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Application of a Hierarchical Habitat Unit Classification System: Stream Habitat and Salmonid Distribution in Ward Creek, Southeast Alaska

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Abstract

A hierarchical classification system separating stream habitat into habitat units defined by stream morphology and hydrology was used in a pre-enhancement stream survey. The system separates habitat units into macrounits, mesounits, and micro-units and includes a separate evaluation of instream cover that also uses the hierarchical scheme. This paper presents an application of the system to a pre-enhancement survey of habitat and salmonid populations. Application of this method accompanied by snorkel counts of fish allowed us to determine habitat area, salmonid densities within habitat units, and an estimate of the total salmonid population by species. Differences in salmonid densities among mesohabitat units and among microhabitat units were detected with this method. The method is useful to rapidly describe and stratify stream habitat to determine salmonid distribution and abundance during stream surveys.

Keywords: Stream surveys, salmonid habit, habitat classification, salmonid density, salmonid distribution, southeast Alaska.

Introduction

An accurate quantitative assessment of existing habitat and its use by fish is one of the most important parts of an enhancement project (Everest and others 1991, Hankin and Reeves 1988). A critical part of this process is an efficient and reliable stream survey. Although a variety of survey methods have been developed, we have found that nearly all entail varying degrees of subjectivity and judgment by the observer. Even among the best of these, such as the system developed by Bisson and others (1981), identification of a habitat type is based on a comparison to a model (that is, "this habitat unit looks about like the one in the picture"). Furthermore, most habitat classification methods use only one level. The habitat classification system that we used was adapted from Sullivan (1986) and separates habitat into discrete units with measurable criteria and separates habitat units into subsets ranging from macrounits to microunits. We also superimposed a cover component on the habitat units as a separate description of the habitat.

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We used the method for a pre-enhancement survey of Ward Creek near Ketchikan, Alaska (fig. 1). The objectives of the survey were:

1. To determine the type and area (square meters) of habitat in the surveyed section.
2. To estimate the density of juvenile salmonids by species in each habitat type.
3. To estimate the total number of juvenile salmonids in the section surveyed.
4. To compare densities of salmonids by each species and age group among habitat types.

The results from each of these objectives provided the basis for recommendations for habitat enhancement for the surveyed reach.

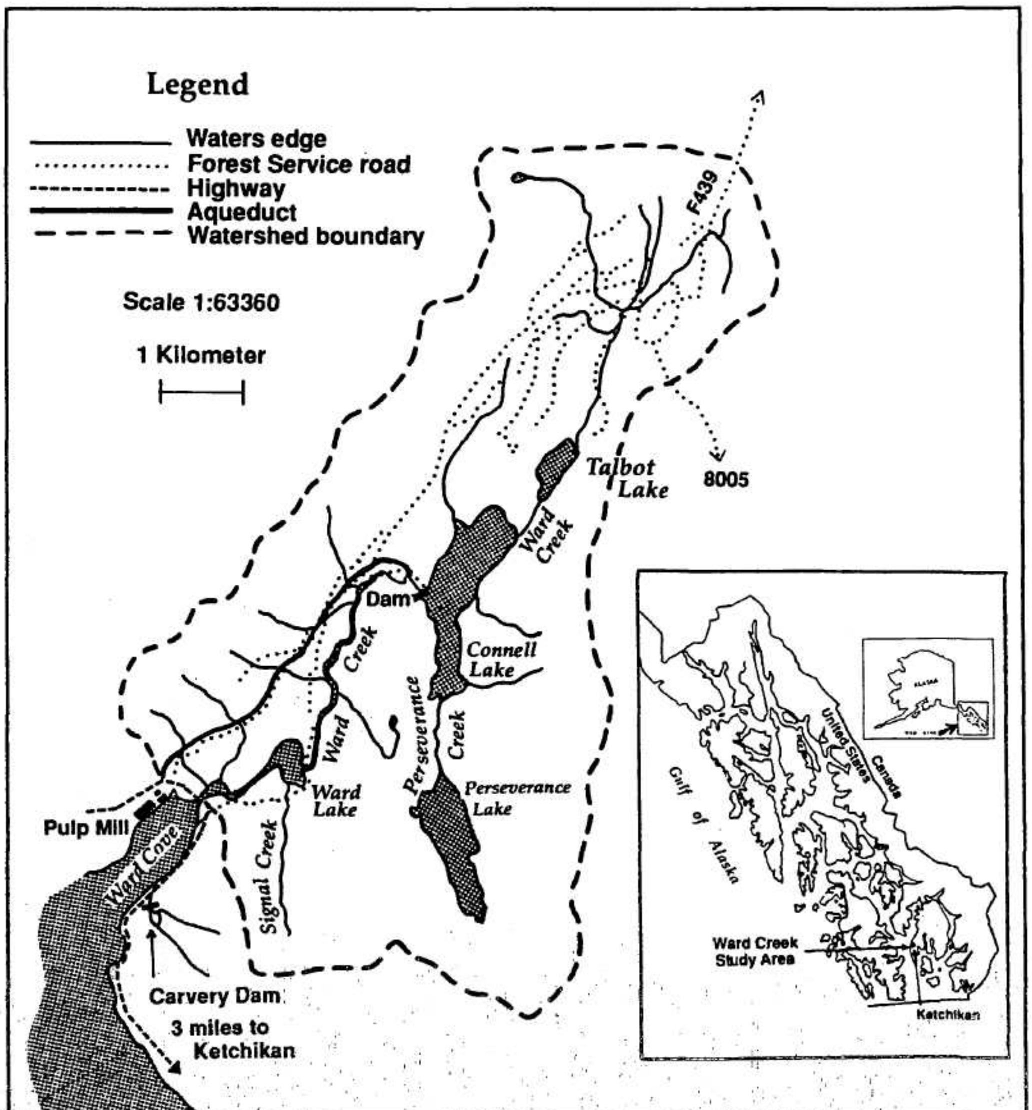

Figure 1 —Ward Creek drainage and survey area.

Table 1—Stocking record of coho salmon and steelhead trout for Ward Creek 1980-89

Year	Species	Stock source	Age	Number released
1980	Steelhead	Ketchikan Creek	Smolt	1,723
1981	Coho salmon	Ketchikan Creek	Presmolt	52,536
1981	Steelhead	Ketchikan Creek	Smolt	2,816
1982	Coho salmon	Ketchikan Creek	Presmolt	99,578
1982	Steelhead	Ketchikan Creek	Smolt	1,479
1983	Coho salmon	Ketchikan Creek	Presmolt	80,993
1983	Steelhead	Ketchikan Creek	Smolt	12,036
1984	Coho salmon	Ketchikan Creek	Fry	38,444
1985	Steelhead	Klawock Hatchery	Smolt	27,500
1986	Steelhead	Klawock Hatchery	Smolt	28,600
1987	Coho salmon	Reflection Lake	Presmolt	21,200
1987	Steelhead	Klawock Hatchery	Smolt	28,700
1988	Coho salmon	Reflection Lake	Presmolt	55,700
1988	Steelhead	Klawock Hatchery	Smolt	19,600
1989	Steelhead	Klawock Hatchery	Smolt	36,700

The Study Area

Ward Creek drains about 4,000 hectares with flows regulated by a dam that forms Connell Lake (fig. 1). Mean annual precipitation is 381 centimeters with the highest rainfall occurring during October and decreasing monthly to June.' Precipitation during the winter typically occurs as snow in higher elevations; low flows also occur in winter—January through April. As snow melts in spring and early summer, flows increase. The dam on Connell Lake moderates peak flows; high-flow peaks tend to be short and intense. The lake is the water source for the Ketchikan pulp mill, and summer low flows may be exacerbated by low rainfall and increased water demand by the mill.

Below Connell Lake, the stream flows about 4 kilometers to Ward Lake. From Ward Lake, it flows another 2 kilometers to where it empties into the ocean at Ward Cove. The outlet is about 1 kilometer south of the Ketchikan pulp mill and is 92 kilometers north of Dixon Entrance. The survey section extends about 3.8 kilometers from the dam at Connell Lake to Ward Lake and is classified as a C-type channel (Marion and others 1987). The upper part of the section is classified as a C-1 channel—low gradient (0.5-1.5 percent) and moderately incised; this channel flows into a C-2 channel—moderate gradient (1.0-3.0 percent) and moderately incised; the channel then returns to a C-1 channel type. The section entering the lake is classified as a C-3 channel—low gradient, very shallow banks, and a well-developed flood plain.

Because the watershed is subject to heavy use for recreation and sport fishing for adult coho salmon (*Oncorhynchus kisutch* (Walbaum)) and steelhead trout *(O. mykiss),* it has been stocked by the Alaska Department of Fish and Game. In the past several years, both coho salmon and steelhead have been stocked in the watershed, primarily below Connell Lake, to improve the sport fishery on the stream. In 1988, over 55,000 coho salmon presmolts and 19,000 steelhead smolts were released into the stream. In spring 1989, 36,700 steelhead smolts were released in the stream. Smolts typically migrate from the stream by mid-June. A summary of hatchery releases from 1980 through 1989 is given in table 1.

[1]Bartos, L 1989. R10 water resources atlas. On file with: USDA Forest Service, Alaska Region, Ketchikan, Alaska 99901.

Methods

Survey methods for the stream were adapted from Hankin and Reeves (1988); habitat unit descriptions were similar to those of Sullivan (1986). Our survey of habitat was done in July 1989 and included 4 kilometers of stream from the base of the dam forming Connell Lake to Ward Lake (fig. 1).

Each habitat unit was assigned a number for identification on the data sheet (fig. 2). Reach numbers were assigned to linear channel sections and could include one or more habitat units; for example, several eddy pools could occur along a reach that was primarily a glide or riffle. A single habitat unit such as a large scour pool or riffle could extend over an entire reach. To avoid "microsampling," a minimum size for a habitat unit was established at 4 square meters, or less than one channel width for scour pools. Small units were integrated into the reach unit; for example, step-pool cascades are composed of a series of small pools and falls, and riffles often have small shallow pools associated with them.

Habitat units were separated into a hierarchical system based on stream hydrology. The system used macrounits (pools, fast water, and side channels), mesounits (subdivisions of the macrounits), and microunits, which further divided habitat units (table 2). Water velocity and direction were the primary criteria used to separate

STREAM HABITAT SURVEY

LOCATION Ward Creek DATE 7/11/89

REACH NO.	HABITAT NO.	HABITAT TYPE	COVER	RIPARIAN	LENGTH	WIDTH1	WIDTH2	COMMENTS
1	1	PL-pp	C	Ald	48.	34.8		Next to dam
2	2	GL	C	/	34.7	17.9		Ald = Alder
3	3	RF	C		35.5	14.5	13.2	
4	4	GL	C/LW		26.5	11.0		
5	5	RF	C		5.6	9.5	9.3	
5	6	PL-ed	C		3	3		(Right bank)
6	7	GL	C		17.1	8.9		
6	8	PL-ed	C		5.4	2.5		(left bank)
6	9	PL-ed	B/C		8	2.5		(Right bank)
7	10	RF	C		8.4	10.3	10	
8	11	GL	C		21.0	12.5		
8	12	PL-ed	C		2	2.5		(Right bank)
9	13	RF	C/P		14.7	12.2	6.9	P = CR
10	14	GL	C/P	AL/OG	26.8	8.9		OG = Old growth
10	15	PL-ed	C/P	" "	4.5	2.5		
11	16	RF	C	Ald	21.8	12.9	11	
12	17	GL	C/B	"	57.5	8.9	8.2	(Side channel
12	18	PL-bw	C/SL	Cedar	11	5		on left bank)
12	19	PL-ed	C		4	2		Right bank
13	20	GL	BR	Ald/OG	3	1		Side Channel
13	21	RF	BR	Cedar	1.5	.6		
13	22	PL-dm	BR		5.4	3.0		
13	23	CS	BR		.7	.6		
13	24	PL-dm	BR		4.0	4.7		

Abbreviations:
Pool=PL eddy=ed plunge=pp dam=dm
lat. scour=lsc mid-chan scour=msc
Cascade=CS steppool=sp slipface=sf
Glide=GL cobble=cb
Riffle=RF riffle=rf gravel=gr boulder=bd
Rapids=RP
Chutes=CH
Large Wood=LW Root wads=RW Slash=SL
Bedrock=BR Boulder=BD Cobble=CB
Gravel=GR Sand=SD

Figure 2—Sample of data sheet used to survey Ward Creek.

habitat units. Instream cover was described within each habitat unit with a similar hierarchical system that separated cover into two levels: macrounits consisting of wood, rock, or fabricated structures; and mesounits that subdivided the macrounits (table 3).

Table 2—Habitat units and descriptions used In the habitat survey of Ward Creek

Macrounits	Mesounits	Microunits
Pools (PL). Water is slower and deeper than reach average; gradient less than 1 percent.	**Backwater pool (Bw).** Associated with an obstruction; water flow diverges from the axis of the channel.	**Dammed pool (dm).** Upstream of an obstructon; partially or completely blocks flow.
		Eddy pool (ed). Downstream of a partially blocking obstruction; usually along a bank.
	Drawdown pool (Dd). Associated with thalweg; flow rapid at entrance, slow in middle, and accelerates at the exit.	**Plunge pool (pp).** Downstream of a completely blocking obstruction.
		Lateral scour pool (lsc). Deepest part of pool along channel bank; may be associated with channel constriction.
		Midchannel scour pool (mcs). Deepest part of pool midchannel; may be associated with channel constriction on both banks.
Fast water (FW). Water is faster and shallower than reach average; gradient greater than 1 percent.	**Riffles (Rf).** Streambed disturbs surface; less than 10 percent of streambed breaks surface.	**Riffles (r).** Gradient from 2 to 4 percent; flow consistent over reach.
		Low-gradient boulder riffle (lbr). Gradient from 1 to 3 percent; typically low velocity with larger substrate protruding surface; similar to glide but with large boulders protruding the surface.
	Glide/Run (GR). Flow slower and deeper than a riffle but greater than a pool; water surface generally smooth.	**Glide (GL).** Water depth less than channel width.
		Run (RN). Water depth equal to or greater than channel width.
	Cascades (CS). Shallow, high-velocity flow; gradient usually greater than 4 percent.	**Slip-face cascade (sf).** Flow converges over unit; relatively uniform flow.
		Step-pool cascade (sp). Series of small falls and pools; pool lengths are less than one channel width.
	Rapids/Falls (FLS). High-velocity, high-turbulence; gradient greater than 5 percent.	
Side Channel (SC). Subchannel of the main channel; water either flowing or standing; may be disconnected at low flows; source of water is the main channel. May be subdivided into mesounits or microunits.		

Source: Adapted from Sullivan 1986.

Table 3—Cover components used in the survey of Ward Creek

Macrounit	Mesounit	Description
Geologic	Bedrock (BR)	Single piece, either solid or fractured.
	Boulder (B)	Large rock greater than 256 millimeters in diameter.
	Cobble (C)	Medium rock between 64-256 millimeters in diameter.
	Gravel/pebble (GR)	Small rock 2-64 millimeters in diameter.
	Sand (S)	Fine rock less than 2 millimeters in diameter.
	Fines (F)	Silt, clay (mud).
Wood debris	Rootwads (RW)	Base of tree and root structure.
	Log(s) (LW)	Tree boles or pieces greater than 30 centimeters in diameter and 2 meters long.
	Slash (SL)	Branches or pieces less than 30 centimeters in diameter; greater than 10 millimeters in diameter.
	Fines (FW)	Pieces less than 10 millimeters in diameter; fine organic particulate matter.
	Debris jams (DJ)	Large accumulations of organic material; 10 or more logs.
Fabricated structures	Gabions	Rock-filled wire baskets.
	Log structures	Dams, deflectors used to control flow direction or retain gravel.
	Road crossings	Bridges, culverts.
	Wood debris	Artificially placed trees.

Habitat units were identified, and measured with a tape or sonic distance-measuring device. Area (square meters) was computed from length and width measurements. For most units, one width measurement was taken; for irregular or triangular-shaped units, top and bottom widths were taken to compute an average width. All units were measured.

The cover component was the most subjective description of the channel. Our analysis used the primary feature in the habitat unit to describe cover; however, a secondary feature and occasionally a tertiary feature also were identified. The primary cover component was based on the amount of area it occupied in the habitat unit and its relative importance as cover within the unit; for example, in a habitat unit with a submerged rootwad along the bank of a pool with a gravel substrate, the rootwad would be the primary cover component of that unit.

Fish were counted in every 5th pool unit and every 10th fast water unit during snorkel surveys. The first unit was selected at random, and fish were counted in habitat units selected at regular intervals thereafter. In most cases, a single count was taken for each habitat unit by one diver. When two counts were made by two divers over the complete unit, the counts were averaged to obtain an estimate of the number of fish in the unit. Larger habitat units were divided into smaller sections, and divers made separate counts in each section. The counts were summed to provide a total count for the unit. Although a 100-percent count of all fish was assumed, it is likely that some fish were missed; therefore, the counts represent a minimum population estimate. No correction factor was applied to the counts. Density estimates were based on water surface area. We did not estimate water volume; therefore, no estimate of the number of fish per cubic meter was made.

A one-way analysis of variance (ANOVA) using the general linear models procedure in SAS (1988) was used to compare salmonid densities (number of fish per square meter) among habitat units. A total of 86 observations—estimates of fish density in a habitat unit were made. A separate ANOVA was run for each species and age group. The first set of comparisons was made among fish densities in four habitat units: glides (GL), pools (PL), riffles (RF), and side channels (SC). The second comparison was run on seven units—glides, pools, backwater pools (PL-bw), eddy pools (PL-ed), midchannel scour pools (PL-msc), fast water, and side channels. Statistical significance was set at alpha = 0.05. Differences among mean densities of salmonids by species for habitat units were compared with Tukey's HSD test (Sokal and Rohlf 1969). All analyses were done by using the SAS statistical package (SAS 1988).

Results

Habitat Distribution

Where identification of a habitat unit was in question, it was placed into the next higher, more general, classification. Within the fast water habitat, nine cascades were placed into the mesounit, cascade (CS) (fig. 3). Although 16 pools (PL) were placed into the macrounit level, these were probably drawdown pools at the mesounit level and, based on their similarity to scour pools with respect to average size, appeared to be gradations between plunge pools (PL-pp) and scour pools (PL-lsc, PL-mcs), (fig. 4). Backwater pools (PL-bw) tended to be smaller in average size than scour pools but occurred in greater numbers.

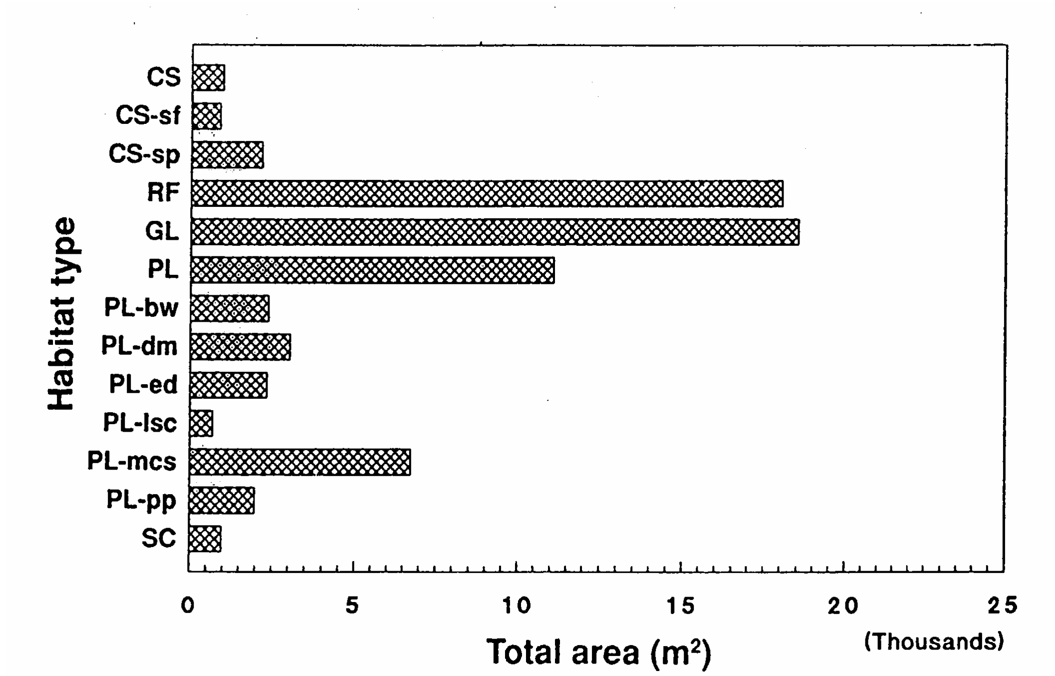

Figure 3—Total area of habitat units in Ward Creek survey area. CS=cascades; CS-sf=slipface cascades; CS-sp=step-pool cascades; RF=riffles; PL=unclassified pools; PL-bw=backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-mcs=midchannel scour pools; PL-pp=plunge pools; and SC=side channels.

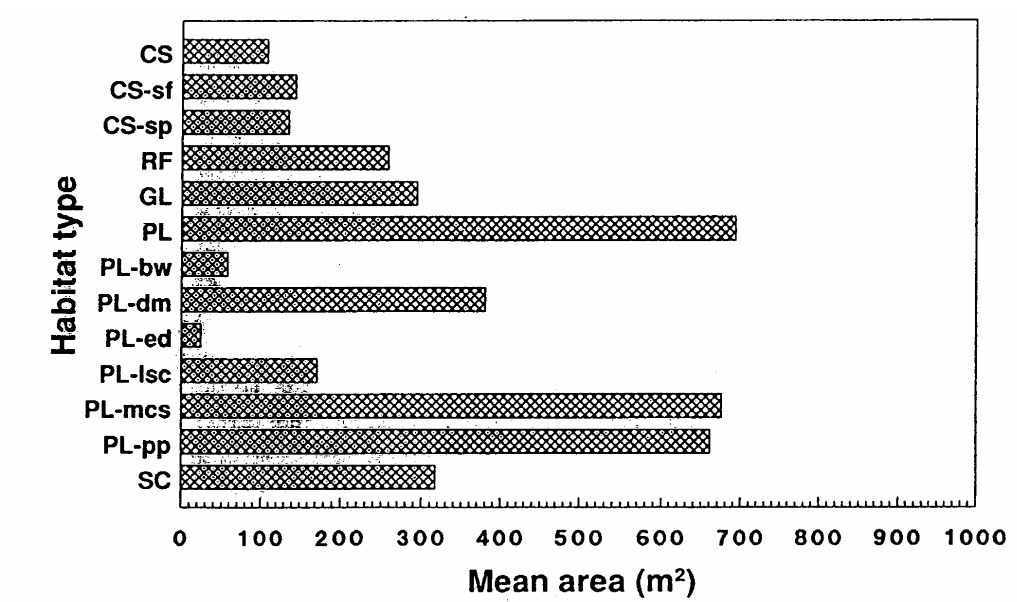

Figure 4—Mean area of habitat units in Ward Creek survey area. CS=cascades; CS-sf=slipface cascades; CS-sp=step-pool cascades; RF=riffles; PL=unclassified pools; PL-bw= backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-mcs=midchannel scour pools; PL-pp=plunge pools; and SC=side channels.

Side channel habitat units were similar to those in the main stream. Scour pools were larger than backwater pools (fig. 5). Although the total area of all habitat units in the side channels was less than that in the main stream, pools comprised a greater proportion of the total area (fig. 6). Side channel habitat was about 1 percent of the stream area that was surveyed. As expected, the mean sizes of all habitat units in the side channel habitat were smaller than those in the main channel. This reflected the smaller size of the side channel.

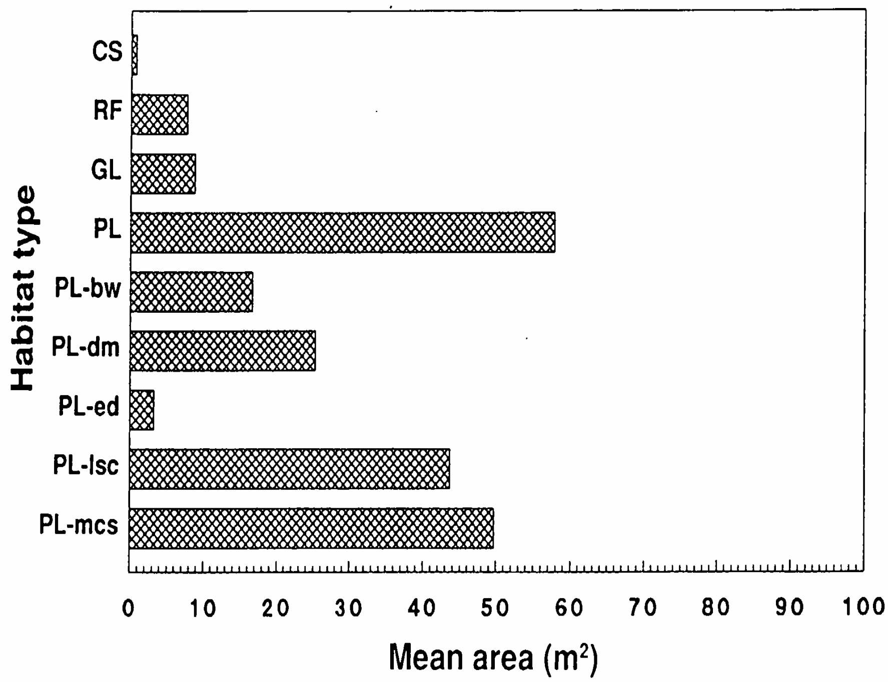

Figure 5—Mean area of habitat units in side channel habitat in Ward Creek survey area. CS=cascades; CS-sf=slipface cascades; CS-sp=step-pool cascades; RF=riffles; PL=unclassified pools; PL-bw=backwater pools; PL-dm=dammed pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-mcs=midchannel scour pools; PL-pp=plunge pools; and SC=side channels.

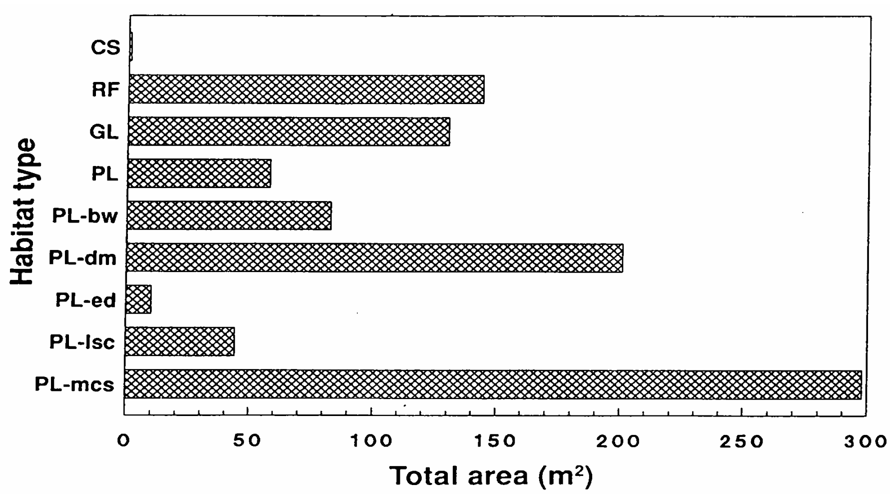

Figure 6—Total area of habitat units in side channel habitat in Ward Creek survey area. CS=cascades; RF=riffles; GL=glides; PL=unclassified pools; PL-bw=backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; and PL-mcs= midchannel scour pools.

In the main channel, glides accounted for more area than did any other single habitat type with 27 percent (18,546 square meters), followed by riffles with 26 percent (18,055 square meters) (fig. 3). Eddy pools comprised less than 4 percent of the area (2,347 square meters), but they were the most abundant habitat unit throughout the survey reach. A total of 97 eddy pools were identified throughout the study area. A total of 71 riffles were counted. Six pool microhabitat units, not including side-channel pools (SC-pl) or unclassified pools (PL), were identified (fig. 3). The total pool habitat, including unclassified pools, comprised 40 percent of the area (28,286 square meters). Cascade habitat comprised 5 percent (4,085 square meters).

Drawdown pools (PL-mcs and PL-pp) were larger than other habitat units (fig. 4). These pools generally are formed by scour. Without large wood present to fragment the stream and retain gravel, scour pools tended to be larger than other pool units. Backwater pools (pools formed by obstructions) were smaller and usually associated with rock outcrops along the bank. Backwater pools also were associated with small tributary confluences and secondary channels. Eddy pools tended to be the smallest habitat units and frequently were associated with boulders or bedrock outcrops along the bank. In other streams, these are typically associated with large wood or rootwads.

Fast-water habitat units (cascades and riffles) were small to intermediate in mean size (fig. 4). The mean size of riffle units was relatively small. The size of the riffles was influenced by channel gradient and the frequency of obstructions, primarily bedrock intrusions. Few riffles were observed that were caused by embedded logs across the channel. Cascades typically were associated with bedrock or boulders. Step-pool cascade (CS-sp) habitat generally was composed of a composite of small—less than 1 channel width—falls, plunge pools, and eddy pools.

Large wood (LW) was a minor part of the cover component throughout the survey section of Ward Creek and was influential in less than 2 percent of the total habitat area. Five habitat units had rootwads as the primary habitat component (fig. 7).

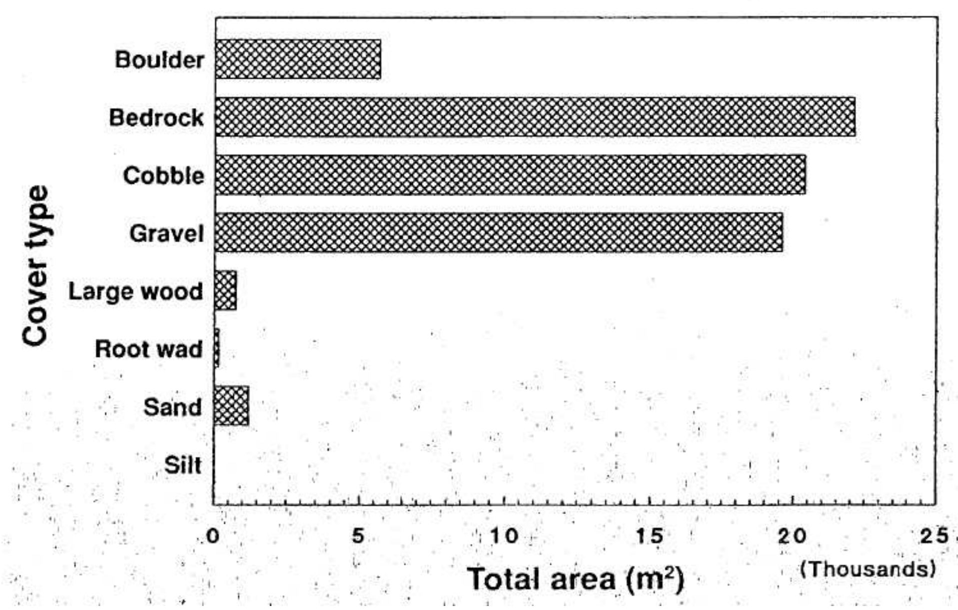

Figure 7—Stream area associated with cover types

Bedrock (BR) was the predominant cover characteristic in more than 22,000 square meters of the stream area, or about 32 percent of the total area (fig. 7). Cobble (C) and gravel (GR) combined was associated with about 40,000 square meters or 57 percent of the area in the stream.

The small amounts of woody debris in the survey section were not unexpected given the general channel morphology. Typically, C-1 and C-2 channel types have low amounts of woody debris (Bryant and others 1991). Most of the stream channel is constrained with moderate to steep banks that will channelize and intensify high-flow velocities and increase stream power. This will result in low retention of woody debris in the channel. In addition, streamside vegetation was comprised of smaller western hemlock *(Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce *(Picea sitchensis*(Bong.) Carr.) (<1 meter in diameter at breast height), which tend to be less stable when entering the stream.

Salmonid Distribution and Abundance

The total number of salmonids in the survey reach, extrapolated from mean densities of each species for a habitat unit and the total habitat unit area, was 45,965 fish (table 4). More than 69 percent were coho salmon, and of these, 48.2 percent were fry. Steelhead trout comprised 30 percent of the total. The estimates are considerably lower than the number of coho salmon and steelhead trout smolts that were stocked in spring 1988 and 1989. It is likely that most of the stocked smolts left the system before the survey in July 1989, and we suspect that a high percentage of both coho salmon and steelhead fry were produced by returning adult salmon. We did not attempt to differentiate between stocked and naturally spawned fish.

Table 4—Salmonid population estimates for Ward Creek, July 1989

Habitat	Coho salmon		Dolly Varden		Steelhead trout		Total
type [a]	Fry	Parr	Fry	Parr	Fry	Parr	fish
CS	0	0	0	0	0	245	245
GL	5,217	2,867	158	91	1,174	2,993	12,500
PL	3,486	3,153	0	23	62	275	6,999
PL-bw	2,365	228	0	0	24	27	2,644
PL-dm	1,100	323	0	88	0	396	1,907
PL-ed	3,987	954	35	4	265	310	5,555
PL-lsc	373	319	2	2	5	23	724
PL-mcs	4,050	874	0	46	2,830	1,433	9,233
RF	719	204	13	36	2,024	1,629	4,625
SC-gl	131	143	0	0	0	4	278
SC-pl	709	543	0	0	0	3	1,255
Total salmonids [b]	22,137	9,608	208	290	6,384	7,338	45,965
	(48.16)	(20.90)	(0.45)	(0.63)	(13.89)	(15.96)	(100)

[a] CS=cascades; GL=glides; PL=pools, PL-bw=backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-msc=midchannel scour pools; RF=riffle; SC-gl=side channel glides; and SC-pl=side channel pools.
[b] Percent of population is given in parentheses.

Significant differences were detected for coho salmon fry densities among seven habitat units including both measured microhabitat units (table 5). Mean densities of coho salmon fry were significantly higher in eddy pools than in riffles and glides ($P<0.05$; Tukey's HSD test). No significant differences were detected for other size classes or species among microhabitat units (table 5).

Table 5—Comparison of salmonld densities in microhabitat units with one-way analysis of variance[a]

Number/m^2	df (model, error)	F-value	P>F[b]
Coho salmon:			
Fry	6,79	3.87	0.002
Parr	6,79	2.22	.05
Dolly Varden:			
Fry	6,79	.20	.98
Parr	6,79	.58	.74
Steelhead:			
Fry	6,79	.56	.76
Parr	6,79	.23	.97

[a] Microhabitat units include RF=riffles, GL=glides, PL=pools, PL-bw=backwater pools, PL-ed= eddy pools, PL-mcs=midchannel scour pools and SC=sidechannels.
[b] Probability of F-value greater than random distribution, do not reject null hypothesis at P>0.05.

Comparison among mesohabitat units (PL, GL, RF, and SC) followed a similar trend with significant differences among habitat units for coho salmon fry and parr (table 6). Significant differences were not detected among mesohabitat units for Dolly Varden or steelhead. Tukey's HSD test of means showed significant differences ($P<0.05$) for coho salmon fry densities between pool and riffle habitat, and between side channels and riffles for coho salmon parr.

Number/m^2	df (model,error)	F-value	P>F[b]
Coho salmon:			
Fry	3,82	4.44	0.01
Parr	3,82	3.47	.02
Dolly Varden:			
Fry	3,82	.15	.93
Parr	3,82	.60	.62
Steelhead:			
Fry	3,82	.25	.86
Parr	3,82	.25	.86

Table 6—Comparison of salmonid densities in mesohabitat units with one-way analysis of variance[a]

[a] Pools, glides, riffles, and side channels.
[b] Probability, of F-value greater than random distribution', do not reject null hypothesis at P>0.05.

The lack of statistical significance among habitat types may be partly due to the high variability in densities of fish within habitat types caused by the absence of fish in several sampling units. Because of the limited number of samples, we were unable to test the effects of cover on the distribution of salmonid densities among the sampling units. Trends, nonetheless, appeared in the distributions in both the habitat types and the cover classifications that agree with general results observed elsewhere (Bisson and others 1981, Bryant and others 1991). The trends observed in Ward Creek are shown in figures 8-10 and discussed below.

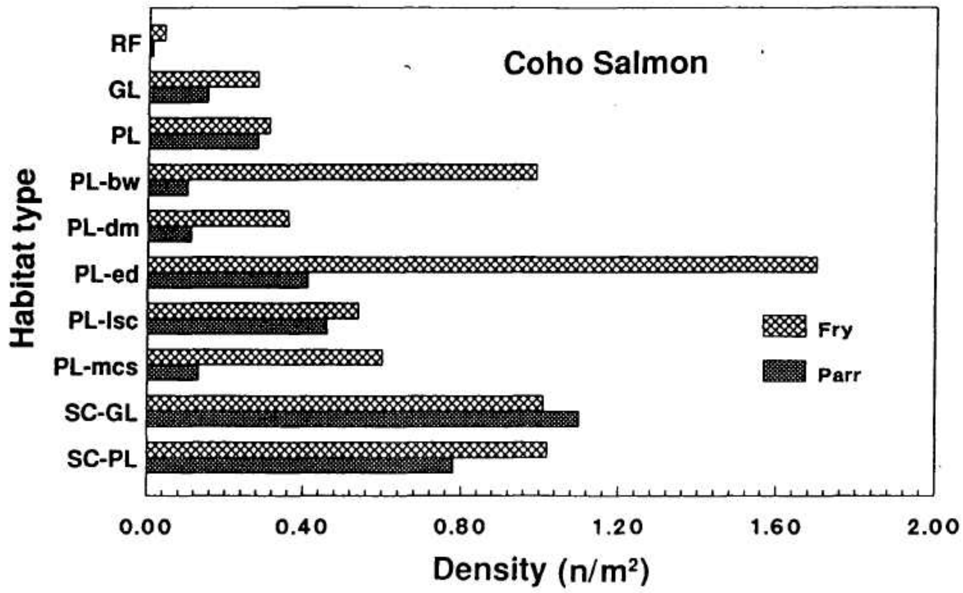

Figure 8—Mean density of coho salmon fry and parr in habitat types surveyed in Ward Creek, July 1989. RF=riffles; GL=glides, PL=unclassified pools; PL-bw=backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-mcs=midchannel scour pools; SC-GL=glides in side channels; SC-PL=pools in side channels.

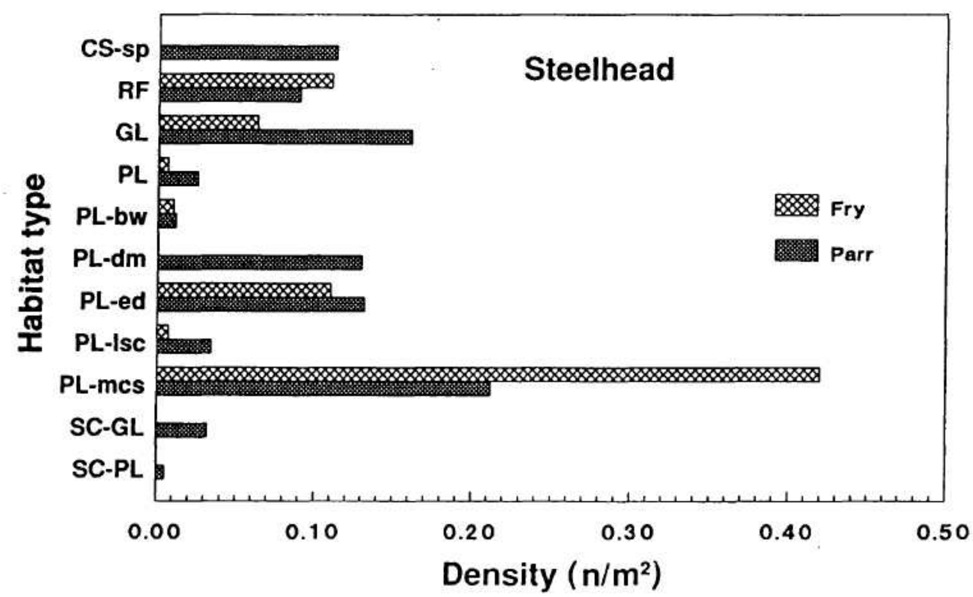

Figure 9—Mean density of steelhead fry and parr in habitat types surveyed in Ward Creek, July 1989. CS-sp=step-pool cascades; RF=riffles; GL=glides, PL=unclassified pools; PL-bw= backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-mcs= midchannel scour pools; SC-GL=glides in side channels; SC-PL=pools in side channels.

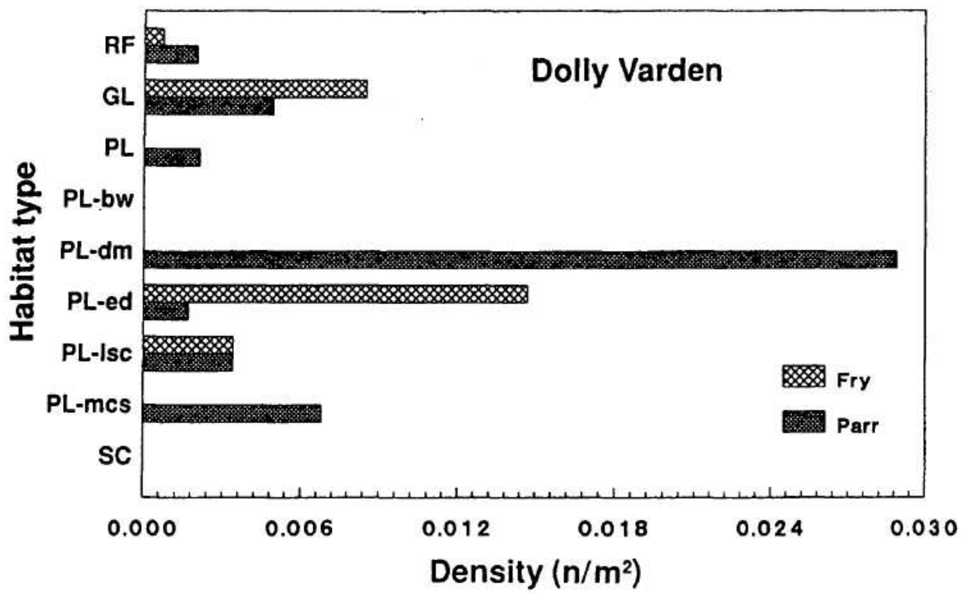

Figure 10—Mean density of Dolly Varden fry and parr in habitat types surveyed in Ward Creek, July 1989. RF=riffles; GL=glides, PL=unclassified pools; PL bw=backwater pools; PL-dm=dam pools; PL-ed=eddy pools; PL-lsc=lateral scour pools; PL-mcs=midchannel scour pools; SC=side channel habitat.

Generally the highest densities of all salmonids were found in pools, but side channels were important for coho salmon parr (fig. 8). Coho salmon fry and parr were found in the widest range of habitat units throughout the stream (fig. 8). Steelhead fry and parr were more common in riffles, glides, and scour pools than in other habitat types (fig. 9). Higher densities of steelhead fry and parr were observed in riffles than any other species. Dolly Varden *{Salvelinus malma* (Walbaum)) fry were found in the fewest habitat types (fig. 10). Fast-water habitat generally supported the lowest densities of all salmonids. Side-channel habitat supported higher densities of coho salmon parr than did mainstream habitat. Dolly Varden fry and parr were not observed in side-channel habitat (fig. 10).

Low densities of both steelhead and Dolly Varden were observed throughout most habitat units in the survey section (figs. 9 and 10). The low densities of Dolly Varden and steelhead fry may be partly due to their small size, which made them difficult to detect during the snorkel surveys. Although many fry may not have been counted, the parr were easy to detect and also were low in abundance. The highest densities of Dolly Varden parr were observed in dammed pools, with a mean density of 0.029 fish per square meter (fig. 10). The high density of steelhead fry in midchannel scour pools may be attributed to a large school counted in a single pool about 500 meters upstream from Ward Lake. In general, steelhead appear in higher densities in fast-water habitat than do the other two species. In all cases, the variability of densities in each habitat unit was high because no fish were observed in several units.

The data were insufficient to statistically compare differences among cover types and fish densities, but higher mean densities offish usually were observed associated with woody debris, either stash or large wood, with the exception: of coho salmon fry and Dolly Varden parr (figs. 11-13). Highest densities of coho salmon fry were observed in bedrock habitat (fig; it), and highest densities of Dolly Varden parr were observed in gravel dominated habitat. Large wood accumulations were not common in Ward Creek, and only one habitat unit with slash was sampled;

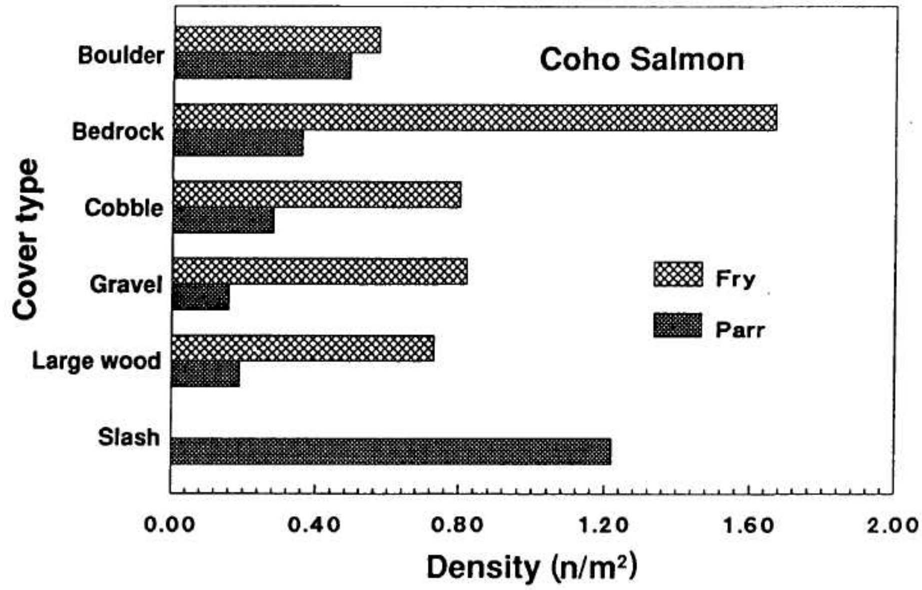

Figure 11—Mean density of coho salmon fry and parr by cover type observed in habitat units in Ward Creek, July 1989.

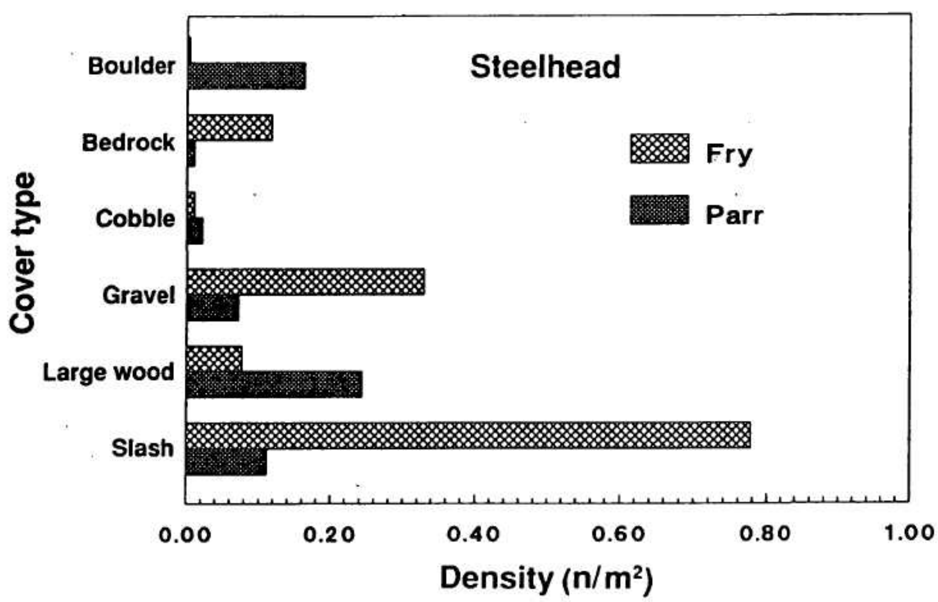

Figure 12—Mean density of steelhead fry and parr by cover type observed in habitat units in Ward Creek, July 1989.

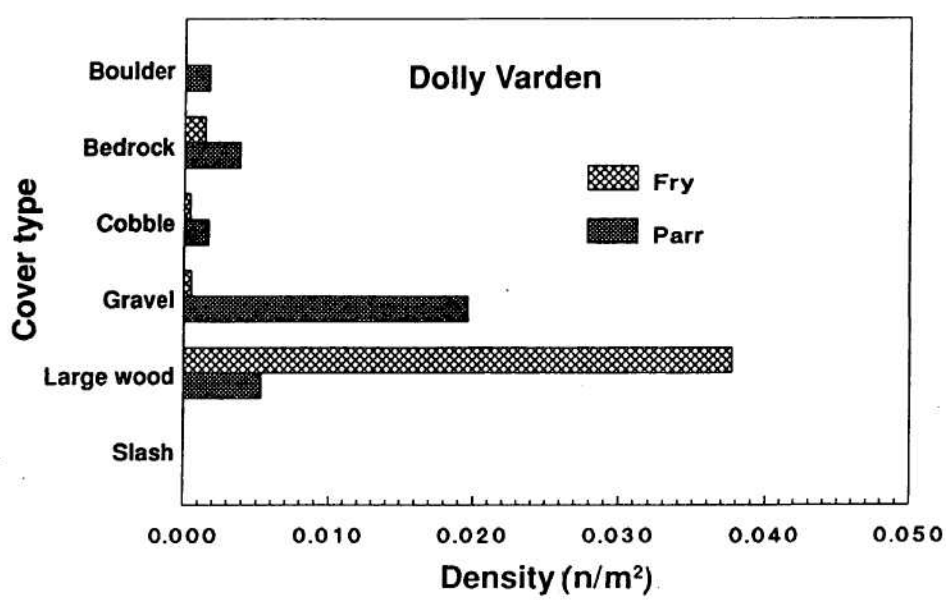

Figure 13. Mean density of Dolly Varden fry and parr by cover type observed in habitat units in Ward Creek, July 1989.

Discussion

Densities of coho salmon fry in Ward Creek ranged from 0.04 to 1.70 fry per square meter, which was slightly lower than densities observed in similar systems; however, parr densities ranged from 0.01 to 1.1 parr per square meter, which were close to the range of densities observed for other C-1 and C-2 channels (Bryant and others 1991). Densities of coho salmon fry and parr in C-1 and C-2 channel types ranged from 0.106 to 3.12 fry per square meter and from 0 to 0.687 parr per square meter in a set of streams surveyed during midsummer 1986 in southeast Alaska (Bryant and others 1991). Densities of coho salmon in pool habitat in Maybeso Creek, a logged watershed on Prince of Wales Island, ranged from 0 to 1.057 fry per square meter and from 0.119 to 4.4 parr per square meter. In Maybeso Creek, the highest densities of parr were found in backwater pools (4.4 per square meter) and eddy pools (1.06 per square meter). Scour pools supported the lowest densities.[2] The low densities of coho salmon observed in Ward Creek may be attributable to low volumes of woody debris in the stream, but highest densities of coho salmon parr in both streams were found in the small eddy pools or off-channel backwater pools (that is, side channels) in both Ward Creek and Maybeso Creek. This suggested that the hydraulic characteristics of these habitat types are preferable to other types (scour pools and riffles) for coho salmon.

Tables 2 and 3 are adapted from a dichotomous key developed for field use. Habitat units described in table 2 were relatively easy to identify, and most of the criteria have been measured in detail by Sullivan (1986). We modified and simplified the criteria for field use after several trials in the field. For the most part, all the habitat units including the microunits were easy to identify and measure. Although pools and cascades were often relatively easy to distinguish, riffles and glides tended to be less distinct. In the survey of Ward Creek, glides were distinguished by an even, relatively uniform stream bottom, uniform width, and unbroken surface. Low-gradient boulder riffle units were not identified, and if they occurred they were grouped either as a riffle—if the water depth was shallow, with more than 15-20 percent of the substrate breaking the water surface—or a glide. The predominance of glides in Ward Creek may reflect the lack of woody debris in the stream.

Glides comprised a disproportionate amount of the area in Ward Creek in comparison to other streams in southeast Alaska (see footnote 2) and in the Pacific Northwest (Bisson and others 1981). Glides comprised 27 percent of the habitat in Ward Creek, whereas Bisson and others (1981) observed glides in less than 10 percent of the area of the streams they surveyed in Oregon. Similar observations were found in surveys of Maybeso Creek in 1988 (see footnote 2) and in two streams surveyed in the White Mountains of New Hampshire (Bryant 1988). Although pools comprised more than 50 percent of the habitat in streams surveyed by Bisson and others (1981), large wood was a major component of the habitat.

The survey of cover components of Ward Creek showed that woody debris has little influence on the stream channel. In comparison to other systems in the area, Ward Creek has low densities of debris-controlled habitat and apparently has low potential for its development. Similar densities of large woody debris were observed in Indian Creek, an undisturbed (in the surveyed section) watershed on Prince of Wales Island, but densities of woody debris in both Indian and Ward creeks were lower than in Maybeso Creek (Bryant 1985). The surveyed section on Indian Creek, like Ward

[2] Bryant, M.D. Unpublished data. On file with: USDA Forest Service, Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, Alaska 99802.

Creek, has an incised, constrained channel. The absence of large wood in the stream appears to be related to the potential stream power (a function of channel morphology and water flows) and the type of streamside vegetation. Both factors indicate that limited opportunities are available for using woody debris to improve salmonid habitat in Ward Creek.

Side channels, although a smaller proportion of the stream, supported proportionately more coho salmon juveniles. Because this has been a common observation in other surveys, side-channel habitat was separated at the macrounit scale, and microunits were identified within the side-channel reach. The highest densities of coho salmon parr were observed in the side-channel habitat of Ward Creek. This habitat in streams such as Ward Creek is similar to that in small tributary streams that are usually associated with coho salmon rearing habitat.

One of the more important uses of a stream habitat classification system is to stratify stream area by fish densities. In the Ward Creek survey, we were able to detect differences among habitat units at two levels, the microunit and mesounit levels, in spite of a relatively wide variation among density estimates of all species of fish. By using the area and frequency of each habitat unit, we were able to rapidly estimate the number of fish by species in the survey section.

The survey of about 4 kilometers of stream was completed in less than 4 days with a crew of four people. It provided a description and enumeration of the available habi-tat in the stream as well as an estimate of the salmonid population in the surveyed section. For the most part, all units were identified to the microunit scale. Those that could not be identified at the microhabitat unit were identified at the next higher level. Furthermore, the system provided a method to stratify salmonid populations to obtain a total population estimate of the survey section. Additional work remains to refine some of the microunit classification criteria.

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