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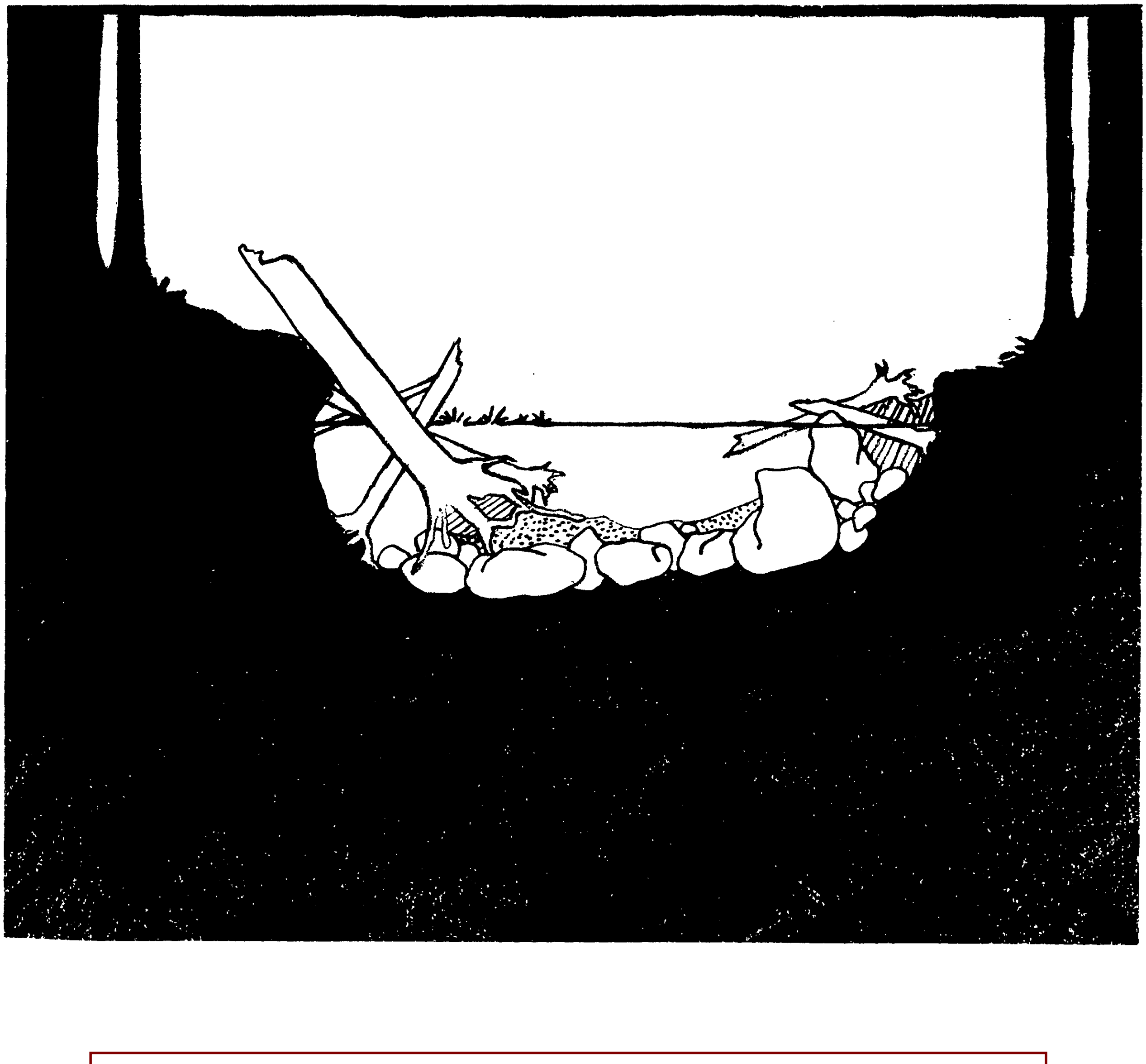
Organic Debris in Small Streams, Prince of Wales Island, Southeast Alaska

**Frederick J. Swanson, Mason D. Bryant,
George W. Lienkaemper, James R. Sedell**



Authors

Frederick J. Swanson is a research geologist, Mason D. Bryant is a research fisheries biologist, George W. Lienkaemper **is** a geologist, and James R. Sedell **is** an ecologist at the Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, 3200 Jefferson Way, Corvallis, Oregon 97331.

Abstract

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Quantities of coarse and fine organic debris in streams flowing through areas clearcut before 1975 are 3 and 6 times greater than quantities in streams sampled in old-growth stands in Tongass National Forest, central Prince of Wales Island, southeast Alaska. The concentration of debris in streams of clearcut Sitka spruce-western hemlock forests in southeast Alaska, however, is about half that in streams of clearcut Douglas-fir-western hemlock forests in western Oregon. Management guidelines for maintaining natural debris conditions include minimizing the addition of fresh material to a channel during management activities, leaving natural accumulations of debris, and managing streamside areas for production of a continuous, long-term supply of large debris for channels. Considerations in planning stream cleanup include the length of time the debris has resided in the channel and the stability of debris, which is a function of its size, orientation, and degree of burial and decay.

Keywords: Stream debris, fluvial processes, fish habitat, watershed management, logging hydrology, (-hydrology, Alaska (southeast), southeast Alaska.

Introduction

Organic debris can greatly influence the physical and biological character of small to intermediate-sized streams flowing through forest land. Forest management practices, therefore, have the potential to alter aquatic ecosystems through changes in the quantity, size, spatial distribution, and configuration of organic debris in and adjacent to streams. Although these generalizations are widely recognized, few studies have quantified relationships among forest practices, stream debris conditions, and their effects on aquatic organisms.

These relationships are being examined by an interdisciplinary research group studying several small streams in the drainages of Staney and Shaheen Creeks within Tongass National Forest on Prince of Wales Island, southeast Alaska (fig. 1). Study sites include both streams in forested areas and streams flowing through 6- to 10-year-old clearcuttings. Objectives of the overall study are to (1) characterize and contrast quantity, stability, and spatial distribution or organic debris in streams flowing through forested and clearcut areas, (2) examine seasonal population dynamics of fish and community structure of invertebrates in small streams, and (3) determine effects of debris removal from streams flowing through clearcuttings on aquatic habitat and organisms. This article summarizes preliminary results of the first objective, characterizing conditions of debris in small streams.

Research on effects of logging on organic debris in streams is sparse. Rothacher (1959), Froehlich (1971), and others point out that floated organic debris aggravates flood damage under natural conditions, and logging and road construction may increase the problem by supplying channels with slash of size classes floatable at high flow. Froehlich (1973) reports debris loading in streams of steep forests in western Oregon and the effects of several falling and yarding practices on debris conditions. He observed increases in debris concentration from 0 to over 400 percent, depending on the type of logging practice employed. Other researchers (Heede 1972a, 1972b;

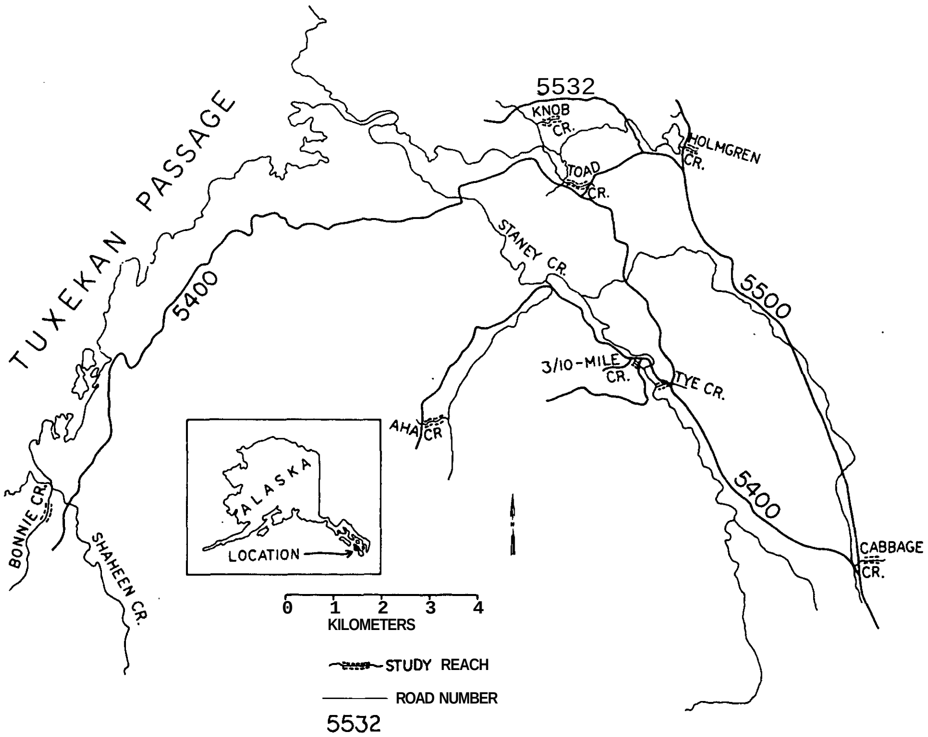

Figure 1.—Location of study streams in central Prince of Wales Island, Alaska.

Swanson and others 1976, Swanson and Lienkaemper 1978; Keller and Talley 1979) have examined organic debris in streams flowing through forest areas and suggest practices to minimize the effect of forest management activities.

Each of these studies recognizes organic debris as an integral part of the natural condition of streams in forested areas. In general, suggested management guidelines emphasize maintaining quantities of debris and size and spatial distributions similar to natural conditions. Establishing these guidelines as a management objective poses special problems when debris loading of a stream was altered some years previously. What are the environmental effects and the economic costs and benefits of various cleanup or rehabilitation options? This paper takes the first step in addressing this question for low-gradient streams in southeast Alaska.

Study Sites

Study sites are located in the drainages of Staney and Shaheen Creeks in the central portion of Prince of Wales Island, southeast Alaska. The landscape has been sculpted by glaciers that cut flat-bottomed, U-shaped valleys and formed broad areas of low relief. Study streams are in valley bottoms in areas of gentle channel gradients (table 1).

Natural, old-growth forests in the study area are dominated by mixed-aged stands of Sitka spruce (Picea *sitchensis*) and western hemlock (*Tsuga heterophylla*) in which some individual trees exceed 400 years in age. Areas were clearcut by free falling and high lead cable yarding systems 6 to 10 years before the study. Slash appears to have accumulated in the shallow depressions of drainages from logs being yarded across a logging unit.

The central portion of Prince of Wales Island has a cool, wet, maritime climate with a mean annual temperature of about 7°C and annual precipitation of about 2500 mm (Barr and Swanston 1970). No gaging records have been kept on any small streams in the area, but streamflow is highly responsive to changes in precipitation, and snowmelt in steep valley-wall drainages.

Study streams selected and their sampled reaches are representative of small, low-gradient, fish-bearing streams in the region. Sampling criteria for the fisheries phases of the overall study dominated site selection; the work reported here supports the fisheries study. Characteristics of channel geometry are listed in table 1. The streams in clearcuttings where debris manipulation was planned contained juvenile Coho salmon (*Oncorhynchus kitsutch*), Dolly Varden (*Salvelinus malma*), and cutthroat trout (*Salmo clarki*). A large stream, Bonnie Creek, was also selected for study because (1) it contained natural debris typical of streams its size in the area, (2) logging began in the adjacent stand in summer 1978; resulting changes in debris conditions could be followed, and (3) the site had contiguous, 100-m reaches with relatively high and low concentrations of debris, providing opportunity for comparisons.

All names of small streams are informal.

Table 1--Characteristics of channel geometry at study sites, Prince of Wales Island, Alaska

Creek	Length sampled	Number of transects	Average width[1]	Average gradient
	Meters		Meters	Percent
Aha	300	30	4.8	3
Cabbage	100	11	4.2	7
Holmgren	90	19	2.1	1
3/10-Mile	90	19	3.0	5
Knob:				
Upper	100	11	2.6	2
Lower	100	11	2.8	
Toad:				
Upper	100	11	1.4	7
Lower	100	11	1.9	
Tye:				
Upper	85	9	7.0	4
Lower	85	8	6.0	

[1] Average width of channel at transects.

Methods

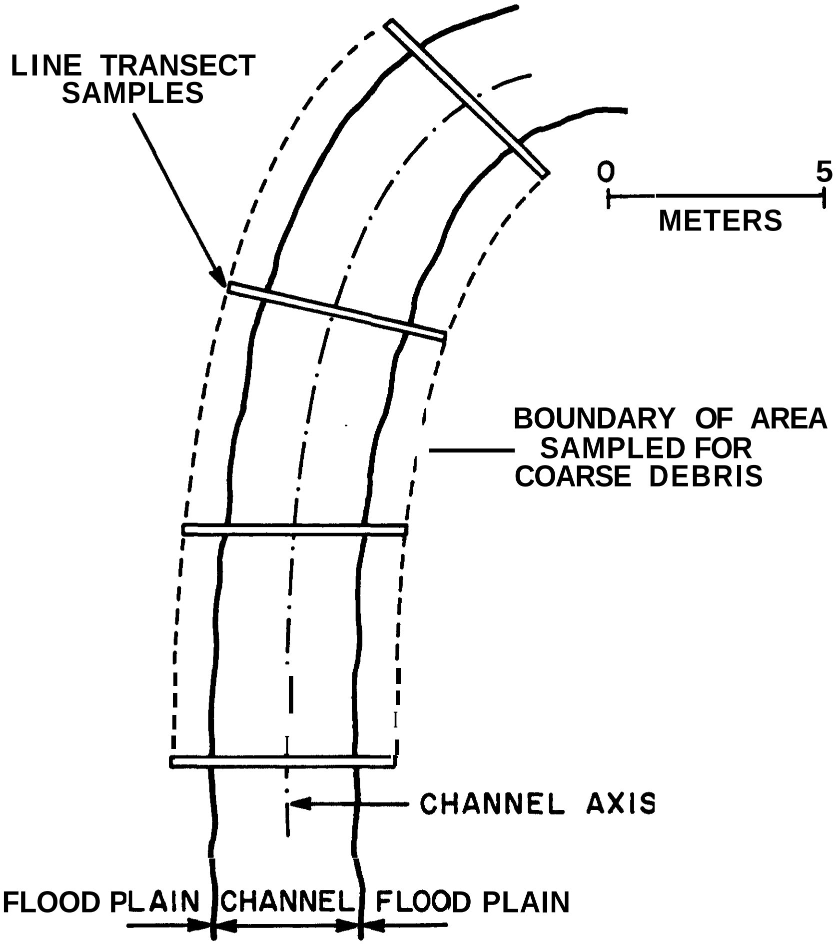

Figure 2.—Line transects and coarse debris sampling plots.

Quantities of organic debris were measured using methods developed by Froehlich (Froehlich and others 1972, Lammel 1972, Froehlich 1973). Froehlich drew on methods originally used to sample conditions of forest fuel. Fine debris (less than 10 cm in diameter) was sampled by using line transects crossing the stream; larger wood was sampled by scaling all pieces between successive line transects. Unlike Froehlich, however, we distinguished channel from flood plain. Channel was the area we judged to be wetted during annual high flow and bounded by low banks. Flood plain included streambanks and areas back from the bank less frequently inundated.

Fine woody debris was sampled by three diameter classes (less than 1 cm, 1 to 3 cm, 3 to 10 cm), using a line intersect method along a series of transects crossing the channel at regular intervals (fig. 2). In some cases, 25 percent of a length of transect was sampled in a series of randomly positioned, 30-cm-long segments of the line. The entire line transect was sampled on other streams. We counted all sticks in the three diameter classes that intersected a vertical plane along the sampled portion of the transect. Volume of fine debris per unit area of horizontal surface (V) in each size class was calculated by:

$$V = \frac{\pi^2 n d^2}{8L}$$

where n = number of intersections of all sticks in a diameter class, d = mean diameter of that class, and L = length of transect actually sampled (see Van Wagner 1968 for derivation). For mean diameters of each size class we used values determined by Froehlich and others (1972) in old-growth Douglas-fir (*Pseudotsuga menziesii*)–western hemlock forests in the western Cascade Range, Oregon: 0.423 cm for less-than-1-cm class, 1.792 cm for 1 to 3 cm, 5.049 cm for 3 to 10 cm. Specific weight of organic debris was assumed to be 0.50 g/cm^3 (USDA Forest Service 1974) for calculating mass of organic debris sampled.

Pieces of coarse organic debris (greater than 10 cm in diameter) were scaled individually by measuring diameters of the large and small ends and length, using calipers and tape. We scaled only portions of debris pieces that fell within a belt bounded by ends of line transects (fig. 2). Coarse debris in and over the channel was segregated into "potential" (material more than 1 m above the streambed) and "effective" debris (within 1 m of the bed). We interpreted effective debris as being capable of influencing streamflow, although in some instances the influence might occur only at very high flow. Potential debris consisted of fallen trees spanning the channel that would eventually collapse into the stream. The volume of each piece of large wood was calculated assuming it to be a section of a cone. Total wood volume was divided by sample area to determine concentration of large wood in terms comparable with data for fine woody debris.

Line transects on Cabbage and Tye Creeks extended 5 m back from the channel edge or until a steep, high (greater than 1 m) bank was encountered. Toad Creek was sampled with a 10-m-long transect centered on the stream. A 5-m length of transect was used on Holmgren, 3/10-Mile, and Knob Creeks. In all cases, line transects were truncated where they encountered steep, high banks.

Results

Means and standard deviations (s) of debris loading and surface area were calculated from measurements of transtransects for coarse material. Standard errors (S.E.) were determined for each mean:

$$\text{S.E.} = \frac{s}{\sqrt{n}}$$

where n = number of transects or intervals (table 1). A standard error of the mean could not be calculated for total effective loading because different sampling methods were used for fine and coarse debris.

The stream reaches flowing through clearcuttings (Tye, Toad, and Knob Creeks) and forested areas (Cabbage and Aha Creeks), were mapped at a scale of 1:120 using tape and compass. Bonnie Creek was mapped at 1:200 with the same methods. Ages of trees growing on gravel bars and large debris at the Bonnie Creek site were determined by counting tree rings in cores taken with an increment borer. Planimeter measurements from the maps of study streams were used to estimate the percent of the stream area in large debris, accumulations of fine debris, and undercut banks—an important component of fish habitat.[1] Channel gradient was measured with a hand-held clinometer.

Comparison of Debris From Streams in Clearcuttings and Forested Areas

Concentrations of organic debris in streams flowing through forested areas are significantly lower ($P < 0.010$) than in streams in 6- to 10-year-old clearcuttings (figs. 3 and **4,** and tables 2 and 3). Reaches of streams in clearcuttings are dominated by accumulations of fine organic debris (less than 10 cm in diameter), mainly logging slash. Large organic debris in reaches in forested areas

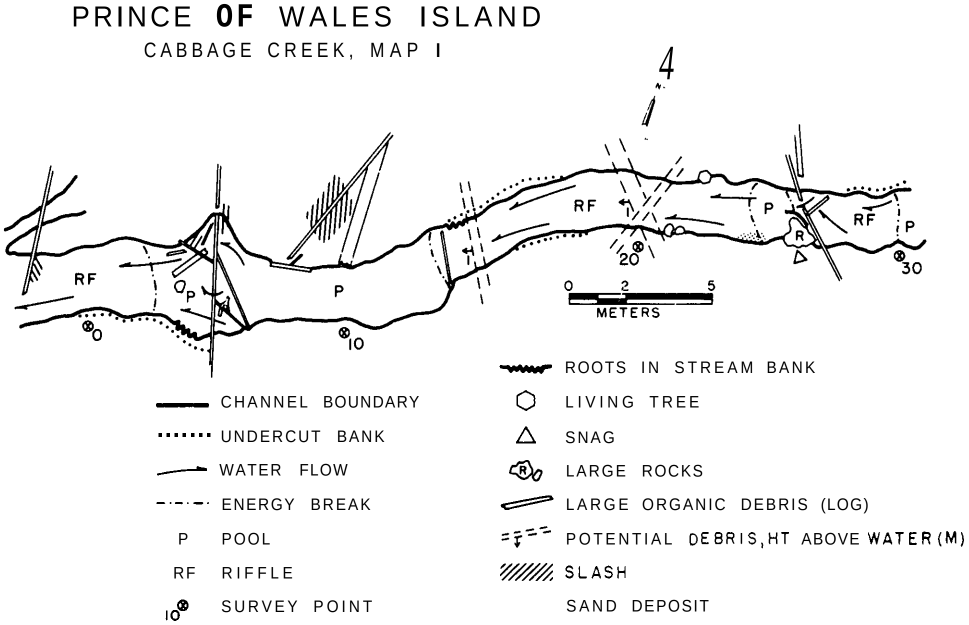

Figure 3.—Organic debris in Cabbage Creek.

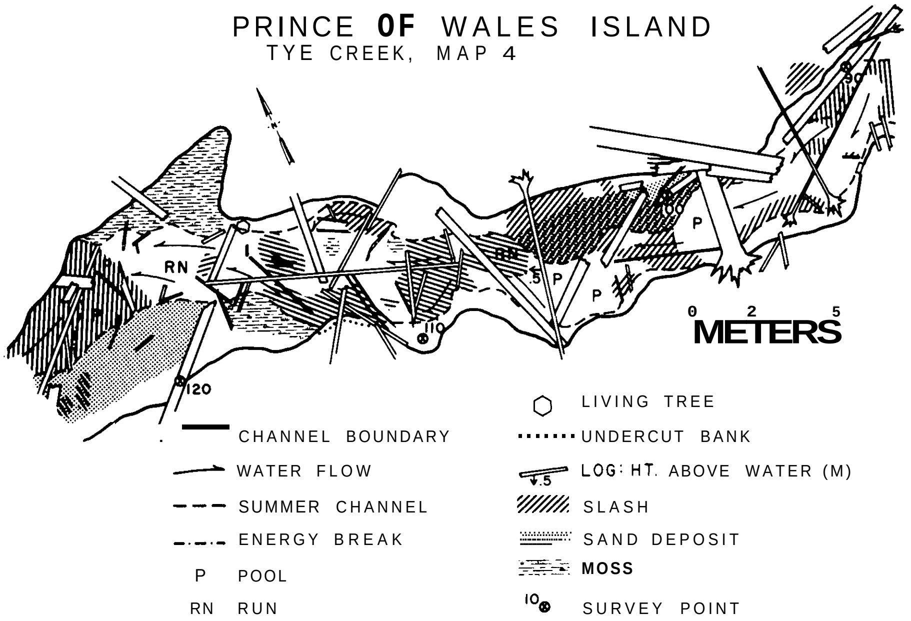

Figure 4.—Organic debris in Tye Creek.

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[1] Unpublished maps on file with Research Work Unit 1653, Forestry Sciences Laboratory, Corvallis, Oregon, and Research Work Unit 1705, Forestry Sciences Laboratory, Juneau, Alaska.

Table 2--Debris loading in sampled reaches of study streams at forested sites, Prince of Wales Island, Alaska[1]

Creek	Area	Fine debris loading	Coarse debris		Total effective loading
			Potential	Effective	
	m^2	kg/m^2			
Cabbage:					
Channel	225	0.5 ±0.2		2.8 ±0.8	3.3
Flood plain	249	1.0 ±0.4		4.6 ±2.1	5.6
Total	474	0.8	1.3 ±0.5	3.8	4.6
Holmgren:					
Channel	187	2.6 ±0.5		7.1 ±1.5	9.7
Flood plain	263	0.5 ±0.1		4.7 ±1.8	5.2
Total	450	1.4	1.0 ±0.9	5.7	7.1
3/10-Mile:					
Channel	273	1.0 ±0.3		11.7 ±2.6	12.7
Flood plain	176	0.4 ±0.2		5.7 ±1.8	6.1
Total	449	0.8	2.7 ±2.1	9.4	10.2
Alha:					
Channel	1383	0.8 ±0.1		11.4 ±2.3	12.2
Flood plain	646	1.0 ±0.2		12.0 ±3.0	13.0
Total	2029	0.9	2.0 ±0.8	11.6	12.5
Average:					
Channel		1.0		10.1	11.1
Flood plain		0.8		8.4	9.2
Total		0.9	1.9	9.4	10.3

[1] Debris values include mean ± standard error of the mean.

Table 3--Debris loading in sampled reaches of study streams at clearcut sites, Prince of Wales Island, Alaska[1]

Creek	Area	Fine debris loading	Coarse debris		Total effective loading
			Potential	Effective	
	m^2	kg/m^2			
Tye:					
Channel	626	6.7 ±1.3		27.8 ±9.9	34.5
Flood plain	514	4.1 ±0.8		38.8 ±7.2	42.9
Total	1140	5.5	2.5 ±1.2	32.8	38.3
Toad:					
Channel	420	8.5 ±2.1		53.3 ±13.1	61.8
Flood plain	497	12.3 ±2.2		23.2 ±5.1	35.5
Total	917	10.6	6.6 ±3.2	37.1	47.7
Knob:					
Channel	532	3.6 ±0.5		12.1 ±2.7	15.7
Flood plain	468	2.7 ±0.5		8.4 ±2.0	11.1
Total	1000	3.1	1.4 ±0.8	10.4	13.5
Average:					
Channel		6.1		29.3	35.4
Flood plain		6.4		23.9	30.3
Total		6.2	3.4	26.8	33.0

[1] Debris values include mean ± standard error of the mean.

generally occurs as discrete accumulations composed of a few pieces, whereas accumulations of debris in clearcuttings extend for tens of meters down the length of the channel.

Loading of organic debris in stream reaches in forested areas contrasts markedly with that in the three reaches in clearcuttings (tables 2 and **3**). Coarse and fine debris loading in the clearcut areas exceeds that in forested areas by about **3** and 6 times, respectively. Flood plains in clearcutttings have higher debris loading than in forested areas by factors of **3** and 8 times for coarse and fine debris. The quantity of overhanging (potential) large debris appears similar in streams flowing through clearcuttings and forested areas.

Average quantities of coarse and fine debris are quite variable both within and between sites. Concentrations of debris are not systematically different between channels and flood plains areas for either forested or clearcut sites. For the sampled channels in forested areas, fine debris ranges from 0.5 to 2.6 kg/m^2 and coarse debris varies from 2.8 to 11.7 kg/m^2. The magnitude of variation among clearcut study sites appears somewhat less.

The average amount of coarse and fine debris in logged areas appears greater than in unlogged areas, but the differences are difficult to detect statistically because of the small sample size. Because the distribution did not appear to be normal, the Mann-Whitney test was used to test for equality of distribution functions of fine debris, coarse debris, and total effective debris loading between stream reaches at logged and unlogged sites (Conover 1971). The hypothesis of equality of distributions is rejected at $P = 0.10$ ($T_2 = 6.0$, $P = 0.054$) in all three cases. It is important to note, however, that our scope of inference is limited by the very small sample size.

Some types of wood processing by invertebrates and organisms causing decomposition are regulated by surface area of available wood rather than volume of wood. Although much of the mass or volume of wood in streams is contained in a few large pieces, much of the surface area is in the smallest size classes of debris (tables 4 and 5). Coarse material in channels accounts for 73 to 93 percent of total concentration by weight, but it contributes only 20 to 53 percent of total wood surface area. Within the fine debris category, the less-than-1-cm-diameter class generally contributes as much or more surface area of wood as the 1- to 3- and 3- to 10-cm-diameter classes.

In addition to measuring influence of debris in terms of concentration, we also tallied the number and size of debris accumulations over the length of study reaches. Debris accumulations extending over more than two-thirds of the width of sampled streams in forested areas occurred with a spatial frequency of about 1 per 13 m of channel length (1 per 4 channel widths.)[2] Accumulations extending across less than two-thirds the width of streams in forested areas had an average spacing of 1 per 11 m of channel length (1 per 4 channel widths). Similar determinations in streams flowing through clearcuttings were difficult to make because debris coverage was nearly continuous over long reaches of some channel sections.

Table 4--Summary of debris loading (kg/m^2) and surface area (m2 of wood surface/m^2 of horizontal surface) by class of debris in four study streams at forested sites, Prince of Wales Island, Alaska[1]

Creek	Fine Debris			Effective coarse debris >10 cm
	<1 cm	1-3 cm	3-10 cm	
Aha:				
Channel --				
Surface area	0.09 ±.02	0.09 ±.02	0.09 ±.02	0.26 ±.05
Loading	0.05 ±.01	0.2 ±.04	0.6 ±.11	11.4 ±2.3
Flood plain--				
Surface area	0.28 ±.12	0.12 ±.03	0.12 ±.04	0.28 ±.07
Loading	0.2 ±.06	0.3 ±.06	0.8 *.3	12.0 ±3.0
Cabbage:				
Channel --				
Surface area	0.08 ±.02	0.06 ±.03	0.06 ±.03	0.12 ±.03
Loading	0.04 ±.01	0.1 ±.07	0.4 *.2	2.8 ±0.8
Flood plain--				
Surface area	0.17 ±.02	0.10 ±.03	0.11 ±.06	0.14 ±.06
Loading	0.1 ±.01	0.2 ±.07	0.7 ±0.4	4.6 ±2.1
Holmgren:				
Channel --				
Surface area	0.27 ±.06	0.12 ±.02	0.37 ±.07	0.25 ±.04
Loading	0.2 ±.03	0.3 ±.05	2.4 ±.42	7.1 ±1.5
Flood plain--				
Surface area	0.19 ±.04	0.04 ±.01	0.04 ±.01	0.15 ±.03
Loading	0.1 ±.02	0.1 ±.09	0.3 ±.09	4.7 ±1.8
3/10-Mile:				
Channel --				
Surface area	0.11 ±.03	0.08 ±.02	0.12 ±.04	0.34 ±.06
Loading	0.06 ±.02	0.2 *.1	0.8 ±.3	11.7 ±2.6
Flood plain--				
Surface area	0.12 ±.02	0.03 ±.01	0.04 ±.02	0.15 ±.06
Loading	0.06 ±.01	0.1 ±.03	0.3 ±.1	5.7 ±1.8

[1] Values include mean • standard error of the mean.

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[2] Channel width is a measure commonly used by geomorphologists to describe spacing of geomorphic features along stream channels.. Pools and riffles, for example, are typically spaced 5 to 7 channel widths apart along the channel length.

Table 5--Summary of debris loading (kg/m^2) and surface area (m^2 of wood surface/m^2 of horizontal surface) by class of debris in three study streams at clearcut sites, Prince of Wales Island, Alaska[1]

Creek	Fine Debris			Effective coarse debris
	<1 cm	1-3 cm	3-10 cm	>10 cm
Knob:				
Channel --				
Surface area	0.28 ±.05	0.28 ±.04	0.45 ±.07	0.33 ±.05
Loading	0.2 ±.03	0.6 ±0.1	2.9 ±0.5	12.1 ±2.7
Flood plain--				
Surface area	0.22 ±.06	0.19 ±.03	0.35 ±.07	0.22 ±.04
Loading	0.1 ±.03	0.4 ±0.1	2.2 ±0.5	8.4 ±2.0
Toad:				
Channel --				
Surface area	1.37 ±.41	0.56 ±.12	1.05 ±.31	0.88 ±.17
Loading	0.7 ±0.2	1.3 ±0.3	6.6 ±2.0	53.3 ±13.1
Flood plain--				
Surface area	1.43 ±.41	1.04 ±.18	1.46 ±.29	0.56 ±1.0
Loading	0.8 ±0.1	2.3 ±0.4	9.2 ±1.8	23.2 ±5.1
Tye:				
Channel --				
Surface area	0.73 ±.26	0.47 ±.15	0.83 ±.15	0.50 ±.09
Loading	0.4 ±0.1	1.1 ±0.3	5.3 ±0.9	27.8 ±9.9
Flood plain--				
Surface area	0.35 ±.10	0.32 ±.08	0.51 ±.10	0.71 ±.09
Loading	0.2 ±.05	0.7 ±0.2	3.2 ±0.6	38.8 ±7.2

[1] Values include mean • standard error of the mean.

Organic debris in channels can also be assessed in terms of the cover it provides for fish. We measured the cover formed by fine and coarse organic debris and by overhanging banks in the mapped sections of Cabbage and Aha Creeks in forested areas and Toad and Tye Creeks in clearcuttings. Organic debris, predominantly logging slash, covers a much higher proportion of the channel area in the clearcuttings than does the debris at the forested sites (table 6). Fine organic matter comprises the greatest proportion of cover in clearcut areas.

Undercut banks provide 4.5 times more cover in the streams flowing through forested areas than in the channels in the clearcuttings. Although this comparison is based on only four stream reaches, it follows our general impressions from other field observations. Observed cavities below overhanging banks in study streams were typically about 10 to 50 cm high and of similar depth. Roots of both herbaceous and woody streamside vegetation reinforce the banks. Area of overhanging banks may be reduced by crushing during felling and yarding operations. Aggradation after logging may fill channel margins where cover for fish had been provided by overhanging banks.

Table 6--Percent stream channel cover by large and fine debris and undercut banks in mapped sections of study streams, Prince of Wales Island, Alaska

Creek	Stream channel cover		
	Large debris	Fine debris	Undercut banks
Forested sites:			
Cabbage	2.7	0.6	5.8
Aha	11	3.1	1.8
Clearcut sites:			
Toad	15	36	0.4
Tye	12	22	1.3

Conditions of Debris in an Intermediate-Sized Stream

Organic debris in intermediate-sized and large streams poses special management problems: during a flood, floating debris can damage structures such as bridges and culverts. To characterize stability of organic debris in general and the effect of debris on channel geometry in an intermediate-sized stream, we examined a 200-m long section (14 channel widths) of Bonnie Creek about 400 m upstream from its confluence with Shaheen Creek.

The Bonnie Creek study site is divided into two reaches; the upstream 100-m section contains only about one-third as much large debris as the downstream 100-m section (table 7). Although the gradients of the two reaches are similar, the downstream section is dominated by debris and has nearly twice the average width of the upstream section. Bank-full width in the downstream section is quite variable, ranging from 9.0 to 32.9 m, whereas width in the upstream reach varies only from 7.8 to 11.9 m. Trees appear to have contributed to irregularity of channel width in two ways. Windthrow and streambank erosion lead to root throw of large Sitka spruce; this widens the channel (fig. 5). Downed, dead debris tends to divert streamflow into banks and multiple channels (fig. 5).

Aquatic habitat in the two reaches contrasts markedly. The upstream reach is primarily a continuous riffle through boulders with very little pool area. The debris-dominated section has numerous pools created by patterns of streamflow controlled by large logs. These logs also provide cover and cause deposition of gravel and sand. Influence of large debris in this section of Bonnie Creek increased stream area of pools. Debris-caused deposition of gravel suitable for spawning does not occur in the open reach.

Table 7--Channel characteristics and concentration of large organic debris in Bonnie Creek, Prince of Wales Island, Alaska

Reach	Average length	Average width	Average gradient	Coarse debris loading	
				Effective	Potential
	- - - - m - - - -		Percent	- - - - kg/m^2 - - - -	
Upstream	100	9.7	1.5	6.8	3.9
Downstream	100	18.8	2.0	**23.6**	1.5

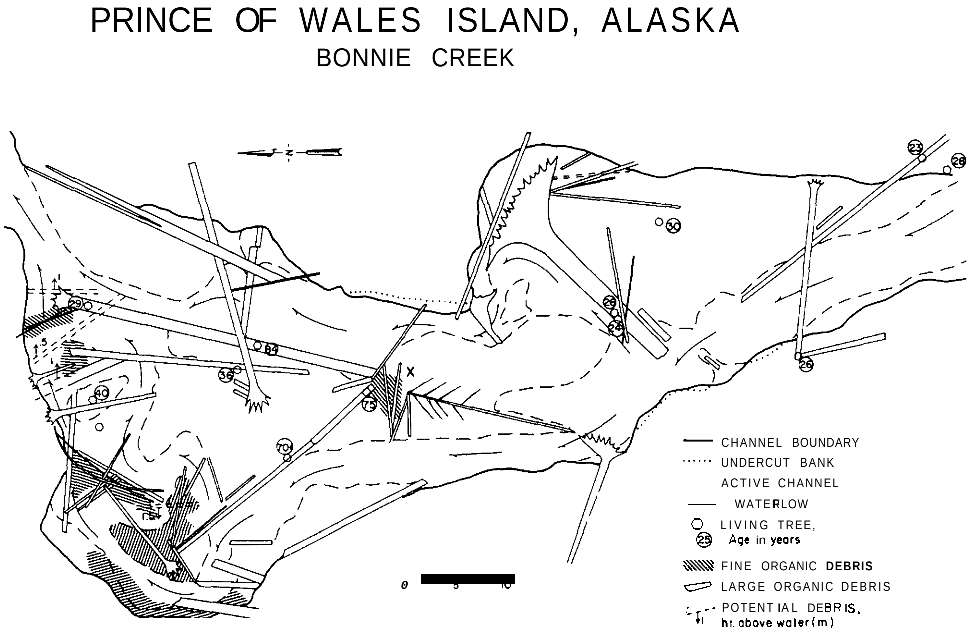

Figure 5.—Organic debris in the downstream reach of Bonnie Creek.

Discussion

The long-term stability and mobility of large organic debris in the study section of Bonnie Creek are indicated by the length of time major pieces of debris reside in the channel and by the size of pieces floated into their present position. Ages of trees growing on downed logs and sediment deposits in the channel (fig. 5) reveal that configurations of the channel and large debris have changed little in the past 20 to 30 years. Major pieces of debris in the northern half of the mapped section have been in place for more than 70 years. Such long times in residence are attributable to slow decay of large pieces of conifer wood, stable orientation in channels, partial burial by fine sediment deposited in slack water set up by the logs, and binding by tree roots growing through pieces of debris and into sediment substrates. Stabilization by partial burial may take several years; substantial root binding may not develop for a decade or more.

The size of large pieces of debris floated onto the head of the split channel section (location marked "X, fig. 5) provides a measure of the size of debris pieces readily floated in this channel. Pieces up to about 8 m long have been floated downstream at high flows. Four logs greater than 4 m in length have accumulated in this pile. This suggests that pieces of debris with lengths up to about half bank-full channel width can be floated through the upstream portion of this reach.

General observations here and elsewhere indicate that pieces with lengths about equal to bank-full width can be transported distances more than several channel widths downstream at high flow (Lienkaemper and Swanson 1980). Longer pieces may have much of their weight supported on ground outside the channel, and they are easily lodged across channels or against trees on banks. Lengths of readily transported pieces may be substantially less than bank-full width where numerous large, stable pieces of debris or rocks break up streamflow and provide sites where floated debris is trapped.

Debris Loading in Streams in Clearcuttings and Forested Areas

The four streams sampled in old-growth forested areas contained an average of 9.4 kg/m^2 of coarse debris and 0.9 kg/m^2 of fine debris. These concentrations of coarse debris are similar to streams sampled in Engelmann spruce-lodgepole pine (*Picea engelmannii-Pinus contorta*) stands in Idaho and spruce-true fir (*Picea sp.-Abies* spp.) stands in New Hampshire and Tennessee (Anderson and Sedell 1979). But values of coarse and fine debris loadings in the study streams of forested southeast Alaska are 24 and 30 percent, respectively, of values reported for small streams flowing through old-growth Douglas-fir-western hemlock-western redcedar (Thuja *plicata*) stands in western Oregon (table 8). Concentrations of large debris in streams flowing through coast redwood (Sequoia *sempervirens*) stands are still higher (Keller and Talley 1979; F. J. Swanson, unpublished data). Contrasts in conditions of stream debris in different forest types reflect differences in quantities and size distribution of woody biomass in adjacent forests, rates of wood decay, and successional dynamics of the forest ecosystems supplying large debris to streams. Sitka spruce-western hemlock stands along the southeast Alaska streams, for instance, tend to carry lower biomass than the Douglas-fir— western hemlock forests sampled in western Oregon because the stocking density of large (greater than 60 cm) stems is less in southeast Alaska and the trees are shorter. Trees in the Alaska forest type are also more densely limbed, however, accounting for the higher proportion of fine debris in the southeast Alaska streams.

The apparent magnitude of the effect logging has on the concentration of organic debris in southeast Alaska streams is similar to situations in western Oregon where the same methods of logging and stream protection were employed (table 8). The sampled streams in clearcut areas in southeast Alaska have about three times as much coarse debris and seven times as much fine debris as that measured in streams of forested areas. Froehlich (1973) observed that logging effects in western Oregon depend on the falling methods used and width of buffer strips employed. Highest increases in stream debris were associated with free-falling without buffer strips, the system used at the southeast Alaska study sites. At three western Oregon sites, these harvest methods resulted in about two- and four-fold increases in coarse and fine debris loading, respectively.

Table 8--Organic debris loading (kg/m^2) in sampled reaches of study streams at forested and clearcut sites in western Oregon and southeast Alaska[1]

Condition of stand adjacent to study stream	Number of reaches sampled	Before logging		After logging	
		Coarse[2]	Fine	Coarse[2]	Fine
Western Oregon:[3,4]					
Old-growth forest	10	39.1	3.0		
Clearcut--					
Free-fall	3	24.9	2.6	56.6	11.5
Cable-assisted directional fall	4	50.1	3.8	46.0	12.0
Free-fall with buffer strip	3	38.5	2.5	35.8	3.2
Prince of Wales Island, Alaska:[5]					
Old-growth forest	4	9.2	0.9		
Clearcut, free-fall	3			27.5	6.2

[1] Stream width varied from 1 to 8.5 m.

[2] Diameter of coarse debris = >10 cm.

[3] Bulk density of wood in Oregon streams was assumed to be 0.58 g/cm^3

[4] Oregon data from Froehlich (1973) and Lienkaemper unpublished data

[5] Bulk density of wood in Alaska streams was assumed to be 0.50 g/cm^3

Differences in loading of large debris between the Alaska and Oregon sites are so great in other respects that even in Alaska streams in clearcut areas, concentrations of coarse debris are about 70 percent the average value of the forested Oregon sites. Concentrations of fine debris after logging at the Alaska sites are about twice the values of forested Oregon sites but much less than concentrations in the seven Oregon stream reaches adjacent to stands logged without buffer strips.

Implications for Management

Implications for management of organic debris in streams can be viewed from a broad range of perspectives—aquatic ecosystems, movement of water and sediment, aesthetics, and others. Effects of organic debris with respect to each perspective are poorly documented, except to say that organic debris is an important component of most streams in natural condition in forested areas.

At present, it is impossible to quantitatively predict the biological or geomorphic consequences of adding, removing, or changing the size distribution of debris in streams. Anderson and Sedell (1979) provide a general conceptual framework linking functional groups of aquatic organisms to debris conditions in streams. This way of viewing the system provides a basis for future efforts to assess biological effects of altered conditions of debris. Current research in western Oregon and in this study has begun to determine the response of the aquatic community to experimentally manipulated debris loading. Research at these sites, and at Hubbard Brook in New Hampshire (Bilby 1979) and in the Redwood Creek basis (Anne MacDonald, University of California at Santa Barbara), is also documenting changes in channel geometry and the storage and transport of sediment following debris removal.

Our meager understanding of effects of altered organic debris conditions leads us to the simple and conservative approach of basing management guidelines on debris conditions typical of streams in natural conditions flowing through forested areas. Debris conditions could also vary in response to natural stand disturbance (Swanson and Lienkaemper 1978). This approach is supported by the growing understanding of the benefits of debris in streams for fish and other aquatic resources. Many workers argue that logging practices should (a) introduce little or no new debris to channels, (b) maintain the natural debris in channels, and (c) manage streamside vegetation as a potential future source of large debris for channels, as well as allowing it to play other ecological roles such as a source of shade and litter (Froehlich 1973, Meehan et al. 1977, Swanson and Lienkaemper 1978, and others). These guidelines pertain to streams and rivers of all sizes.

Debris management poses another set of questions: What debris should be removed from previously disturbed streams and when should it be removed. Again, we must use natural organic debris loading and distributions as a guide. In the debris removal work at small (bank-full width less than 5m), low-gradient streams flowing through clearcuttings on Prince of Wales Island, the following criteria were used for identifying debris to be removed, retained, or added.

1. Remove accumulations of branches, twigs, and needles not buried in sediment.

2. Leave large, stable pieces of debris in quantities and spatial distributions typical of forested reaches. (Stability of pieces is determined by orientation, length of piece relative to stream width, degree of burial by sediment, and stage of decay.)

3. Move large debris into the channel where there are 20-m (5 to 10 channel widths) or longer reaches with no large debris. Place this material in a stable position.

Onsite decisions about what pieces to remove should consider how channel geometry, sediment deposition, and streamside vegetation have responded to existing debris conditions. If debris has been in the channel less than a year or two, channel or sediment systems may still be adjusting to its presence. Debris removal may prolong the period of channel instability. After several years, channel geometry and patterns of sediment deposition adjust to debris conditions. Debris removal in these cases may initiate a new period of instability, particularly if the removed debris is trapped and retained sediment. The rate of this readjustment and sediment release from a cleaned stream reach will depend on a number of factors including history of storms and degree to which root networks have developed in sediment deposits. Deposits in place more than 10 years may be extensively penetrated by fine roots of streamside vegetation. These root systems slow release of sediment from cleaned channel sections and promote stability in the aquatic environment as it adjusts to altered debris loading. Thus, residence time of debris in channels is an important consideration in developing strategies for debris removal.

Providing future sources of large debris for streams is difficult in southeast Alaska, where tree species are shallow rooted and prone to blowdown—especially when the adjacent stand has been removed. Moore (1977) and others offer guidelines for selecting and designing streamside management units (SMU) for maximum effectiveness over both the short and long term. It is important to recognize that some trees in an SMU will fall into the stream years or decades after initial harvest to carry out the important biological and physical roles of large debris in streams. This new debris replenishes residual debris from logging or the previous mature forest—residual debris that is lost from the system by biological and physical breakdown and downstream transport (Keller and Swanson 1979).

Land managers now have difficulty designing SMU's, partly because the composition and structure of natural vegetation along small streams is not often well suited for stream protection once the adjacent stand is removed. This suggests that forest managers should be developing streamside vegetation in managed stands that will provide good SMU's at the end of the present rotation. Strategies for doing so may include (1) coppicing hardwoods by selective pruning *so* they can be carried through a whole rotation and provide abundant, wind-firm shade early in the next rotation, (2) establishing hardwoods along streams late in a rotation, and (3) thinning around or topping streamside conifers of low commercial value to develop desired, wind-firm crown structure and height. Some of these treatments should be designed to benefit wildlife also. These activities could be carried out as a special phase of standard precommercial and commercial thinning contracts. Exercising such foresight may make tomorrow's SMU's more effective in protecting streams while making sites easier to log and involving the least trade-off in timber volume.

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English Equivalents

1 centimeter (cm) = 0.3937 inch
1 meter (m) = 3.28 feet
1 kilogram (kg) = 2.2046 pounds (avoirdupo.is)
1 gram **(g)** = 0.0353 ounces (avoirdupois)
“Celsius (C) = **5/9(°F -32)**

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Organic debris in small streams, Prince of Wales Island, southeast Alaska. Gen. Tech. Rep. PNW-166. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1984. 12 p.

Quantities of coarse and fine organic debris in streams flowing through areas clearcut before 1975 are **3** and 6 times greater than quantities in streams sampled in old-growth stands in Tongass National Forest, central Prince of Wales Island, southeast Alaska. The concentration of debris in streams of clearcut Sitka spruce-western hemlock forests in southeast Alaska, however, is about half that in streams of clearcut Douglas-fir-western hemlock forests in western Oregon. Management guidelines for maintaining natural debris conditions include minimizing the addition of fresh material to a channel during management activities, leaving natural accumulations of debris, and managing streamside areas for production of a continuous, long-term supply of large debris for channels. Considerations in planning stream cleanup include the length of time the debris has resided in the channel and the stability of debris, which is a function of its size, orientation, and degree of burial and decay.

Keywords: Stream debris, fluvial processes, fish habitat, watershed management, logging hydrology, (-hydrology, Alaska (southeast), southeast Alaska.

Pacific Northwest Forest and Range
Experiment Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208