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Evaluation of a Stream Channel-Type System for Southeast Alaska

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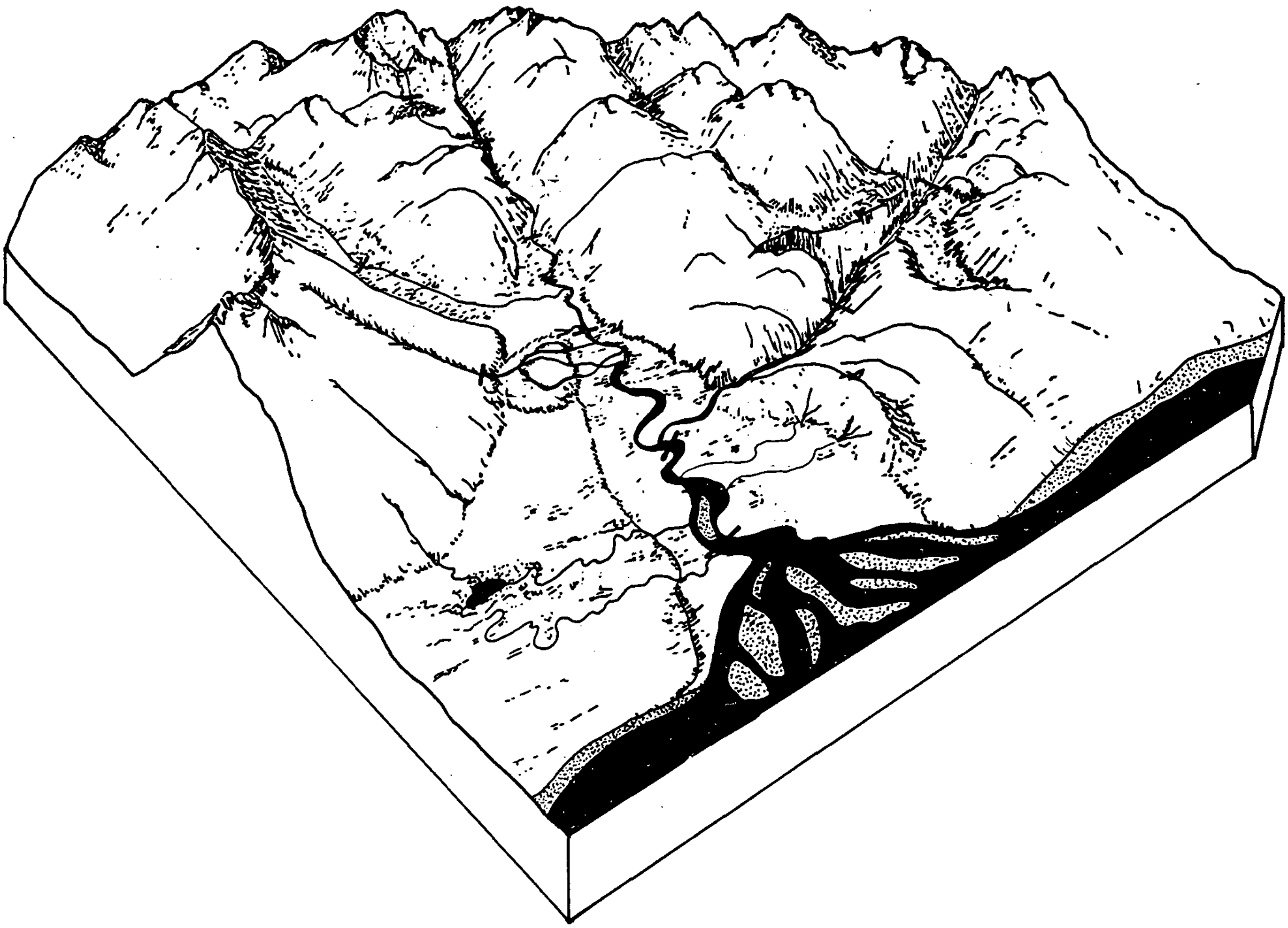

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Abstract

Bryant, M.D.; Porter, P.E.; Paustian, S.J. 1990. Evaluation of a stream channel-type system for southeast Alaska. Gen. Tech. Rep. PNW-GTR-267. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 p.

Nine channel types within a hierarchical channel-type classification system (CTCS) were surveyed to determine relations between salmonid densities and species distribution, and channel type. Two other habitat classification systems and the amount of large woody debris also were compared to species distribution and salmonid densities, and to stream channel types. Although trends appeared in salmonid densities and channel types, population estimates were too variable to show a relation between density and channel types. Depth-velocity criteria that separated habitat into shallow-slow, deep-slow, shallow-fast, and deep-fast were poorly related to fish populations and channel types. Within the Bisson classification system, coho salmon (*Oncorhynchus kisutch* (Walbaum)) parr were positively correlated to off-channel habitat types. Large wood was more abundant in depositional channel types, and coho salmon densities were positively related to debris accumulations of 10 or more pieces and to rootwads. Although salmonid densities were not statistically related to channel types within the CTCS, the system seems to be a useful tool to classify stream habitat and to identify its use by salmonids.

Keywords: Stream surveys, stream habitats, salmonid habitat, stream management.

Introduction

Paustian and others (1983) classified stream reaches by landform and stream channel morphological features that can be identified on large-scale (1:15,840), color aerial photographs. The channel-type classification system (CTCS) was developed as a management tool to determine the potential sensitivity of stream systems to management activities, such as logging and road building. In addition, it can provide a means to determine fish habitat capability based on physical features, such as size, gradient, and channel depth, that influence large woody debris distribution and stability, off-channel habitat development, and pool and spawning habitat distribution. No empirical data were available to relate fish numbers to channel types or the other indices. Murphy and others (1987) used an index of relative abundance of salmonids to compare channel types to fish populations and found differences among catch per unit of effort and channel types; however, differences varied among regions throughout southeast Alaska. They did not estimate salmonid densities.

The purpose of our study was to assess salmonid density and species distribution by stream channel types and included streams throughout southeast Alaska. Our objectives were to:

1. Compare salmonid densities by species to selected channel types.
2. Compare species composition among channel types.
3. Relate microhabitat features, such as pools, riffles, and large woody debris, to salmonid densities within sample sites and to determine the relation of these features to channel types.

Stream classification systems have been developed for various purposes and have used numerous physical attributes. Platts (1974) reviewed systems proposed by Klugh (1923) and Pearse (1939) who used water velocity and stream substrate for classification, and Thompson and Hunt (1930) and Horton (1945) who used size of drainage and stream branching. Platts (1979) used a set of specific habitat features, based on geomorphic characteristics, to classify streams. In general, the geomorphic types described by Platts (1979) showed differences in relative fish abundance, but more detailed analysis of his results showed the relation between geomorphic types and fish abundance and species distribution to be highly variable. In addition, the geomorphic characteristics were developed for a specific landform, the Idaho Batholith. Parsons (1984) proposes a hierarchical system to describe fish habitat relations over a broad regional area. His hypothesis is that "lakes and streams draining lands that have been formed by similar processes will be similar in fishery production potential..." but it has not been verified. A classification system proposed by Rosgen (1985) keys on morphological features, but it does not directly include drainage area or stream size. The system was not designed for a specific region.

The channel types examined in this study were developed for a specific region—southeast Alaska—and for a relatively specific purpose. The details are discussed by Paustian and others (1983), but essentially they use geomorphic features identifiable on aerial photographs to classify stream channels into units that can be used to assess fish habitat quality and to identify sensitive habitat segments. As with most habitat classification systems, it does not include biological interactions; but for southeast Alaska, it has the advantage of being designed for a specific region and is applied to a region with relatively few fish species. In addition, it provides a way to describe a large number of streams more rapidly and efficiently than on-the-ground surveys can. For these reasons, this system has a greater potential as a useful management tool for resource planning than do many other classification systems.

Marion and Paustian (1983) discuss the application of CTCS in the aquatic portion of the integrated resource inventory (A-IRI) for the Tongass National Forest in southeast Alaska. The CTCS was linked to fish habitat with the aquatic value rating (AVR) proposed by Perkinson (1986).[1] The AVR system is based, however, on several qualitative indices, such as a habitat quality index and a riparian sensitivity index. Although the CTCS may provide a framework to develop predictive models for fish densities, it was not designed to provide quantitative and accurate estimates of fish densities.

Methods

Study Areas

Streams and channel types were selected from three areas in the Tongass National Forest: Chatham, Stikine, and Ketchikan representing, respectively, northern, central, and southern areas of southeast Alaska (fig. 1). Sample locations and channel types were selected from maps and aerial photographs and by field reconnaissance. Channel types were verified on the ground and rechecked on maps and aerial photographs. Individual streams were selected to provide a representative sample of channel types that would be found throughout southeast Alaska. Throughout the three areas, nine channel types were sampled at 42 sites in 34 streams (table 1).

The CTCS is described by Paustian and others (1983), but the system has been modified and the alpha-numeric system changed since 1983. The primary features used to identify the channel types used in this study were hydraulic and sediment regimes and geomorphic setting (table 2). Although the CTCS includes five primary channel types, only B and C channel types were used in this study. Not all B and C channels types were selected and in some instances channel types were not sampled in all areas. The channel types described in tables 3 and 4 were selected because we expected to find higher salmonid densities in them than in the others and these types are often located in areas of potential timber harvest. Anadromous salmonids are generally absent from A channels. Channel types D and E generally occur in areas not subject to intensive land management, such as logging. The D channel types are represented by glacially influenced or alpine systems. The E channel types are found in the lower coastal areas and are usually influenced by tidal regimes and include streams in coastal dunes, estuaries, or coastal glacially dominated systems.

[1] Perkinson, R.D. 1986. Hierarchical classification of the Tongass National Forest for management of aquatic ecosystems. Unpublished paper presented at the 13th annual meeting of the American Fisheries Society, Alaska Chapter, 1986 November 3-7. Anchorage, AK. On file with; Anadromous Fish Habitat Research Project, P.O. Box 020909, Juneau, AK 99802.

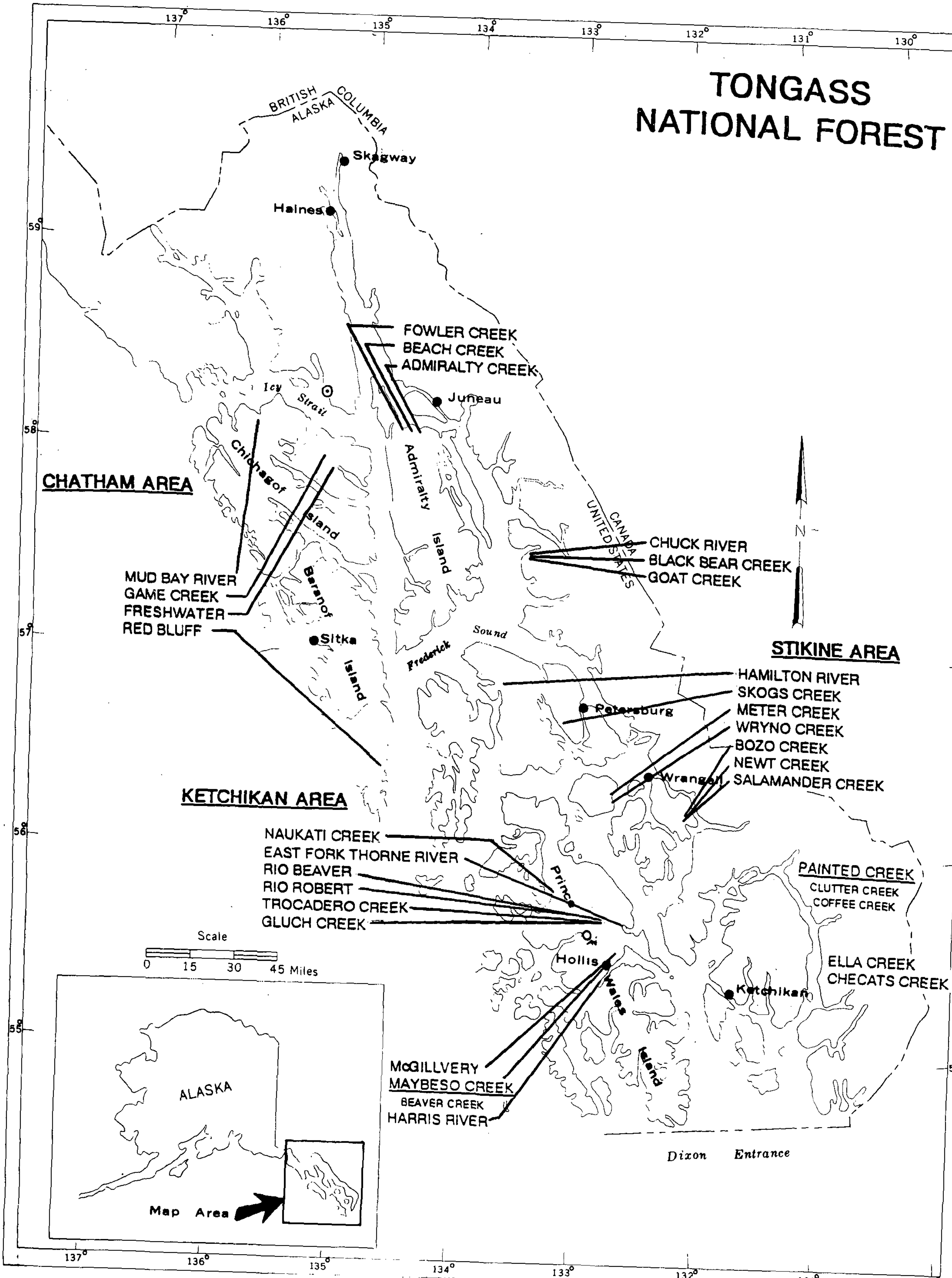

Figure 1—Study streams throughout southeast Alaska.

Table 1—Number of sample sites in B and C channel types in geographic locations in southeast Alaska

Channel type	Number of sample sites by area			Total sample sites
	Chatham	Stikine	Ketchikan	
B1	3	3	2	8
B2	0	0	1	1
B3	0	1	2	3
B6	2	2	1	5
C1	3	1	3	7
C2	1	2	3	6
C3	3	3	3	9
C5	1	0	1	2
C7	0	0	1	1
Total	13	12	17	42

Table 2—Description of major channel-type associations described by Paustian and others (1983)

Channel type	Hydraulic regime	Sediment regime	Geomorphic setting
A	Precipitation, headwater area	Sediment source area	Upper slopes, steep slopes
B	Precipitation transition zone	Sediment transfer	Slope-valley interface
C	Precipitation runoff	Sediment deposition	Valley bottom
D	Glacial runnoff	High sediment load	Glacial outwash, valleys
E	Tidal	Sediment deposition	Estuarine

Table 3—Description of B-type channels sampled for salmonid densities[a]

Channel type	Gradient	Channel incision	Watershed area	Vegetation	Substrate	Geomorphology
B1	Less than 2 percent	Less than 1 m	Less than 13 m^2	Spruce/blueberry/devils club; spruce/alder/ salmonberry	Sand; small gravel; rubble	Undissected footslopes; flood plains
B2	Less than 1 percent	Less than 1 m	Less than 13 m^2	Sedge/hemlock; sphagnum/sedge	Fine gravel; organic muck	Muskeg or meadow channel; placid flows
B3	Between 2 and 6 percent	Less than 5 m	Less than 13 m^2	Spruce/blueberry/devils club; hemlock/blueberry/ skunk cabbage	Coarse gravel; bedrock; large rubble	Moderate to shallow incised channels
B6	Between 2 and 6 percent	Between 5 and 15 m	Less than 13 m^2	Variable	Bedrock; small rubble; gravel	Moderately incised into lowlands

[a] Attributes of B-type channels:
Hydrology: precipitation dominated.
Geomorphology: transition between steep mountain slopes and valley bottoms.
Drainage area: less tha 13 km^2.
Gradient: less than 6 percent.

Table 4—Description of C-type channels sampled for salmonid densities[a]

Channel type	Gradient	Channel incision	Watershed area	Substrate	Geomorphology
C1	Less than 2 percent	Less than 5 m	Less than 50 m^2	Gravel; cobble	Moderate
C2	1 to 4 percent	5 to 15m	Less than 130 m^2	Bedrock; coarse gravel; rubble	Moderately incised into lowlands; usually single channel with large flood plains
C3	Less than 2 percent	Less than 5 m	Greater than 50 m^2	Gravel alluvium	Multiple channels in common flood plain
C5	1 to 4 percent	Greater than 15 m	Less than 130 m^2	Bedrock and boulders with pockets of gravel	Narrow valley or gorge channel with frequent rapids
C7	Less than 1 percent	Less than 5 m	Less than 130 m^2	Variable substrate incised in bedrock	Single deep channel with placid flow

[a] Attributes of C-type channels:
Hydrology: precipation-dominated runoff.
Geomorphology: lower valley bottom.
Drainage area: less than 130 km^2.
Channel gradient: less than 4 percent.

In most streams, two sample sites were selected for each channel type. The length of each site depended on the size of the stream and ranged from 100 to 200 m. A section about 200 m long was generally sampled for streams greater than 20 m wide. Natural breaks, such as riffles, gravel bars, or debris dams, were used as starting and ending points for each site. No criteria were used to select sites within a channel type. Fish populations at all sites were sampled from July 8 through July 28, 1986. Habitat measurements were made concurrently with fish sampling. Ten teams of at least two people each collected the field data.

Salmonid Populations

Coho salmon (*Oncorhynchus kitsutch* (Walbaum)), Dolly Varden char (*Salvelinus malma* Walbaum), and steelhead tourt (*O. mykiss* Richardson) were the target species for the study. Other species such as chinook salmon (*O. tshawytscha* (Walbaum)), threespine stickelbacks (*Gasterosteus aculeatus* (Linnaeus)) and sculpins (*Cottus* spp.) were considered incidental catch and were neither included in the population analysis nor grouped as other species.

Fish at all sites were captured with either 3.1-mm (1/8-in) or 6.2-mm (1/4-in) wire-mesh minnow traps. The 3.1-mm traps were used at most locations because the traps with 6.2-mm mesh did not effectively capture fry less than 50 mm long. Separate Peterson population estimates with the Bailey modification were made for each species by size group (Rickér 1975). Coho salmon were divided into groups: those larger than 55 mm total length and those less than 55 mm total length. The latter were considered to be young-of-the-year fry. Each site was sampled twice. During the first sample, all captured fish were marked by punching a hole in the caudal fin. The same location was trapped a second time, usually 2 or 3 days later, to recapture marked fish. During both samplings, total and fork lengths were measured. A subsample of individual fish from each stream was weighed.

Natural breaks in the stream, the relatively short period of time between the mark and recapture samples, and territorial behavior of the juvenile fish during the summer reduced the effect of immigration and emigration in the sample areas. During summer, coho salmon do not generally undertake extensive movements, and marked fish are thoroughly mixed with unmarked fish when the former are returned to the stream. Estimates were made separately for each species and for the two size groups of coho salmon to remove the effect of unequal vulnerability to the minnow traps. Length-frequency results are presented and include only locations where 3.1-mm traps were used.

Habitat Measurements

Two sets of microhabitat measurements were used. The first set was the easiest to use and separated stream habitat into four groups based on water depth and velocity: deep-slow, deep-fast, shallow-slow, and shallow-fast. Deep was defined as water depth greater than 0.5 m; slow was defined by a surface velocity of less than 30 cm/sec. The second set of habitat measurements was a set of habitat types developed by Bisson and others (1981) and slightly modified for our use. These provide a more detailed habitat description and include specific habitat features. Additional measurements of habitat included stream width and depth transects, thalweg length, stream channel gradient, and counts of large woody debris accumulations (material greater than 1 m in length and 30 cm in diameter). Large woody debris accumulations were separated into groups of 1 to 4, 5 to 10, and more than 10 pieces. Rootwads were counted separately.

Area measurements for all study sites and habitat areas within sites were computed with a planimeter from scale maps constructed on site (Platts and others 1987). Additional data on the map included location of debris accumulations, undercut banks, and other significant habitat features such as boulders and rootwads.

Analysis

A one-way analysis of variance (ANOVA) was used to compare salmonid densities among channel types. Separate comparisons were made by species—coho salmon, Dolly Varden, and steelhead trout. Coho salmon were further divided into size groups—fry and parr. Mean densities from channel types in 36 streams were compared. The model used nine channel types (8 df). Sample size and distribution of samples for channel types were inadequate to test for differences among the three geographic areas; therefore, we had to assume that area effects were small. This assumption was examined using a C3 channel type and a single classification ANOVA among the three areas. The C3 channel type was sampled in all three areas. This test examines differences only for the one channel type, but in the absence of a more complete data set, it provides an indication of possible geographic effects.

All three habitat classifications were examined separately with a stepwise linear regression model to test the relation between salmonid densities and habitat measurements. The dependent variable for the model for each classification method—depth-velocity, Bisson habitat, and channel type—was fish density (no./m^2). Independent variables were the area measurements in each habitat category for a sample site.

In the analysis of the depth-velocity method, for example, the model was:

$$Y_i = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 ,$$

where: Y_i = number of fish/m^2 of species i, i = 1,4 (1 = coho salmon fry, 2 = coho salmon parr, 3 = Dolly Varden, 4 = cutthroat trout);
X_1 = area of habitat classified as shallow-slow;
X_2 = area of habitat classified as shallow-fast;
X_3 = area of habitat classified as deep-slow; and
x_4 = area of habitat classified as deep-fast.

Similar analysis was done with the Bisson habitat classification method where X_i = area of habitat classified in habitat type i; for the channel type method, X_i = channel types i = B1, B2, B3, B6, C1, C3, C5, and C7.

A discriminant analysis was used to determine if the area measurements in either the depth-velocity or Bisson method would accurately predict channel types. Discriminant groups were channel types B1 to C7; independent variables were measurements of area (m^2) in each habitat category. Separate coefficients were computed for the depth-velocity method and for the Bisson habitat method. Independent variables were selected with a stepwise method by using a p-value to include of 0.05. A tolerance level of 0.001 was specified. The discriminant functions were used to predict group membership in a channel type on the basis of the habitat area measurements. The results from this analysis provide a basis for comparing the various methods of classifying habitat and to determine if the two methods of habitat classification relate to the CTCS.

Results

Salmonid Densities

Population estimates were highly variable within channel types for all species, and as a result, density estimates varied widely. The mean density of coho salmon fry in B3 channel types, for example, was 0.775 fish/m^2 (fig. 2a), but ranged from 0 to 3.11 fish/m^2 (table 5). Even with the differences shown in figure 2, a-d, ANOVA tests showed differences at $P \leq 0.05$ only for coho salmon parr at $P=0.03$. Tests of ANOVA among channel types for coho salmon fry, Dolly Varden, and steelhead trout were all at $P=0.19$ or greater. Given the variability in the population estimates and resulting variation in density estimates, observed differences among channel types included a large error term.

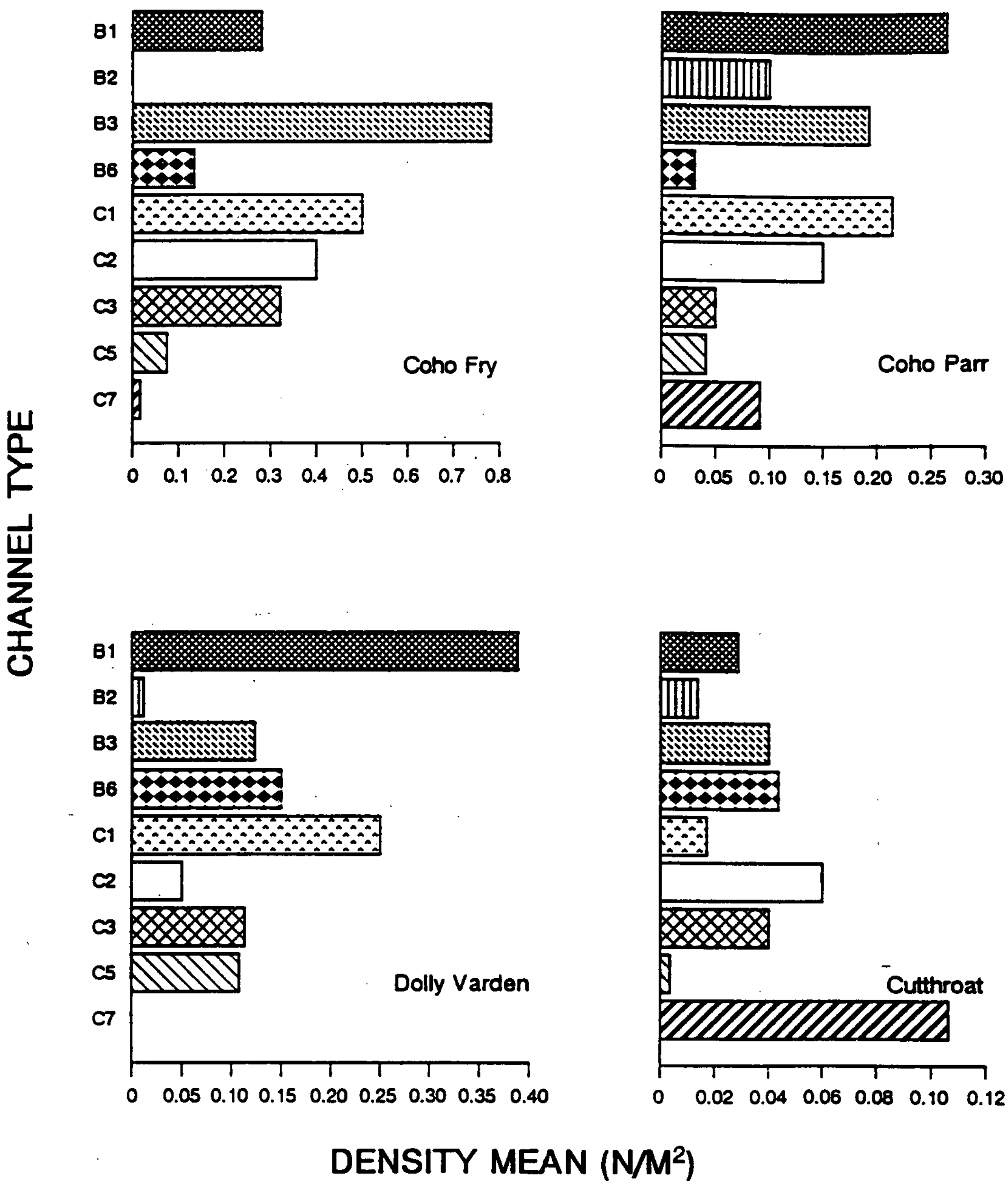

Figure 2—Mean densities of coho salmon fry and parr, Dolly Varden, and cutthroat trout in B and C channel types for all study streams combined.

Table 5—Summary of mean, minimum, and maximum densities of coho salmon fry and parr, Dolly Varden, and steelhead trout and standard deviation of mean by channel type for streams sampled

Channel type	Number of samples	Species	Number of fish/m² Mean	Minimum	Maximum	Standard deviation
B1	6	Coho salmon:				
		Fry	0.271	0	1.124	0.441
		Parr	.257	.039	.622	.241
		Dolly Varden	.382	0	.693	.298
		Steelhead	.033	0	.075	.037
B2	1	Coho salmon:				
		Fry	0	0	0	—
		Parr	.055	.055	.055	—
		Dolly Varden	.01	.01	.01	—
		Steelhead	.016	.016	.016	—
B3	3	Coho salmon:				
		Fry	.775	.089	1.354	.639
		Parr	.194	.045	.436	.211
		Dolly Varden	.134	0	.261	.131
		Steelhead	.042	.034	.048	.007
B6	5	Coho salmon:				
		Fry	.138	0	.61	.266
		Parr	.034	0	.058	.024
		Dolly Varden	.148	0	.53	.219
		Steelhead	.045	0	.097	.044
C1	7	Coho salmon:				
		Fry	.499	0	3.12	1.158
		Parr	.22	.142	.305	.065
		Dolly Varden	.255	.052	.687	.233
		Steelhead	.018	0	.128	.048
C2	6	Coho salmon:				
		Fry	.397	0	.724	.288
		Parr	.106	0	.22	.083
		Dolly Varden	.061	0	.185	.069
		Steelhead	.061	0	.325	.13
C3	8	Coho salmon:				
		Fry	.323	0	.805	.298
		Parr	.052	0	.135	.052
		Dolly Varden	.0126	0	.405	.158
		Steelhead	.041	0	.197	.077
C5	2	Coho salmon:				
		Fry	.072	.022	.122	.071
		Parr	.046	0	.092	.065
		Dolly Varden	.112	.002	.222	.156
		Steelhead	.002	0	.003	.002
C7	1	Coho salmon:				
		Fry	.028	.028	.028	—
		Parr	.095	.095	.095	—
		Dolly Varden	0	0	0	—
		Steelhead	.107	.107	.107	—

Coho salmon fry were found in the highest densities throughout most channel types, but they ranged from 0 to 1.35 fish/m^2. No detectable differences were observed in coho salmon fry between the larger C- and the smaller B-type channels—typically tributaries—(ANOVA P>0.75). Although the densities were not consistent, high fry densities in the C-type channels may be attributed to nomad fry (Chapman 1962) that moved out of the B-type channels.

Higher densities of Dolly Varden were found in the B1 channel type than in other channel types (fig. 2c), but densities were not significantly different (P>0.19) among channel types. Trout densities were higher in the C3 channel type, but densities were not significantly different (P>0.93). Trout were found in fewer streams and the range of densities observed was less than those found for either Dolly Varden or coho salmon in all channel types.

Species Distribution

Coho salmon were the most abundant species in all channel types (fig. 3), but a large proportion of those captured were fry. Except in the C1 channel type, coho salmon fry were often the most abundant group in the larger channel types, such as the C3 type (fig. 3). The percentage of Dolly Varden in the catch showed the greatest variability, ranging from less than 1 percent in the C7 channel type to 34 percent in the B1 channel type. Coho salmon comprised between 43 percent and 88 percent of the catch.

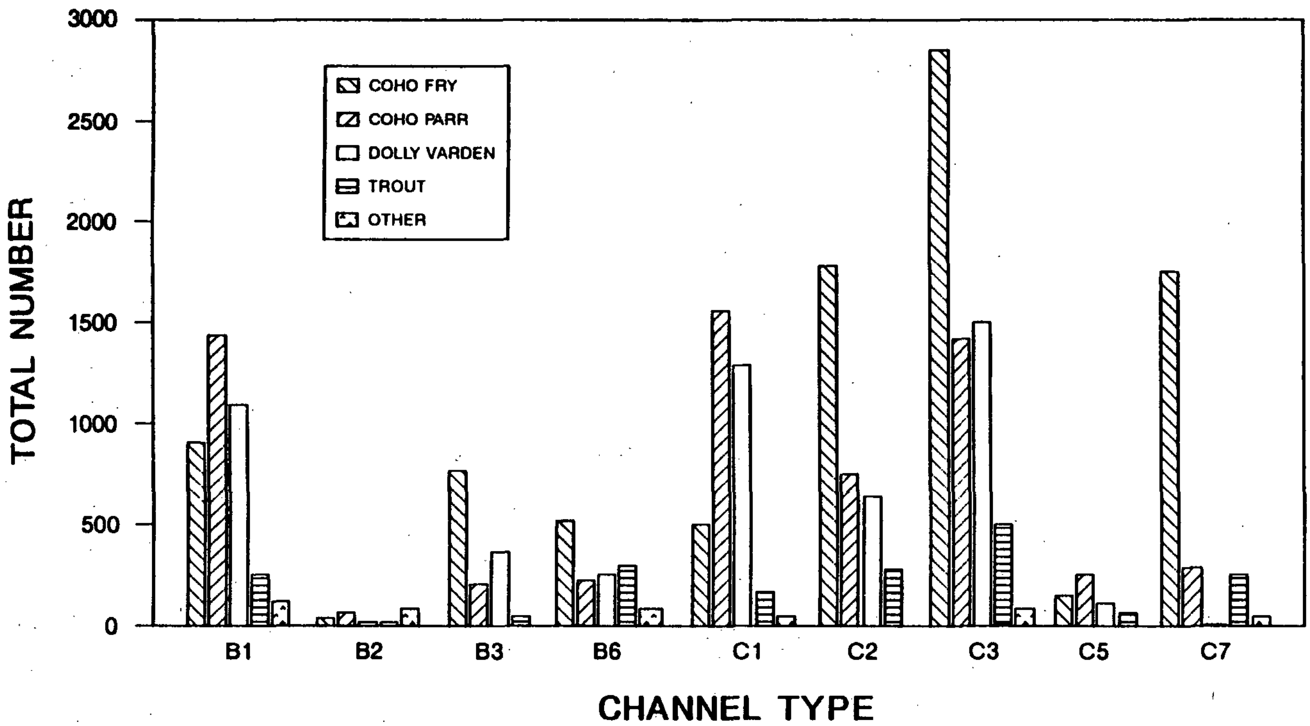

Figure 3—Total number of coho salmon fry and parr, Dolly Varden, and other species caught in B and C channel types for all study streams combined.

Table 6—Species distribution in B and C channel types for all size groups combined and for fish longer than 55 mm total length

Channel type and size group	Coho salmon	Dolly Varden	Cutthroat trout	Other[a]
	Percent of catch			
B:				
Fry and parr	64	27	3	5
Parr only (>55 mm total length)	47	41	8	4
C:				
Fry and parr	72	18	8	1
Parr only (>55 mm TL)	49	34	16	1

[a] Includes all other species captured.

Coho salmon fry tended to be the most abundant fish in most streams, and their numbers affected the species distribution in all channel types. When coho salmon were excluded from the total catch, the percentage of coho salmon decreased noticeably in all channel types; for example, when fish less than 55 mm total length were excluded from the analysis in the B channel types, the percentage of coho salmon in the catch decreased from 64 to 47 percent of the total catch, and the percentage of Dolly Varden increased from 27 to 41 percent of the catch (table 6). Similar changes were observed in the C channel types when fish less than 55 mm total length were excluded. Exclusion of fish less than 55 mm reduced the proportion of coho salmon in the C7 channel from 88 to 54 percent of the total catch.

Trout comprised less than 20 percent of the catch in all channel types except the C7 type, where they made up 45 percent of the catch. Trout were more abundant in the C-type channels than in the B-type channels, where they consistently comprised less than 10 percent of the catch.

Chinook salmon, threespine sticklebacks, and sculpins were consistently less than 9 percent of the catch (fig. 3) except in the B2 channel where 41 percent of the fish captured were sticklebacks; however, most of the area in the two sample segments was shallow beaver pond habitat and not representative of a B2 channel. Less than 140 fish were caught in the two sections of the stream. Chinook salmon were represented in one channel type, C3, in the Chatham area.

Length and Condition Factor Comparisons

Coho salmon fry (less than 55 mm total length) and parr (greater than 55 mm total length) were analyzed separately to examine differences in total length among channel types and locations. For coho salmon parr, one-way ANOVA did not show significant differences among channel types. Differences were detected for coho salmon fry among channel types ($P \leq 0.01$). Significant differences ($P \leq 0.05$)of mean total lengths were detected between C1 and C7 channel types, and between C1 and B1 channel types (Tukey's HSD test). The largest fry were found in the B1 channel type, and the smallest fry were found in the C7 channel type.

Regressions of length by weight were computed for all sample areas; condition factors were based on estimates of weight from the regressions. One-way ANOVA did not detect differences ($P>0.05$) in condition factor among channel types for coho salmon fry or parr.

Habitat Comparisons

Depth and velocity—Classification of stream habitat into categories of shallow-slow, shallow-fast, deep-slow, and deep-fast did not relate well to channel types. The percentage of area classified as deep-fast appeared to increase in the larger channels (table 7). Because the method classified "deep" as water depth greater than 0.5 m, more area of water deeper than 0.5 m would be expected in the larger channels represented by the C channel types when compared to smaller tributaries, such as the B channel types. A discriminant analysis of this data showed a 37-percent-correct classification of channel types on the basis of the depth-velocity measurements. Stepwise regression of population density (Y) by species with area of the sample area in shallow-slow (X_1), shallow-fast (X_2), deep-slow (X_3), and deep-fast (X_4) was not significant ($P>0.05$) for any variable for coho salmon fry or parr or for trout. Dolly Varden were negatively related to area classified as shallow-fast and deep-slow. At this level of habitat description, however, the significance probably has little if any predictive value and no biological significance in terms of habitat use by salmonids.

Table 7—Percentage of area classified as shallow-slow, shallow-fast, deep-slow, and deep-fast in B and C channel types

Channel type	Shallow-slow	Shallow-fast	Deep-slow	Deep-fast
	Percent			
B1	22	57	17	4
B2	9	47	37	7
B3	19	60	14	7
B6	24	51	7	18
C1	23	47	18	12
C2	24	49	16	11
C3	28	29	15	28
C5	12	31	6	51
C7	15	8	77	0

Bisson habitat classification—Bisson and others (1981) provide a more detailed description of stream habitat than of the depth-velocity classification. Their method dissects habitat into subsets of pools and fast water (that is, riffles, rapids). The habitat types, area (m^2), and percentage of habitat occurring in each channel type are given in table 8. Riffles were the dominant feature in all channel types except C2, C5, and C7. The B2 channel type was comprised almost entirely of pool habitat formed by an old beaver dam, which is not representative of a B2 channel and was classified as "other" habitat in the Bisson classification system. Observer disagreement in microhabitat classification also contributed to variation within the system but was not measurable. The Bisson method provided a slightly better association with channel type classifications than did the depth-velocity method. Discriminant analysis resulted in a correct classification of 43 percent of the total for all channel types.

When the Bisson habitat types were combined into fast water, rock, wood debris, and other habitat types, area in fast water increased as size of the channel type increased, with the exception of the C7 channel type (table 9). As a lake outlet, the C7 channel type represented a special case and most of the habitat was classified as a glide. The C2 and C5 channels were usually more deeply incised with constrained flows and showed a higher percentage of fast water habitat than was observed in the other channel types. Wood-influenced habitat tended to comprise a greater percentage of the area in the smaller B1 and B3 channels.

A stepwise regression between salmonid density by species and the complete set of the Bisson habitat variables showed a positive and significant relation ($P \leq 0.05$) between density of coho salmon parr and percentage of area classified as lateral scour pools and as backwater pools formed by large woody debris. Similarly, density of coho salmon fry was positively related to percentage of area classified as lateral scour pools with large debris and secondary channel pools. Density of Dolly Varden was related to the percentage of area classified as backwater pools with large debris. These relations agreed with qualitative observations of salmonid distribution in most streams throughout southeast Alaska during the summer.

Table 8—Area and percentage of area of Bisson habitat types for B and C channel types

Channel type	Area	Riffle	Rapids	Glide	Side channel	Backwater pools: Rock	Backwater pools: Rootwad	Backwater pools: LWD[a]	Trench pool	Plunge pool	Lateral scour pools: Large	Lateral scour pools: Rootwads	Lateral scour pools: Bedrock	Pools dam	Other	Total area
B1	m^2	3278	27	234	25	8	0	636	11	549	562	302	6	0	0	5638
	%	58.14	.48	4.15	.44	.14	0.00	11.28	.20	9.74	9.97	5.36	.11	0	0	
B2	m^2	0	0	0	0	0	0	0	0	0	0	0	0	0	282	282
	%	0	0	0	0	0	0	0	0	0	0	0	0	0	100	
B3	m^2	2131	114	128	143	0	0	345	0	89	95	71	0	29	0	3145
	%	67.76	3.62	4.07	4.55	0	0	10.97	0	2.83	3.02	2.26	0	.92	0	
B6	m^2	4140	1431	446	383	177	0	422	1555	23	60	5	24	37	0	8703
	%	47.57	16.44	5.12	4.40	2.03	0	4.85	17.87	.26	.69	.06	.28	.43	0	
C1	m^2	7928	371	1383	1034	0	1	1005	0	379	1214	288	0	118	0	13721
	%	57.78	2.70	10.08	7.54	0	.01	7.32	0	2.76	8.85	2.10	0	.86	0	
C2	m^2	4077	382	4465	0	312	0	497	457	77	220	242	65	6	0	10800
	%	37.75	3.54	41.34	0	2.89	0	4.60	4.23	.71	2.04	2.24	.60	.06	0	
C3	m^2	10218	987	10971	968	226	2	1663	626	117	1815	598	0	0	0	28191
	%	36.25	3.50	38.92	3.43	.80	.00	5.90	2.22	.42	6.44	2.12	0	0	0	
C5	m^2	1635	2237	610	0	425	0	509	0	117	56	0	0	0	0	5589
	%	29.25	40.03	10.91	0	7.60	0	9.11	0	2.09	1.00	0	0	0	0	
C7	m^2	0	0	1339	0	0	0	0	0	0	0	0	0	0	8171	9510
	%	0	0	14.08	0	0	0	0	0	0	0	0	0	0	85.92	
Total area m^2		33407	5549	19576	2553	1148	3	5077	2649	1351	4022	1506	95	190	8453	85579
Total percent		39.04	6.48	22.87	2.98	1.34	0	5.93	3.10	1.58	4.70	1.76	.11	.22	9.88	100

[a] LWD = large woody debris.

Table 9—Percentage of Bisson habitat types (combined into major categories) for B and C channel types

Channel type	Habitat			
	Fast water[a]	Rock[b]	Wood[c]	Other[d]
	Percent			
B1	58.6	0.5	36.7	4.2
B2	0	0	0	100
B3	75.5	0	20.0	4.5
B6	69.1	20.2	6.3	4.4
C1	70.6	0	21.9	7.5
C2	82.6	7.7	9.7	0
C3	78.7	3.0	14.9	3.4
C5	80.2	7.6	12.2	0
C7	14.0	0	0	85.9

[a] Fast water = riffles, rapids, glides.
[b] Rock = backwater pool with boulders, trench pool with bedrock, lateral scour pool with bedrock.
[c] Wood = backwater pool with rootwad, backwater pool with large debris, plunge pool with large debris, lateral scour pool with rootwad, lateral scour pool with large debris, wood debris dam pool.
[d] Other = secondary channel pool and other habitat types.

Large woody debris—The number of accumulations of large woody debris reflected the stream channel morphology described by the channel type (table 10). The smaller channels (B type) held fewer large accumulations but were comparable to the C channels in the number of accumulations of one to four pieces. The number of rootwads observed differed among channel types. The C5 streams with narrow or gorge channels had relatively low numbers of accumulations in all categories. In contrast, the C3 streams that were wider and more braided and had lower gradient had more accumulations in all categories, particularly in number of rootwads and accumulations with 10 or more logs. The C3 channels are depositional and more active; therefore, more large wood will enter the channel through bank cutting and windthrow, and the wood is more likely to remain in place at high flows. In the gorge channel and bedrock-constituted channel types, such as C5, C7, and B6, less material will enter and, because high flows will be constrained in a narrow channel, less will be retained.

Comparison of population densities by species to the four categories of debris showed no significant (P>0.05) relation between coho salmon fry densities and any debris category in a stepwise multiple regression. Coho salmon parr densities increased with the number of rootwads and accumulations of 10 or more pieces. Dolly Varden were positively related to number of rootwads. Trout densities increased with the number of accumulations between one and four pieces. These results agree with field observations and with those from other studies. In some cases, the absence or presence of cover (for example, woody debris) in the site selected within a channel type may have influenced the density of salmonids found in the stream.

Table 10—Mean number of debris accumulations per 100 m of stream channel by large woody debris category, for B and D channel types

Channel type	Number of sites	Categories of debris accomulations by number of pieces: 1-4	5-10	10+	Rootwads
		Mean no./100 m of stream			
B1	7	9.51	0.58	0.14	4.18
B2	2	2.36	0	0	0
B3	4	8.2	.97	0	3.85
B6	3	5.9	.52	0	.47
C1	13	10.59	1.68	.55	5.54
C2	9	4.34	.54	.09	1.34
C3	10	6.31	.43	.59	6.16
C5	2	6.71	.50	0	0
C7	4	5.5	.5	0	.25

Discussion

Other studies and qualitative observations throughout streams in southeast Alaska have shown that juvenile salmonids are associated with large woody debris (Bryant 1985, Dolloff 1983). The results from this study follow this trend. In general, channel types with more accumulations of large woody debris have higher densities of fish and proportionally more coho salmon parr than do those with little or no debris. Higher densities of salmonids were observed in the B1, C1, and C3 channels. All three channel types had more accumulations of large woody debris than did the other channel types.

Although statistical differences were not observed among salmonid densities for the channel types examined, the highest densities occurred in channel types where they were expected; the channel types with the highest densities generally agreed with the estimates of relative abundance found by Murphy and others (1987). The number of samples and location may contribute to the lack of statistical significance, but physical and biological factors also contribute to the variability observed among the channel types. In most channel types, "good" fish habitat, such as backwater pools with large woody debris or lateral scour pools with woody debris or rootwads, was a relatively small percentage of the total area in the stream. Small changes in this habitat will result in large differences in salmonid abundance and in turn will contribute to variability in salmonid densities within channel types. The channel-type classification system does not account for biological variability, including adult escapement and fry recruitment, or for stream-basin heterogeneity. We would expect, for example, more consistent escapement and fry recruitment into a B1 tributary to a larger stream than into a B1 channel emptying directly into the ocean.

Some of the variability may be eliminated in future studies by examining densities among channel types within a single stream basin. The method proposed by Hankin and Reeves (1988) may provide a better technique than the one selecting representative or randomly selected reaches. This method will also give a "basin-wide" perspective of the channel types that will provide consistent recruitment levels among channel types and a perspective into the relation among channel types within a stream basin. Although statistical differences were not observed among channel types, trends in salmonid densities did exist among channel types, and a more selective sampling procedure incorporating complete basins may provide better estimates of densities.

In several instances, specific habitat features could be attributed to either high or low salmonid populations; among those statistically related to coho salmon density were lateral scour pools and rootwads. Both may be classified as off-channel habitat associated with complex alluvial channel types. Other studies have implicated this type of habitat with higher densities and survival rates of coho salmon than in less complex habitat[2] (Bryant 1985). The amount of off-channel habitat was not consistent throughout a given channel type. Backwater and pool habitat was a relatively small proportion of any given channel type, and relatively small changes in these areas could have a disproportionately larger effect on the density of fish found in a given channel type. The study was not designed to examine this effect, and our data were not sufficient to do so.

Comparison of growth indices—size, weight, and condition factor—of salmonids in different channel types did not implicate channel types as a factor influencing growth. Although size differences were observed for coho salmon fry among channel types, no differences were observed among coho salmon parr; differences among fry likely reflect dispersal effects rather than differences in growth. Smaller fry are more likely to be "nomads" moving downstream into the larger C-type channels (Chapman 1962). A more important physical factor controlling growth than channel type may be the temperature regime of the stream basin. This aspect should be examined separately.

Depth and velocity criteria, as used in this study, did not contribute additional information to the survey. The measurements were poorly related to salmonid densities and channel-type classes, although they required on-the-ground survey. Even as a generalized description of stream habitat, the depth and velocity categories were of little use and of no value to the channel-type classification system.

The Bisson habitat classes described more microhabitat features within a stream than did the depth and velocity criteria, but even with more detailed information, the Bisson habitat categories were not good predictors of channel types. This may have been caused, in part, by the number of habitat types used in the Bisson method. There were 14 separate habitat classifications, nine channel types, and a high degree of variability in the amount of area in each habitat within channel type and among channel types. Many distinctions in microhabitat in the Bisson system would not be

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[2] Bryant, M.D. Unpublished data. On file with: Forestry Sciences Laboratory, Anadromous Fish Habitat Research Project, P.O. Box 020909, Juneau, AK 99802.

identified at the level of discrimination used to identify channel types; therefore, to determine microhabitat features, on-the-ground verification is necessary. The regression analysis shows that the more detailed description provided by the Bisson habitat classification provides a better relation with salmonid density than do either the channel-type or the depth-velocity criteria.

The higher density of rootwads and debris accumulations of 10 pieces or more in the B1, C1, and C3 channel types (table 10) reflects their general channel morphology; all flow through flood plains and have active channels. In comparison, the C5 and C7 types have constrained channels flowing through gorges with bedrock control. These results agree with Murphy and others (1987) who found more pieces of large wood debris in C1 and C3 channels than in other channel types; they did not identify individual accumulations by number of pieces. Smaller accumulations (one to four pieces) may be a more important component for juvenile salmonids in the constrained channels represented by the C5 and C7 channel types than in channel types with larger accumulations.

The lack of a significant relation between coho salmon fry and any category of debris was not unexpected. In systems either saturated or close to saturation with fry, all available habitat will be used and many fry often will be found in marginal habitat. Differential mortality of coho salmon fry will rapidly change the densities, and coho salmon parr densities will reflect habitat providing good survival. The significant relation between coho salmon parr and rootwads and large debris accumulations is consistent with observations and other studies (Bryant 1985).

In part, the lack of significance between salmonid densities and channel types may be attributed to the selection of sample sites that did not include all representative habitats or that included nontypical habitat within a channel type. A C1 channel type with few large woody debris accumulations would be expected to support fewer juvenile salmonids than would a similar channel with more accumulations, and a C5 channel with several rootwads in the water along the bank would most likely support higher densities than would other C5 channels lacking this type of habitat.

The results from this study showed that the channel-type classification system is a useful, broad-spectrum method to identify and differentiate streams and their potential as salmonid habitat. The results also point out the wide natural variation in stream systems and the need to evaluate stream systems with an on-the-ground basin-wide survey when an area has been targeted for land management activities. Of the many classification systems developed, the CTCS is the most useful for southeast Alaska: it was designed for the stream systems of the region, incorporates many of the geomorphic features that influence salmonid habitat (for example, gradient, drainage size, and flood-plain characteristics), and has direct management application.

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Nine channel types within a hierarchical channel-type classification system (CTCS) were surveyed to determine relations between salmonid densities and species distribution, and channel type. Two other habitat classification systems and the amount of large woody debris also were compared to species distribution and salmonid densities, and to stream channel types. Although trends appeared in salmonid densities and channel types, population estimates were too variable to show a relation between density and channel types. Depth-velocity criteria that separated habitat into shallow-slow, deep-slow, shallow-fast, and deep-fast were poorly related to fish population and channel types. Within the Bisson classification system, coho salmon (*Oncorhynchus kisutch* (Walbaum)) parr were positively correlated to off-channel habitat types. Large wood was more abundant in depositional channel types, and coho salmon densities were positively related to debris accumulations of 10 or more pieces and to rootwads. Although salmonid densities were not statistically related to channel types within the CTCS, the system seems to be a useful tool to classify stream habitat and to identify its use by salmonids.

Keywords: Stream surveys, stream habitats, salmonid habitat, stream management.

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