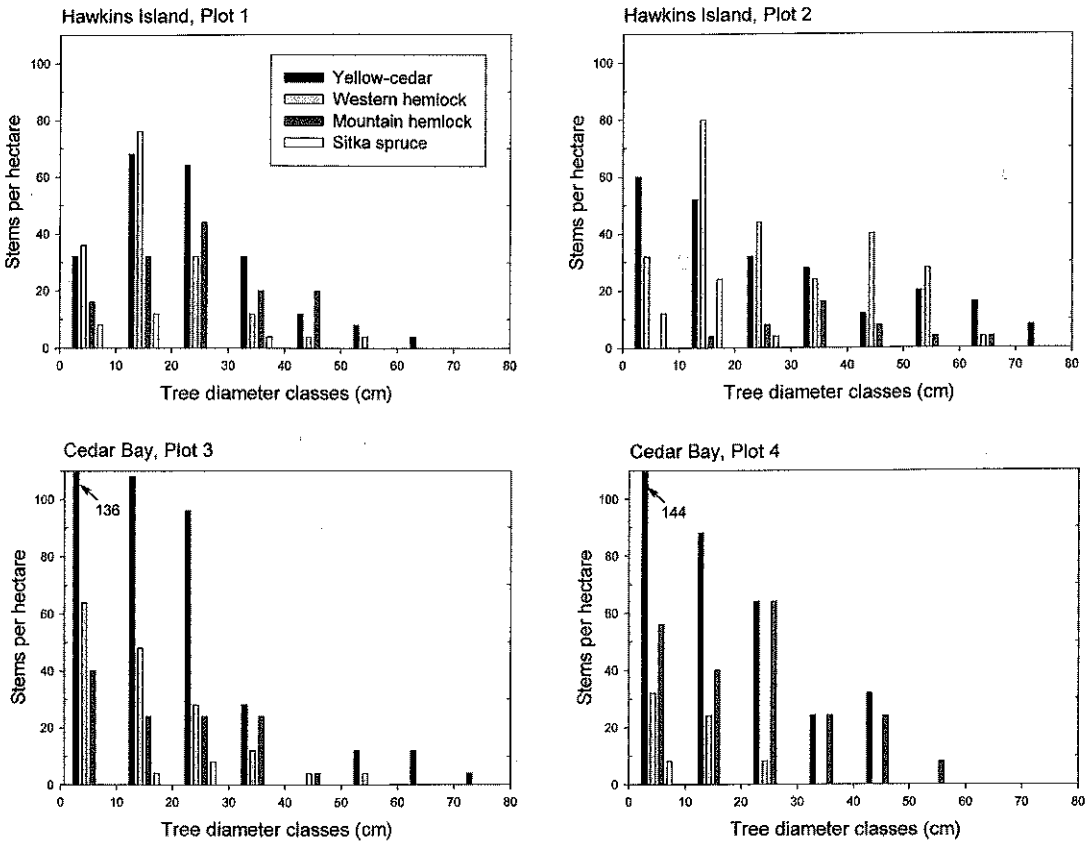

Figure 3. Number of trees per hectare in 10-cm diameter classes from the four plots on Hawkins Island and Cedar Bay, Prince William Sound, Alaska. Values are given per hectare, but actual plots measured 0.25 hectare for plots 1, 2, and 3 and 0.125 ha for plot 4.

(*Picea sitchensis* (Bong. Carr.) occurred sporadically. The two north-central plots had a greater density of trees.

Yellow-cedar had the greatest basal area of tree species on two plots and was a close second to western hemlock and mountain hemlock on the other two plots. The total basal area for all trees was greatest on plot 2, located on Hawkins Island. This plot also had the yellow-cedar tree with the greatest diameter (75.5 cm) and height (28.8 m) of any of our plot trees. Yellow-cedar was the largest tree in diameter on three of the plots. Yellow-cedar was also among the tallest trees on all the plots where it was commonly found as a codominant and dominant tree.

Although it was well-represented among the larger size classes of trees (Figure 3), yellow-cedar tended to be younger than other trees species of the same size (Figure 4). This was most apparent on plot 1 where most yellow-cedar were between 94 and 206 years of age. In general, the yellow-cedars that we observed in Prince William Sound did not have the appearance of some of the veteran yellow-cedars that we commonly observe in Southeast Alaska with large diameter branches, thick bark and irregular tops. In addition, increments from yellow-cedar trees on our plots exhibited rapid early radial growth, suggesting that open growing conditions were present when these trees regenerated. The diameter-age relationship of yellow-cedar indicates that larger trees are not considerably older than the smaller trees.

Mountain hemlocks were the oldest trees on three of the plots and none was less than 200 years old. Western hemlocks tended to be intermediate in age between yellow-cedar and mountain hemlock. The age of few Sitka spruce trees were measured; however, one spruce was 410 years old.

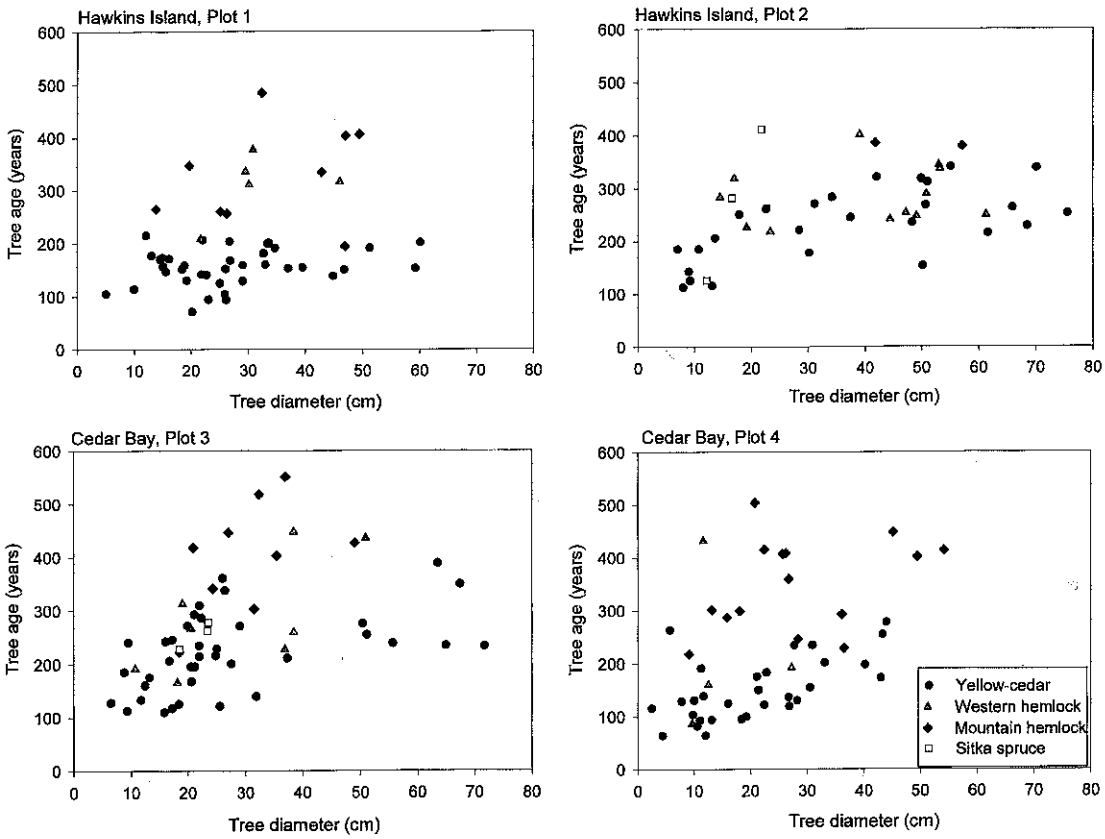

Figure 4. Ages of trees representing a range of diameters from four plots on Hawkins Island and Cedar Bay, Prince William Sound, Alaska.

Understory Vegetation and Yellow-cedar Regeneration

The abundance of understory vegetation is listed in Table 3. By cover class, the most abundant plants were *Vaccinium alaskensis* and a group of mosses that covered the forest floor. These plants and other taxa are common inhabitants of coastal forests. Several, including *Fauria crista-galli* and *Coptis trifolia,* indicate wet, poorly drained conditions.

Yellow-cedar was the most common seedling on all of our plots (Table 3). The total number of yellow-cedar seedlings was similar between the plots at Windy Bay and Cedar Bay. Except for one seedling, however, all yellow-cedar seedlings at Windy Bay were first year-germinants. Seedlings over one year old were common at Cedar Bay, as were saplings of various sizes. We recorded a greater number of yellow-cedars in our smallest diameter class (5 to 10 cm) at the Cedar Bay plots (136 and 144 stems/ha) than Windy Bay plots (32 and 60 stems/ha). Yellow-cedar was found regenerating abundantly in a landslide area in Cedar Bay (about 20 years old), where it comprised over half of the new trees.

We did not place plots in bogs, but we did observe that yellow-cedar was present as a small, stunted tree in bogs and was abundant on forest edges adjacent to bogs. Yellow-cedar appeared to be reproducing asexually by layering in bogs, a common process in Southeast Alaska (Hennon and Shaw 1997).

Human Use

Evidence of human activities in our plots was limited to stumps and large rectangular scars on trees. The scars were distinguished from natural tree wounds (e.g., trees struck by falling trees) by having a horizontal line cut into the wood. The top of these wounds was frequently triangular, indicating that tissues directly above the cut marks

TABLE 3. Understory vegetation and conifer seedlings occurring on the four permanent plots in Prince William Sound; nomenclature follows Hultén (1968). Plots 1 and 2 occur in eastern Prince William Sound at Windy Bay on Hawkins Island and plots 3 and 4 are in north-central Prince William Sound at Cedar Bay. Cover classes, defined in the methods section, are A = absent, U = uncommon, C =common, and V = very common. Number of conifers seedlings per 4m^2 are displayed at the bottom, with the number of yellow-cedar seedlings > 1 year old in parentheses.

	Overstory Plot			
Species	1	2	3	4
Blechnum spicant	C	U	C	U
Graminoids	C	C	U	U
Cassiope Stelleriana	A	U	U	U
Coptis aspleniifolia	C	U	U	A
Coptis trifolia	A	A	U	U
Cornus canadensis	C	U	U	C
Dryopteris dilatata	A	A	U	A
Echinopanax horridum	U	U	A	A
Empetrum nigrum	A	A	U	U
Fauria crist-galli	C	U	U	U
Gymnocarpium dryopteris	U	U	U	A
Linnaea borealis	A	A	U	A
Listera cordata	U	U	U	U
Lycopodium spp.	U	U	U	U
Maianthemum dilatatum	U	U	U	U
Mosses (other than *Sphagnum*)	V	V	V	V
Menziesia ferruginea	C	C	U	C
Phyllodoce aleutica	U	A	C	C
Plantanthera dilatata	U	A	A	A
Rubus pedatus	U	C	U	C
Sphagnum spp.	C	C	C	C
Streptopus spp.	U	U	U	A
Tiarella trifoliata	A	A	U	A
Vaccinium alaskensis	C	V	V	V
Vaccinium ovalifolium	C	C	V	V
Vaccinium vitis-idaea	C	A	A	U
Conifer seedlings	(Number per 4m^2 plots)			
Chamaecyparis nootkatensis	15(0)	41(1)	14(7)	40(34)
Picea sitchensis	0	0	0	0
Tsuga heterophylla	0	0	3	2
Tsuga mertensiana	0	0	3	1

eventually died. Trees with such wounds are often referred to as "culturally modified trees" and are the result of bark collection, presumably by Native people (Stewart 1984).

These wounds occurred only on yellow-cedar and were found on 3 of our 4 plots (Table 4). Most wounds were on trees with larger diameters and all wounds appeared old. Wounds averaged 40 cm in width and the axe marks were typically 3 to 4 meters in height. Wounds appeared to have little effect on tree vigor except for four trees in plot 3 where the injury, which occurred around the entire circumference of tree boles, probably killed them. By our previous estimates of time-since-death for yellow-cedar trees (Hennon et al. 1990), these trees died between 50 and 100 years ago.

Stumps were found on all four plots and were limited to small trees (mean diameter = 20 cm) (Table 4). Both hemlock and yellow-cedar stumps were common (mean = 17 trees per hectare). This tree harvesting probably occurred long ago as stumps were partially deteriorated and top surfaces were covered by moss. Perhaps smaller trees were selected because the boles were carried out by hand.

Observations at Winter Anchorage, Unakwik Inlet

The main population of yellow-cedar at Winter Anchorage was surrounded by small patches of yellow-cedar with as few as several trees (Figure 2) . Within the main population, abundant seedlings, saplings, and small trees typically surrounded the larger trees. A host-specific fungal pathogen, *Gymnosporangium nootkatense* Arth., was found on the foliage of several yellow-cedar trees. Trees up to 68 cm diameter and 25 m height were found in the main population and on the small adjacent peninsula, but most trees were smaller, apparently younger, and had full crowns indicating high vigor, even when they were growing on bog edges. Twelve of the largest yellow-cedar trees ranged from 115 to 305 years old, but only one tree was over 250 years of age. No dead yellow-cedar trees were found in this population at Winter Anchorage, although the area has many large dead western and mountain hemlock. Also, this is the only location in Prince William Sound where we could not find any culturally modified trees.

Discussion

Although subsequent literature has confused the status of yellow-cedar in Prince William Sound, the early report by Sudworth (1908) appears to have been quite accurate. We now believe the northwest limits of the natural range of yellow-cedar is near Winter Anchorage on the eastern shore of Unakwik Inlet. Sudworth's (1908) reference to yellow-cedar occurring at "Unganik Bay" likely refers to the populations that we found here

TABLE 4. Human use of yellow-cedar and other trees at four sites in Prince William Sound, Alaska. Evidence of use was in the form of rectangular scars on trees with cut marks (still visible) made when bark was harvested or stumps with flat cuts when tree boles were harvested.

	Culturally modified trees			Stumps		
Plot	Tree species	No. trees/ha[1]	Tree DBH $\bar{x}$, range (cm)	Tree species[2]	No. trees/ha[1]	Tree DBH $\bar{x}$, range (cm)
1	Yellow-Cedar	8	49, 47-51	Yellow-Cedar	40	21, 8-39
				Hemlocks	12	29, 20-42
2	Yellow-Cedar	8	58, 51-65	Yellow-Cedar	4	14
				Hemlocks	16	30, 19-51
3	Yellow-Cedar	24	30, 18-43	Yellow-Cedar	24	29, 24-45
				Hemlocks	8	19, 14-23
4	—	—	—	Yellow-Cedar	16	9, 8-9
				Hemlocks	16	12, 8-16

[1] Values for number of trees per plot are converted to number of trees per hectare

[2] Western hemlock and mountain hemlock stumps could not be distinguished. No spruce stumps were found on our plots.

at Unakwik Inlet. Orth (1967) gives several alternative spellings for Unakwik, but none matches Sudworth's spelling. It is possible that further searching north from both arms of Wells Bay or the western shore of Unakwik Inlet could uncover small populations, although we scanned these areas from aircraft and did not detect yellow-cedar.

The distribution of yellow-cedar is discontiguous, with several populations from about Glacier Bay to the limits of the range at Unakwik Inlet. As noted by Cooper (1942), this presents an interesting phytogeographic problem. We do not know whether the populations of yellow-cedar in Prince William Sound are derived relic populations from local refugia or are from patchy migration from Southeast Alaska. Forest communities in Prince William Sound are relatively young. Following deglaciation some 9000 years B.P., conifers (i.e., Sitka spruce, mountain hemlock and western hemlock) began growing in the Prince William Sound area about 3000 yr B.P. and developed large forested areas about 2000 years B.P. (Heusser 1983). Conifer species are believed to have colonized the area from sources originating in Southeast Alaska with their migration aided by northwesterly storms (Heusser 1983). Today, the apparent westerly migration of yellow-cedar is most evident on the eastern shore of Unakwik Inlet where small patches of yellow-cedar occurred. These populations were mainly comprised of small, younger trees and few, if any, dead yellow-cedar trees. Even here, scattered larger trees up to 305 years old were found. Thus, yellow-cedar has been present in this area for at least several hundred years and is currently increasing in abundance. Unfortunately, yellow-cedar was not included in Heusser's pollen studies and the historical abundance of this species has yet to be determined in Southeast Alaska or Prince William Sound.

Alaback and Juday (1989) reported a declining vigor and density of western hemlock near the limits of its range at Green Island in Prince William Sound. By contrast, yellow-cedar generally appears to be thriving at the limits of its distribution, where it often dominates all tree size classes and shows rapid radial growth. We are uncertain what historical disturbances may have influenced these plant communities. Open stand conditions are suggested by the rapid early radial growth of most mature yellow-cedar trees. Catastrophic events, such as storms or tsunamis, would tend to yield nearly single-age stands. Tree ages on our plots indicate that yellow-cedar colonized sites already occupied by the two hemlock species. These forests have experienced outbreaks by the black-headed budworm (*Acleris gloverana*), an insect that defoliates all conifer tree species in the area except for yellow-cedar. Repeated outbreaks would benefit the regeneration and growth of yellow-cedar over its competitors. An alternative explanation for rapid early growth of yellow-cedar trees is changing soil conditions; improved drainage or decreased precipitation in boggy areas could promote faster tree growth as forests encroach on bogs. Variable climate could trigger any of these hypothetical factors.

The age structure of trees on our plots is somewhat surprising. Yellow-cedars tend to be the oldest trees in forested stands in Southeast Alaska. There, they do not regenerate prolifically and are not

common among younger age classes of trees. But once established, yellow-cedar trees persist for many centuries and tend to outlive their competitors (Alaback 1991). In contrast, yellow-cedar trees are establishing in high concentrations and dominate the younger age classes within the limited occurrence of the species in Prince William Sound. We did not find any "old" yellow-cedar trees, with the maximum age at 388 years and few trees more than 300 years old. The apparent vigor and youth of the trees support Cooper's (1942) observation that yellow-cedar appeared "thrifty" in Prince William Sound.

Deer are known to severely limit the regeneration of yellow-cedar in Southeast Alaska (Hennon and Shaw 1997). They are not native to Prince William Sound, but were introduced beginning in 1917 (Nowlin and Abbott 1993; Lethcoe and Lethcoe 1994). Deer are now common throughout Prince William Sound and could limit natural reproduction of the tree in some areas. Their influence on cedar regeneration where we made observations in north-central populations of the sound appears negligible.

The lack of knowledge about the historical abundance of yellow-cedar presents a serious gap in our understanding of how the species came to Prince William Sound and how its populations have fluctuated with other vegetation. Belling (1977) developed techniques to identify *Chamaecyparis* pollen in peat profiles and was able to reconstruct the postglacial migration of Atlantic white-cedar (*C. thyoides* (L.) B.S.P.) along the Atlantic coast of North America. Such an approach could yield valuable information about the history of yellow-cedar in Prince William Sound.

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