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Causes of Basal Scars on *Chamaecyparis nootkatensis* in Southeast Alaska

Abstract

Scars on the lower boles of Alaska yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) trees are common in some unmanaged forests in southeast Alaska, but their cause has not been determined. The association of these basal scars with an extensive decline and mortality of unknown cause that affects Alaska yellow-cedar also has been unclear. Data from ground transects indicate that on Baranof and Chichagof Islands over one-half of the Alaska yellow-cedar trees in some stands are scarred, even though other tree species are not affected. Scars generally face upslope, do not girdle the entire circumference of the bole, average 1.5 m in height, and are most common on the best drained, most productive sites. These productive sites lack cedar decline. Callus tissue slowly forms over these basal scars, but decay develops in the wood, reducing wood volume in the valuable butt logs. Fungi that occur on scars of varying ages are described. Recent scars consistently have teeth marks in the exposed wood—evidence that bears cause this damage. Such basal scars are common on islands in southeast Alaska inhabited by brown bears (*Ursus arctos*), but not on islands inhabited by black bears (*Ursus americanus*). Cedar decline occurs on several islands not inhabited by brown bears and where cedars are not scarred. Scarring was no more common on dying versus healthy cedars or in declining versus healthy stands; thus, basal scars are not a significant factor in decline of Alaska yellow-cedar.

Introduction

Alaska yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach), a long-lived, valuable tree species in southeast Alaska, has been suffering from an extensive decline and mortality that now covers more than 150,000 hectares of primarily unmanaged and remote forest (USDA Forest Service 1988). This forest decline began about 1880 (Hennon 1986), but the primary cause remains a mystery (Frear 1982, Shaw *et al.* 1985, Hennon 1986). In the course of our recent investigations on the causes and epidemiology of decline, we noted the common association of basal scars with dead and dying cedars.

Scars are common on the lower bole of Alaska yellow-cedar trees in some areas of southeast Alaska (Anderson 1959), including some areas where decline and mortality is severe (Shaw *et al.* 1985). The involvement of scars in causing tree death is not known. Ruth and Harris (1979) noted that bears may cause scars on cedar, but this has not been substantiated.

Presently, there is no information on tree species affected by scarring, fungi and decay in scars, the geographical extent of scarring, or, except for the idea proposed by Ruth and Harris, what may be causing these tree scars. The objectives of this study were to 1) describe characteristics of scars, tree species affected and tree responses to scarring; 2) determine the cause(s) of scarring; and 3) determine if there is an association between the occurrence of scarring and the decline and mortality of Alaska yellow-cedar.

Materials and Methods

Most studies were conducted on Chichagof and Baranof Islands northeast of Sitka at Peril Strait, Slocum Arm, and Kennel Creek (Figure 1). Studies were also conducted near Control Lake on Prince of Wales Island and Rainbow Falls on Wrangell Island. The occurrence and size of basal scars were noted for 779 Alaska yellow-cedars as well as for other tree species (western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), mountain hemlock (*T. mertensiana* (Bong.) Carr), and shore pine (*Pinus contorta* Dougl. ex Loud. var. *contorta*)) present on 280 plots along 21 survey lines on Chichagof and Baranof Islands. Survey lines

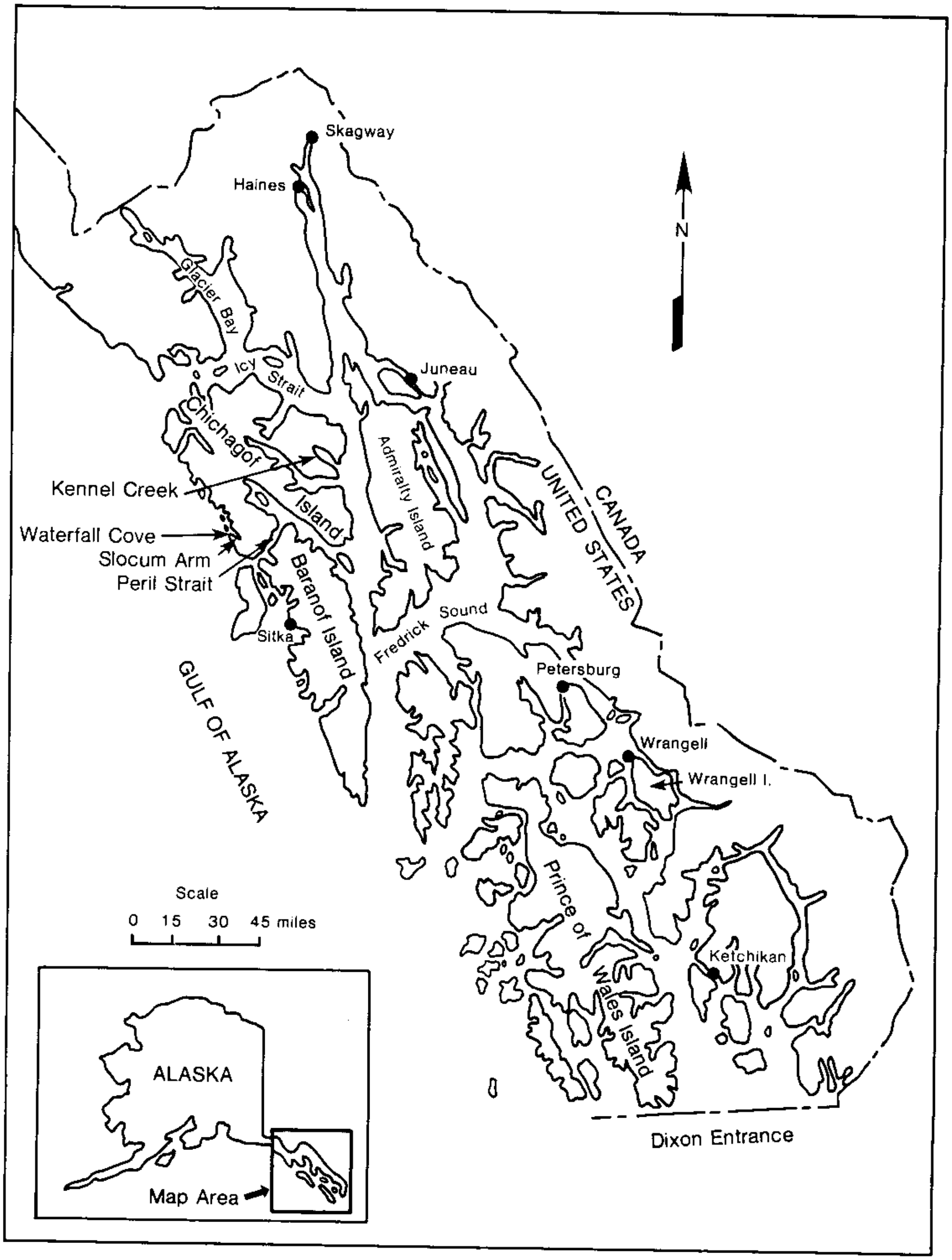

Figure 1. Location of study sites in southeast Alaska.

were designed to pass through and beyond stands with noticeable cedar decline and mortality. Lines commonly began at beaches and ran directly upslope with plots every 50 m until two or more plots were located in "healthy" stands that lacked concentrations of dead and dying trees. Individual trees were selected on each plot with a 3- or 6-m^2/ha basal area factor prism. Most sampling (16 lines) was along Peril Strait, but survey lines were also located in Slocum Arm near Waterfall Cove (one line) and Kennel Creek (four lines), both on Chichagof Island (Figure 1). Scar heights and orientation with slope were measured from an additional 490 Alaska yellow-cedars at three sites at Peril Strait. Heights of 24 fresh scars with noticeable bite marks were measured at Peril Strait to determine how they compared to the heights of the primarily older callusing scars.

Sampling was also conducted further south within the natural range of western redcedar (*Thuja plicata* Donn) on Prince of Wales Island (64 plots with 163 Alaska yellow-cedars) and Wrangell Island (80 plots with 421 Alaska yellow-cedars). In total, 1853 Alaska yellow-cedar trees were examined.

A Chi-square analysis ($P = 0.05$) was used to test if the incidence of scarring 1) differed with location (Peril Strait, Slocum Arm, Kennel Creek, Prince of Wales I., and Wrangell I.) (Fleiss 1981), 2) differed in the Peril Strait area for live cedar trees located within stands suffering from decline ($\geq 33\%$ basal area dead) compared to live cedars within relatively healthy stands ($< 33\%$ basal area dead), and 3) differed in the Peril Strait area for dying cedars (crowns yellow or thin) compared to healthy-appearing cedars. Frequency distributions were drawn for scar height and orientation, and the latter was tested using the Rayleigh test (Batschelet 1965) ($P = 0.05$), a Z statistic which tests for distribution around a circle, to determine if scars faced any particular direction.

An understory plant ordination was used to determine if the occurrence of scarring was correlated with differences in forest communities. The dominance or absence of 55 plant taxa (Hennon 1986) were recorded on each of the 280 plots in Peril Strait, Slocum Arm, and Kennel Creek. Dominance rating included five categories: nearly pure in its layer ($> 50\%$ cover), dominant (25-50%), common (5-25%), rare (0-5%), and absent. A gradient of plot scores was calculated from a computer ordination technique—Detrended Correspondence Analysis (DECORANA), which generates axes that represent gradients of plant species' distribution (Hill and Gauch 1980, Gauch 1982). Based on field observations of the distribution of these plants and their associated overstory, these plot scores from the first and dominant axis represent the gradient from bogs to plant communities with better drainage (Hennon *et al.* 1984). DECORANA plot scores from this first axis using 232 plots (some plots were dropped because cedar was absent or fewer than two trees were alive) with a total of 679 cedar trees were plotted against the proportion of Alaska yellow-cedars with basal scars.

In Peril Strait, three Alaska yellow-cedars with scars were dissected transversely with a chain saw to allow for examinations of decay characteristics and tree responses to wounding. Single discs were cut from the boles of 15 other Alaska yellow-cedars with basal scars and similarly examined.

Fruiting bodies of fungi were collected from fresh and old basal scars to determine the mycoflora present on scars of different ages. Physical characteristics of these scars (e.g., depth of wound in relation to amounts of callus tissue, condition of exposed wood, and presence of fungal fruiting bodies) were also recorded. In addition, 113 attempted isolations were made from basal scars (mostly less than 5 years old) onto two types of artificial sterile media: potato dextrose agar and 1.5 percent malt extract agar (with 2 ppm benomyl). Microscopic and cultural characteristics of collected and isolated fungi are reported elsewhere (Hennon 1986).

Results

Occurrence of Scars

Basal scars were present on 49 percent of the Alaska yellow-cedar trees sampled on Chichagof and Baranof Islands. Scars were common at Waterfall Cover (62%) and along Peril Strait (51%) but were significantly ($P = 0.05$) less frequent at Kennel Creek (16%) and absent on cedars on Prince of Wales and Wrangell Islands. At Peril Strait, at least 30 percent of the Alaska yellow-cedar trees from each of the 16 transects had scars. Except for trees less than 10 cm dbh, all size classes were scarred. Scar incidence at Peril Strait did not differ significantly between live cedars within healthy stands (51% scarred) and those in declining stands (50% scarred) or between healthy (51% scarred) and declining (49% scarred) individual trees.

Scars on Alaska yellow-cedar had a significant (P = 0.05) upslope orientation at each of the three sites where orientation was measured. Most scars were about 150 cm tall, but taller scars were also common (Figure 2).

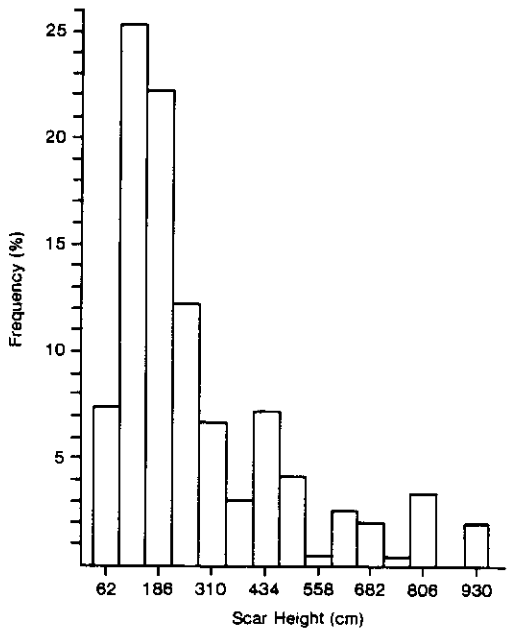

Figure 2. Frequency distribution of scar heights on 229 Alaska yellow-cedar trees located near Peril Strait, Alaska.

Marks, apparently made by animals, were present on nearly all fresh scars (Figure 3 A,B). Heights of the 24 scars with bite marks averaged 164 ± 72 cm (range = 26-270 cm). The actual teeth marks had an average height above ground of 44 ± 20 cm (range = 12-88 cm). Some Alaska yellow-cedar trees had several adjacent basal scars, usually with different depths of callus folds as if they occurred at different times. Scars were generally most common in better drained forest types, although they were found on Alaska yellow-cedars in all communities (Figure 4). Very few basal scars were found on other conifers, and the few observed did not resemble the scars on Alaska yellow-cedars in size or shape.

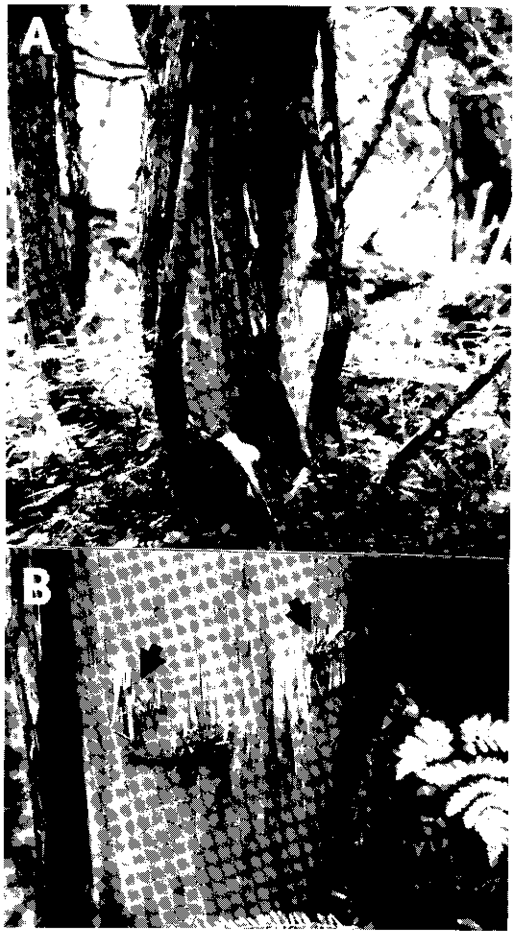

Figure 3. A), Fresh basal scar on Alaska yellow-cedar caused by brown bears; B), note the teeth marks (arrows) on exposed wood caused by bears tearing bark from these trees.

A different type of basal scarring was found on 11 Alaska yellow-cedars along Peril Strait. These scars were distinguishable from others by the presence of a distinct horizontal cut across the top, and often the bottom, of the scars; they were also taller than the scars described above (Figure 5). These scars were on some of the largest Alaska yellow-cedars in the stand, almost all were found close to the beach, and scars did not show any trend for occurring on the upslope side of trees.

Responses to Wounding

The first noticeable tree response was evident the spring following wounding when callus tissue

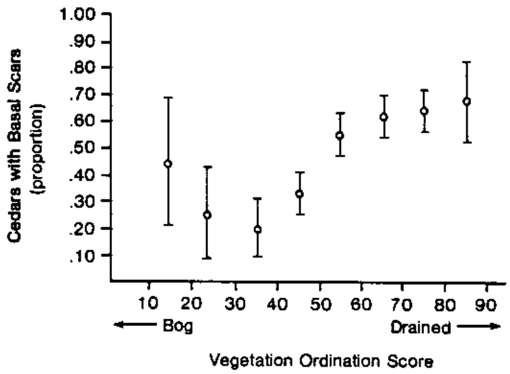

Figure 4. Proportion of Alaska yellow-cedars with basal scars from 8 intervals of understory vegetation gradient from bog (low scores) to better drainage (high scores). Vegetation ordination scores based on DECORANA from 232 plots along 16 survey lines with 679 Alaska yellow-cedars growing along Peril Strait on Baranof and Chichagof Islands, Alaska. Bars are standard errors of the sample proportion mean.

Figure 5. Large basal scar caused by humans collecting bark from Alaska yellow-cedars. Note the horizontal cuts along the top and bottom of the scar.

began to develop along the sides, bottom, and top of the wound. Cross sections cut through tree wounds showed that changes in the sapwood on the edges of the wound occurred within several years. Sapwood exposed by the wound was dead (Figure 6), but live sapwood adjacent to both sides of the wound turned bright yellow, a color more intense than in normal Alaska yellow-cedar heartwood. As callusing sapwood slowly engulfed the sides of the wound, it also developed this bright yellow color. Cross sections cut through older wounds suggested that these reactions confined decay to a narrow crescent-shaped band of the sapwood exposed during the scarring event, but decay eventually developed in surrounding wood in some of the oldest (50+ years) scars.

Fungi on scars

Stain and decay were not confined in the wood above scars. One decay arc extended 3.2 m above the top of the scar, with advanced decay occurring in all but the top 0.2 m. *Leptographium* sp., probably saprophytic on Alaska yellow-cedar (Hennon *et al.* 1984), was the fungus most frequently isolated from the tops of these stain columns.

Dead sapwood within the wound changed from its original near-white color to a tan, and then to greenish black or black within several years after scarring. *Leptographium* sp. was the most common fungus isolated from the stain when tan-colored. Fungi isolated from the black-colored stain included the following: *Sporidesmium* sp., *Phialophora* sp., *Mycelium radicis atrovirens*, and *Leptographium* sp.

Phloem (inner bark), freshly exposed by wounding, was bright and creamy white in color. This phloem, which was stripped away from the sapwood, but often still attached at the top and bottom of the wound, changed color to a cinnamon brown within a few hours after wounding.

Several Alaska yellow-cedars with very fresh scars, initially still with white phloem, were revisited one and two years after being scarred;

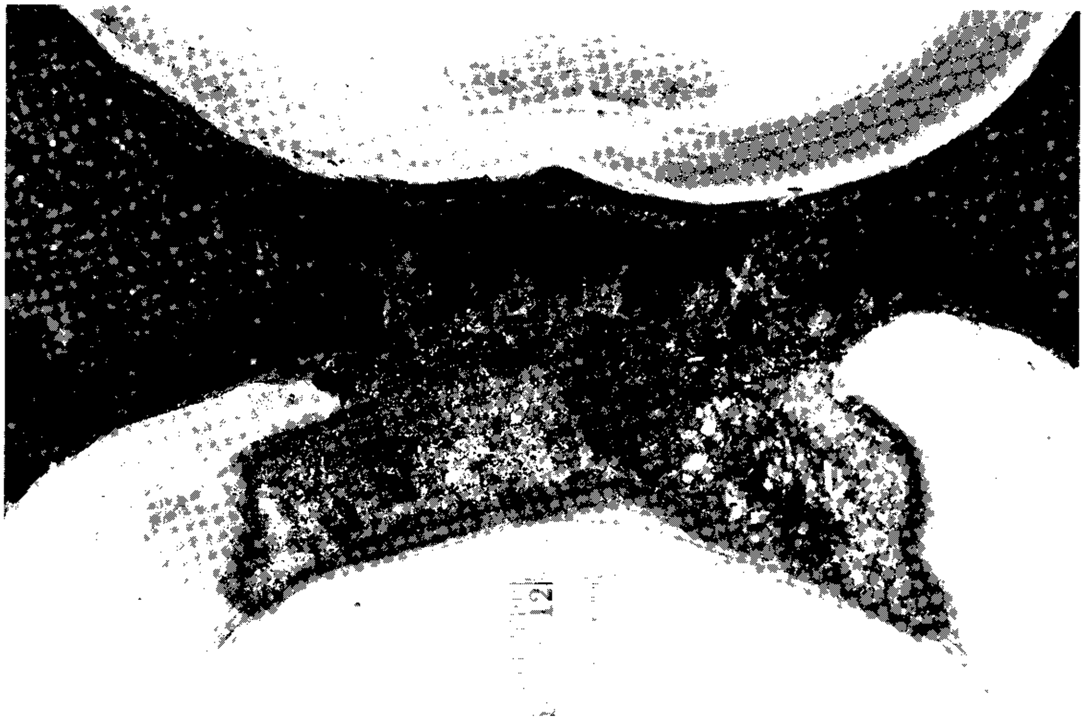

Figure 6. Cross sections through an Alaska yellow-cedar tree with a basal scar. Below: note the callus tissue that grows over the wound and the relative restriction of decay to the sapwood killed during the scarring event. Above: note the incipient decay in this section, which was removed from the bole above the scar.

Ceratocystis sp. and *Pistillaria* sp. were the only fungi found sporulating directly on these young scars. *Ceratocystis* sp. was found only on one-year-old scars and only sporulated on the bark and sapwood where these two tissues were killed, but not permanently separated. After a year or two, the stripped bark fell off, leaving the sapwood fully exposed.

The diversity of fungal species increased as the scars aged, reached a peak as the sapwood began to decay, but decreased once most of the sapwood became thoroughly decayed and eventually rotted away (Table 1). Fungi found on older scars were also found growing as saprophytes on other dead tissues of Alaska yellow-cedars (e.g., dead twigs, limbs, and boles). None of the fungi collected or isolated from basal scars appears to be capable of causing these scars or killing trees (Hennon *et al.* 1984).

Discussion

Scars with teeth marks were almost certainly made by brown bears (*Ursus arctos*). These marks in sapwood are made by canine teeth as the bears attempt to pull bark from trees with their mouths (J. Schoen, AK Dep. Fish and Game, pers. comm.). Hair of brown bear was found in some recently produced scars. The bite marks produced when bears pull bark away were the only obvious marks on the scar; once bark was pulled away, bears did not use their teeth or tear at exposed wood with their claws. Perhaps bears lick exposed phloem which contains concentrations of sugars (primarily sucrose) in spring (Nelson 1964). Fresh scars were most often found in clusters of five or more closely grouped trees, all or most with their scars facing upslope. The upslope orientation and spring wounding (Kozlowski 1971) may be due to easier bark removal, but the thin bark of Alaska yellow-cedar (Anderson 1959) provides little protection against these powerful animals. We found groups of cedars with fresh scars every spring in May and June for seven consecutive years, suggesting that basal scarring occurs in these stands every year.

TABLE 1. Fungi collected (C) or isolated (I) from basal scars on Alaska yellow-cedar. Six classes of scar condition are based on wood deterioration.

	Scar condition					
Fungal species	1 fresh to 1 year old	2 sapwood sound, unstained	3 sapwood stained but firm	4 sapwood soft, intact	5 sapwood decayed, partially missing	6 heartwood exposed
ASCOMYCETES						
Bertia moriformis (Tode: Fr.) de Notaris		C	C	C	C	
Ceratocystis sp.	C,I	C				
Dothidea sp.		C,I				
Herpotrichia sp.		C	C			
Stictis radiata L. Pers. subsp. *radiata*	C					
BASIDIOMYCETES						
Auricularia auricularis (Hooke.) Underw.				C		
Armillaria sp.			C,I	C	C	
Cyathus olla (Batsch) ex Pers.					C	
Dacrymyces deliquescens (Merazt) Duby.		C		C	C	
Galerina sp.				C	C	
Hyphodontia aspera (Fr.) J. Erikss.				C		
Lactarius deliciosus (Fr.) S.F. Gray					C	
Lycoperdon sp.					C	
Pistillaria sp.	C	C				
Polyporus elegans Bull.: Fr.		C,I	C			
Skeletocutis amorpha (Fr.) Kotl. et Pouz.			C	C		
Xeromphalina campanella (Batsch: Fr.) Kuhn. & Maire.					C	
FUNGI IMPERFECTI						
Leptographium sp.	I	C,I				
Mycelium radicis atrovirens Melin		I				
Phialophora sp.		I				
Seiridium cardinale (Wagener) Sutton & Gibson		I				
Sporidesmium sp.	I	I				

The heights of fresh scars with bite marks corresponded closely with the modal height of all measured scars (fresh and old) (Figure 2). Some Alaska yellow-cedars had been repeatedly scarred, a dozen or more times around the base of their boles, showing a range of scar ages. These multi-scarred trees were most often adjacent to well-established bear trails. Brown bears are the only animals on these islands capable of such tree damage (J. Schoen, AK Dep. Fish and Game, pers. comm.). Their hair, scat, trails, and our sightings are evidence of their common occurrence in areas where Alaska yellow-cedars are scarred.

In southeast Alaska significant brown bear populations are restricted to Admiralty, Baranof, and Chichagof Islands and the mainland, with the greatest densities on the three islands (Meehan 1974, Alaska Department of Fish and Game 1977). Most other islands are inhabited by black bears (*Ursus americanus*) but not brown bears. Both bear species occur on the mainland. On Prince of Wales and Wrangell Islands, which have black but not brown bears (the latter are occasionally reported on Wrangell Island), we encountered no scars that resembled the shape of the scars described above. In our general observations throughout southeast Alaska, we have not observed scars on Alaska yellow-cedar in areas without large brown bear populations. Thus, basal scars on Alaska yellow-cedar were infrequent or absent in the absence of brown bears; however, scars were not necessarily frequent wherever Alaska yellow-cedar and brown bears coexist. Scars were infrequent at Kennel Creek, on Chichagof Island, where brown bears are common.

Basal scars are not the primary cause of Alaska yellow-cedar mortality in southeast Alaska. Scar incidence was not greater on dying cedar trees than on healthy trees, nor was it greater on cedars in declining than non-declining stands. Numerous Alaska yellow-cedar trees die with no basal scars (Shaw *et al.* 1985, Hennon *et al.* 1984). Basal scarring was most common in the well-drained, high volume forest type where mortality was least common (Hennon *et al.* 1984). Extensive mortality of Alaska yellow-cedar occurs on Prince of Wales, Wrangell, and other islands (USDA Forest Service 1988) where brown bears are absent and basal scarring was not found. A fresh wound on a declining, weakened Alaska yellow-cedar could, however, contribute to its death. In only a few cases did we observe trees that were completely girdled and died from basal scarring.

Bear damage to conifers has been reported frequently, but only once noted on Alaska yellow-cedar (Ruth and Harris 1979). Girdling of young Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) by black bears is a serious problem in portions of western Washington and Oregon (Lawrence *et al.* 1961) where more than 50 percent of trees may be injured by black bears (Levin 1954). On the Kenai Peninsula in Alaska, scars interpreted to have been caused by black bears were common on white spruce (*Picea glauca* (Moench) Voss) and quaking aspen (*Populus tremuloides* Michx.) (Lutz 1951). The exposed wood in scars caused by black bears usually has shallow grooves made with teeth of lower jaws or claws (Lawrence *et al.* 1961). Such scars can occur from the tree base to 15 m or more up the bole (Childs and Worthington 1955). These vertical feeding marks are in sharp contrast to the horizontal bite marks that we found on Alaska yellow-cedars.

The 11 scars with horizontal cuts on Alaska yellow-cedar trees were likely caused by Alaska Natives collecting bark for making hats, baskets, clothing (Frear 1982), and roofs. Human-caused scars have been reported previously on Alaska yellow-cedar and western redcedar (*Thuja plicata* Donn ex D. Don) (USDA Forest Service 1982, Hicks 1984, Stewart 1984). All but one of the scars that we found was less than 100 m from the closest beach, where these large pieces of bark could have been easily gathered and transported.

Human-caused scars were not common, and this impact will probably be less consequential in the future even though some Alaska Native people still collect and use cedar bark. No recently caused human scars were found in the study areas, however. One of the 11 scars in Peril Strait was made 102 years ago. Similar scars were found in Prince William Sound, Alaska, and were dated to 180 years ago (C. G. Shaw III, unpublished data). The major impact of human-caused scars is that they occur on the largest Alaska yellow-cedar trees and, because of the scar size and age, are probably associated with internal wood decay found in these trees.

Tree responses to scarring and the decay resistance of the non-responsive heartwood seem to slow the radial advance of fungi and, thereby, retard decay. The bright yellow color present in surviving sapwood is probably a reaction to wounding and likely slows fungal advancement. Wood decay towards the pith in heartwood behind the scar is probably limited by the heartwood's anti-fungal compounds (Rennerfelt and Nacht 1955). A significant decay arc can develop vertically above the scar, however. The concept of tree responses to wounding is not new and has been described for many other tree species (Hepting and Blaisdell 1936, Shigo and Marx 1977).

Basal scars cause significant defect and may reduce the value of the butt log of scarred Alaska yellow-cedars to cull. Wood adjacent to scars may be salvageable unless the scar is very old, in which case decay fungi are less limited by tree responses and heartwood properties and decompose much of the bole's wood. Additional study is needed to quantify volume losses on trees with basal scars and to determine which fungi are most responsible for causing the vertical decay column. Several of the dark colored fungi we isolated from basal scars (e.g., *Phialophora, Sporidesmium,* and *Mycelium radicis atrovirens*) may be the same fungi that stain the heartwood of Alaska yellow-cedar (Smith 1970).

The common scarring of Alaska yellow-cedar trees on the better drained, productive sites may affect revenues from future timber sales in these areas. These sites have the tallest trees, the most total volume, and the highest proportion of spruce and western hemlock (Hennon *et al.* 1984). Thus, these stands are among the most likely to be harvested. A high degree of defect or cull of Alaska yellow-cedar, the most valuable wood in these stands, should be expected in stands where basal scarring is common.

In conclusion, we believe brown bears and, to a much lesser extent, humans are responsible for the numerous basal scars on Alaska yellow-cedar on Chichagof and Baranof Islands. These basal scars were not consistently associated with dying Alaska yellow-cedars and are not the primary cause of the extensive decline and mortality of this species.

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