ORGANIC DEBRIS IN SALMONID HABITAT IN SOUTHEAST ALASKA: MEASUREMENT AND EFFECTS[1]

Mason D. Bryant[2]

Abstract.--Woody debris is an important part of the stream habitat used by juvenile salmonids. As part of an examination of the effects of logging debris and its removal, this study examined some methods for measuring the amount and effects. Several indices of channel morphology vere developed from stream cross-section measurements. Some differences were detected. Differences in debris loading following removal were observed, but the patchy distribution of debris and changes in stream channel boundaries masked some differences. Stream maps revealed year-to-year bank changes and changes in debris orientation following debris removal. Coho populations appeared to respond to debris removal with fewer numbers in cleared stream sections.

INTRODUCTION

Woody debris is a natural additive to forest streams. As such, it plays an important role in the structure and function of stream ecosystems. It influences channel shape, provides a colonization habitat and food source for micro- and macro-invertebrates, and provides cover for salmonids. Timber harvest frequently increases the rate and amount of organic debris added to streams. Although the material is natural, the amount of the material in the stream is not. At this point, management of debris becomes a problem; and methods to measure, analyze, and treat organic debris are necessary.

This paper presents some of the techniques that have been used to measure organic debris and its effect on channel morphology and on fish populations. I will discuss the methods used in a specific study of logging debris and its removal in two small salmonid nursery streams. The techniques provide a method to measure the effect of organic debris and its removal on salmonid nursery streams. The results illustrate the effectiveness of the methods and some of the problems in application. The emphasis is on the methods rather than the specific results.

The studies were done on two small streams in the Staney Creek drainage on Prince of Wales Island. The two study streams were small, first and second order, low gradient (less than 5%) streams flowing through areas logged in the late 1960's. Both streams had populations of coho salmon (*Oncorhynchus kisutch* (Walbaum)) and Dolly Varden (*Salvelinus malma* (Walbaum)). Lower numbers of cutthroat trout (*Salmo clarki* Richardson), rainbow trout (*Salmo gairdneri* Richardson), and coastrange sculpin (*Cottus aleuticus* Gilbert) were also present. Both streams had heavy concentrations of logging debris.

A number of studies discuss the effect, function, and physical aspects of wood debris in streams, for example, Swanson et al. (1976), Keller and Swanson (1979), Keller and Talley (1979), and Bilby and Likens (1980). Marzolf (1978) discusses the effects of removing large debris in streams. The importance of fine and coarse organic debris to the stream biota is reviewed by Cumins et al. (1973), Triska and Sedell (1975), and Anderson et al. (1978). Various studies, primarily of natural organic material, show that large debris is extensively used by juvenile salmonids as cover (for example Hartman 1965, Mundie 1969, Hall and Baker 1975).

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[2]Research Fishery Biologist, Forestry Sciences Laboratory, USDA Forest Service, Pacific Northvest Forest and Range Experiment Station, P.O. Box 909, Juneau, AK 99802.

Bustard and Narver (1975) provided direct evidence of use of debris by juvenile coho during winter. Elliott (1976), Lestelle (1978), and Baker (1979) studied effects of various types of debris removal on salmonid populations.

Throughout these studies, a number of different methods were used to measure physical habitat and fish populations. In many cases only visual estimates of debris loading, such as estimated percent of stream covered, were made; elsewhere, detailed measurements of debris volume by scaling and counting were made. Methods to determine effects of debris on stream channel morphology include cross-section profiles, detailed sketch maps, and photography. Estimates of fish populations range from none at all to intensive population estimates over several seasons.

The studies conducted on Prince of Wales Island used relatively intensive survey techniques which may be too time consuming for long stream reaches, but the methods can be used on selected shorter sections of a stream. Sections can be selected either purposely or randomly depending upon the objectives of the study and the characteristics of the stream. In either case, the methods can be used by field personnel to monitor the effects of a treatment on a stream.

METHODS

Both study sections in Tye and Toad Creeks were bounded either by a road and culvert or by the edge of a cutting unit and were isolated by two-way fish traps. The section on Tye Creek was 170 m long; the section on Toad Creek was 320 m long. The forest around the streams was cut in the late 1960's using free falling and high-lead yarding methods. No precautions were taken to protect the streams. Debris was removed in 1979 using the guidelines given in appendix I.

The streams were mapped in 1977 and in 1978 with a fiber tape, stadia rod, and compass. Both streams were remapped in 1981 after treatment in 1979. The tape was stretched along the stream, and the direction and length were drawn on graph paper. Stream bank, water edge, rocks, and logs were recorded by perpendicular distance from the tape measured along the stadia rod. The scale of the map was determined by the size of the squares on the graph paper. For this study, one square on the graph paper with 4 squares to the inch represented one foot. Distances of measurements with the stadia along the tape were determined by the complexity of the stream. Where greater detail was required, shorter distances were used.

Cross-sectional profiles were made at 10-m intervals at marked locations along the stream. Distance from a level tape stretched across the stream was measured to the stream bottom at 30-cm intervals along the tape from bank to bank. Where water was present, depths were recorded. The profiles were drawn from the measurements to give a graphic representation of the stream.

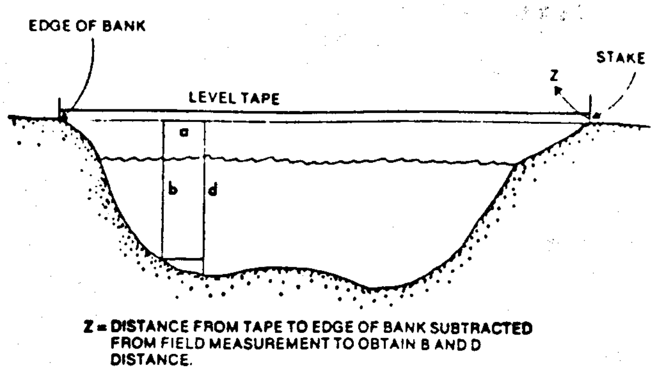

Figure 1.--Stream cross-section profile showing measurements.

Cross-sectional area (A) was calculated from the following equation:

$$A = \Sigma\, 1/2\, (ad+ab) \qquad \text{(see fig. 1)}$$

Cross-section perimeter (W) was calculated by:

$$W = \Sigma \sqrt{a^2+(d-b)^2} \qquad \text{(see fig. 1)}$$

"Average depth" (A/L) at each cross section was calculated by dividing area (A) by the length of the transect (L). Similarly "average perimeter" (P/L) was calculated by dividing cross-section perimeter by the length of the transect. Measurements were made from bank to bank based on summer flow.

Debris volume measurements were made according to the methods described by Froehlich et al. (1972) and Lammel (1972). The method divides organic debris into fine debris less than 10-cm diameter and large debris into material greater than 10-cm diameter. Fine debris is further divided into three classes; less than 1 cm, 1-3 cm, and 3-10 cm. Volume of fine debris per square meter of stream surface (V) was estimated by:

$$V = \frac{\pi^2 \cdot \Sigma(n-d)^2}{8L}$$

Where: n = number of pieces intersecting the transect line,
d = mean diameter, and
L = length of the transect

(Van Wagner 1968). Average diameters for each size group were 0.423, 1.792, and 5.049 cm (Froehlich et al. 1972).

Pieces greater than 10 cm in diameter were individually scaled by measuring top diameter (d_2) and bottom diameter (d_1) and length of each piece in the stream (Froehlich et al. 1972). If part of a log was in the stream, only the part in the stream was measured. Mass (Kg) was estimated by multiplying volume (V) calculated by the following equation:

$$V = \frac{\pi(d_1^2 + d_2^2)L}{8}$$

by 0.5, the estimated specific gravity of softwood.

Salmonid population estimates were made periodically from June through September using between 12 and 20 sections in each creek which were saturated with minnow traps baited with salmon eggs. A Peterson mark-recapture estimate was made during each sampling period. Because the streams were blocked by weirs and because sampling periods were lessthan 10 days, the population was considered to be closed with no immigration or emigration.

RESULTS AND DISCUSSION

Debris Loading

The quantity of fine debris (less than 10-cm diameter) and coarse debris (greater than 10-cm diameter) was estimated in 1977 and in 1981 after debris removal in 1979. Fine debris, estimated from piece counts, shows considerable change in the intervening period. Changes were also observed in coarse debris loading for both streams.

Table 1.— Fine debris (less than 10-cm diameter) for Tye Creek and Toad Creek, 1977 and 1981 (kg/m^2).

	1977	1981	% Reduction
Tye Creek:			
Untreated	41.5	12.85	69
Treated	49.2	1.83	96
Toad Creek:			
Untreated	14.6	2.76	81
Treated	14.3	6.22 (2.29)*	84*

*After removal of a single high transect.

Fine debris estimates in 1981 were substantially lover than those in 1977 for both streams. The estimate for the cleaned section of Tye Creek in 1981 vas about 14 percent of that in the untreated section (table 1). The fine debris density in Toad Creek was lower in 1981 than in 1977. A single transect in the treated section of Toad Creek increased the total loading estimate to 6.22 kg/m^2 (table 1). Removal of this transect in the estimate brings the average density for the treated section of Toad Creek to 2.29 kg/m^2, slightly lover than the estimate for the treated section. A similar point occurs in Tye Creek, but it occurs in the untreated section where greater debris loading vas expected and the effect is less dramatic.

Throughout the study a wide range in quantities of fine debris was observed. Tye Creek values for individual transects ranged from 0.061 to 80.5 kg/m^2; Toad Creek values ranged from 0.512 to 41.63 kg/m^2. This reflects the patchy distribution of fine debris in these streams. Throughout the streams, fine debris frequently occurred as clumps held by larger pieces forming dams or breaks in velocity. In between, riffle and pool areas were relatively clear of material, particularly in the treated sections.

The loading estimates for coarse debris in kilograms per square meter do not follov an expected pattern of decrease withtime and lover densities in the treated section. In fact, Tye Creek shovs an increase in density from 1977 to 1981, but a lover density in the treated section (table 2). Toad Creek shows a decrease in density from 1977 to 1981 in the treated section, whichcould be expected (table 2). Differences may arise from the methods used to compute channel area and in observer differences betveen the tvo sample periods. At Tye Creek, hovever, shifts

Table 2.--Coarse debris (greater than 10-cm diameter) for Tye Creek and Toad Creek, 1977 and 1981 (kg/m2).

	1977		1981	
	Potential	Instream	Potentia1	Instream
Tye Creek:				
Untreated area (m^2)--		595.		243.1
Debris loading (kg/m^2)	1.4	17.0	7.4	31.7
Treated area (m^2)--		512.		272.4
Debris loading (kg/m^2)	4.3	12.1	2.7	21.6
Toad Creek:				
Untreated area (m^2)--		1/191		3/320
Debris loading (kg/m^2)	12.2	40.3	8.5	40.4
Treated area (m^2)--		2/141		4/373
Debris loading (kg/m^2)	19.1	82.6	5/	46.3

1/Area from 200 - 300 meters along the stream.
2/Area from 50 - 150 meters along the stream.
3/Area from 170 - 310 meters along the stream.
4/Area from 0 - 170 meters along the stream.
5/Not estimated.

in the stream channel may account for part of the increase. For example. a large log at 60 m was in the off–channel area in 1977. By 1981, the stream had cut around the log and it was included in the instream estimate (fig. 2).

Loading estimates were recomputed on the basis of total volume (square meters) for each stream to remove the area differences (table 3). The 1981 estimates show lower volumes in the treated sections; hovever, the 1981 estimates for Toad Creek are greater than those for 1977; but in 1981, a longer section of the streamvas surveyed. Because of these difficulties, year to year com–parisons are tenuous, but within year comparisons are reasonable.

The individual estimates of coarse debris for each 10-m section varied considerably. For example, in the untreated section of Toad Creek between 270-280 m, the estimate was 26.1 m^3; and for the section betveen 220–230 m, the esti–mate was 0.67 m^3. For Tye Creek, volume estimates ranged between 0.15 and 5.63 m^3.

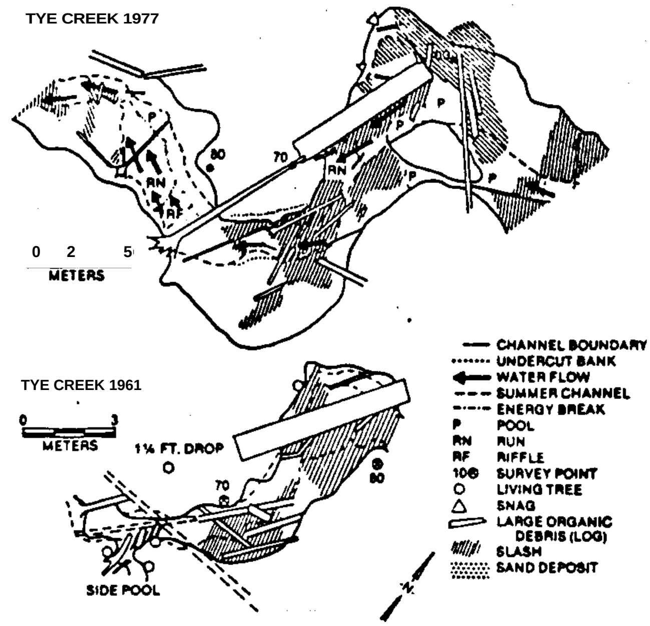

Figure 2.--A section of Tye Creek in 1977 before and in 1981 after debris removal.

Table 3.--Large debris (greater than 10-cm diameter) loading by volume (m^3) for Tye Creek and Toad Creek, 1977 and 1981.

	1977				1981			
	Stream length (L)	Pieces	Debris volume		Stream length (L)	Pieces	Debris volume	
	m	n	m^3	m^3/L	m	n	m^3	m^3/L
Tye Creek:								
Treated	100	48	20.91	.209	100	48	12.28	.123
Untreated	70	85	19.97	.285	70	72	12.44	.178
Toad Creek:								
Treated	50	29	13.68	.274	40	35	13.58	.339
Untreated	70	29	14.48	.207	70	42	82.4	1.177

The methods and the data provide one means of evaluating the intensity of debris loading in streams. The definition of the stream channel boundary must be explicit in both the method to evaluate fine debris and the method to evaluate coarse debris. The calculation of area in the density estimate is incorporated in the method for determining fine debris. but the limits of the transect are not––these are determined by the observer's perception of vhere the bank ends. The same is true of the coarse debris estimates except that area is derived independently. Again, channel boundaries must be defined to determine which pieces should be included and hov much of a piece should be scaled.

The point estimates do not reflect the orien-tation of thc coarse debris. nor do they shov the effect on stream channel morphology. In the case of logs, the position of the material will have a greater effect on the stream than size or amount. To determine distribution of the material, the point estimates must be dissected and the point estimates along the stream must be considered. Orientation and distribution of organic material are more explicitly studied from stream maps con–structed to show specific instream features.

Stream channel morphology

Because the method of debris removal prescribed that stable large material be left in place, changes in the log-sized material in the two treated sections were relatively small. Accumulations of large material were distributed throughout both streams in both years. In many cases, the larger material remained in place with little movement, for example the large log at 60 m on Tye Creek (fig. 2) and the log at 130 m on Pond Creek (fig. 3). Movement of smaller pieces has occurred, however; and in many cases, particularly in Tye Creek, pieces have been moved so that they are now parallel to the streamflow. In other cases, accumulations forming small dams have broken down following debris removal. One example of this is found in Toad Creek at 140 m (fig. 3) where the accumulation has opened into a chute. For the most part, the active channel in the treated sections is clear of most smaller debris, limbs and branches, whereas in 1977, extensive areas were covered.

In several instances large material remained essentially unchanged from 1977 to 1981. For example, in Toad Creek the large logs at 210 m and to some extent those at 200 m are in about the same place. The evidence on the maps is reinforced by on-site inspection. The channel has incorporated the larger pieces, whereas the smaller material has been moved out of the "summer" channel shown in the maps.

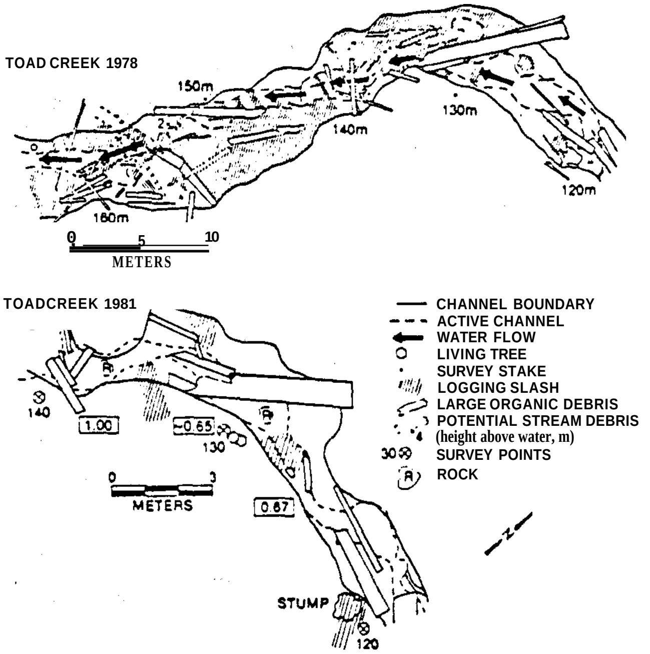

Figure 3.--Stream map sections of Toad Creek before debris removal (1978) and after (1981).

In several instances substantial changes in the stream channel are shown on the maps, the most apparent being in the untreated section above 70 m in Tye Creek. In general, the Tye Creek channel was less well defined than the Toad Creek channel which flows through a V-notch from about 40 m to 200 m.

Stream channel cross-sections were taken in 1977 to document possible changes in channel profile through debris removal. These were translated into numerical measures to reflect the cross-section perimeter and cross-section area.

Table 4 summarizes cross-section perimeters and areas, and average depths and perimeters for 1977 and for 2 years following treatment. Cross-section perimeter and cross-section area show no trends. The average depth for both streams is consistently less in the treated section than in the untreated section for all years. Average perimeter (the ratio of perimeter to cross-section width) decreases following removal in both streams.

This likely reflects removal of irregularities in the channel caused by either individual pieces of debris or of accumulations of debris which were removed during treatment.

Table 4.--Means for cross-section perimeters (P), cross-section area (A), "average depths" (A/L), and "average perimeter" (P/L).

	Section	P	A	A/L	P/L
	m	m	m^2	m	m
Tye Creek:					
		1977			
Untreated	(0-70)	2.43	.286	.167	1.19
Treated	(80-170)	2.79	.266	.110	1.30
		1979			
Untreated	(0-70)	2.89	.51	.181	1.10
Treated	(80-170)	2.79	.41	.133	1.08
		1981			
Untreated	(0-70)	2.64	.34	.153	1.15
Treated	(80-170)	2.90	.35	.131	1.06
Toad Creek:					
		1977			
Treated	(0-170)	3.27	.29	.178	2.33
Untreated	(180-320)	2.77	.30	.208	1.43
		1980			
Treated	(20-160)	2.33	.25	.121	1.05
Untreated	(233-300)	1.72	.28	.163	1.05
		1981			
Treated	(30-160)	1.89	.25	.129	1.04
Untreated	(180-320)	2.42	.38	.162	1.07

The lack of difference shown in the average depth measures is not surprising because cross-section measurements were not stratified with respect to channel type (i.e. pool or riffle). Further analysis from more intensive transect data may show a reduction in average depth in the treated areas, although the present data do not reflect this result. Both area and perimeter are affected by the sire of the system and location of the meaeurement along the system; "average depth" and "average perimeter" are not as likely to be affected within a stream section because the width of the transect is included,

Fish Populations

Coho and Dolly. Varden densities (numbers per square meter) in 1977 and 1978 were about the same for upper and lover sections of both streams. Differences among sampling stations were attributed to specific habitat features. In Tye Creek, densities of coho and smaller Dolly Varden were positively correlated to density of fine and coarse debris. A similar trend did not appear in Toad Creek with the exception of 0-age coho. Cardinal (1980) suggested that the extensive streameide shrub vegetation in Toad Creek masked sny relationships betveen fish densities and debrie density. Tye Creek vas more exposed and did not have the extensive shrub growth along its banks; therefore, debris vas more likely to provide cover.

Figure 4 shows the population levels for coho in both streams following debris removal. In all cases, the treated sections supported smaller numbers of coho than the untreated sections. Surviva1 rates for the summer of 1980 for coho and Dolly Varden do not showany marked differences betveen treated and untreated sections. On the basis of studies by Bustard and Narver (1975), greater differences in mortality rates might be expected during winter than in summer. In both streams, population levels of age 1+ coho in untreated sections are nearly tvice those in the treated sections.

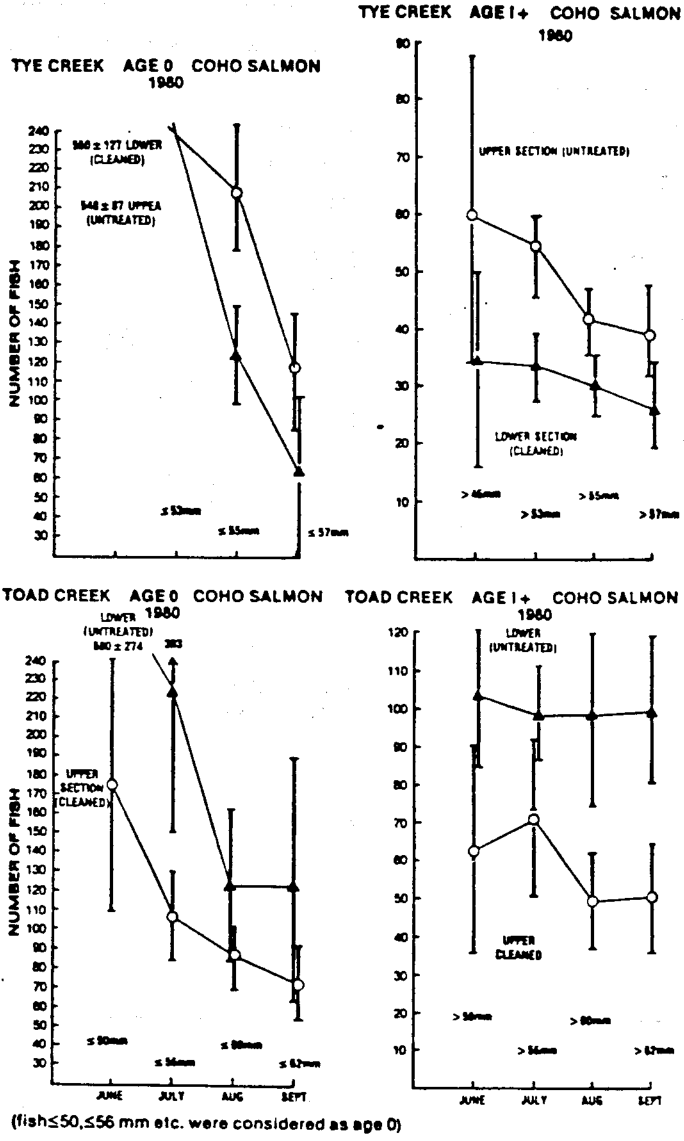

Figure 4.--Monthly population estimates and 75% confidence intervals for age 0 and age 1+ coho salmon for Toad and Tye Creeks.

CONCLUSIONS

1. Instream variation of fine debris accumulations and the patchy distribution of material is likely to mask treatment differences when fine debris is scaled with cross–section transects. An overall index of debris loading of a system can be obtained.

2. Large debris estimates are affected by differences instream area determinations and determinations of channel boundaries by different observers. Seasonal changes in the stream channel may influence year–to–year comparisons.

3. Numerical indices of debris loading do not re–flect the effect of debris on stream channel mor–phology, but may be described with stream channel maps, showing strean course, debris orientation, and locations and extent of accumulations.

4. Absolute measurements of cross-section areas and cross–section perimeters may be influenced by observer perception of stream bank boundaries. Average depths and average perimeter include more consistent year–to–year comparison of cross–section length and yield.

5. There is an apparent reduction of coho popula–tion levels following debris removal.

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APPENDIX I

Criteria for Debris Removal Treatment for Toad and Tye Creeks 1979

(1) All debris less than 60-mm diameter removed.

(2) Larger material, greater than 60-mm diameter removed if it is:
   (a) loose and not firmly embedded,
   (b) completely across the channel blocking flow and is not firmly embedded in the channel or in the bank, and
   (c) part of an extensive debris dam obstructing the channel.

(3) Trailing branches on larger instream material removed.

(4) No material removed in the control sections.