The Relationships of wood debris to juvenile salmonid production and microhabitat selection in small southeast Alaska streams
by Charles Andrew Dolloff

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biological Sciences
Montana State University

Abstract:
Many small streams in Southeast Alaska contain both wood debris deposited by natural causes and/or logging and populations of juvenile salmonlds. Resource managers have assumed that large amounts of wood debris were detrimental to fish populations and have recommended debris removal. This study was initiated to describe the effects of wood debris and debris removal on populations of Juvenile coho salmon and Dolly Varden in four tributary streams of Staney Creek, Prince of Wales Island, Alaska during the summers of 1979-1981. Three streams were located in clearcuts and had debris removed from selected subsections by manual labor.

A fourth stream was located in an uncut forest stand and provided information on fish populations under natural conditions. Population densities and production of both species were typically higher in subsections having debris accumulations intact. Production during the June-September period for age 0+ and age 1+ coho combined ranged from 0.464-2.496 g/square meter. Dolly Varden production ranged from 0.106-0.879 g/square meter. For coho, debris provided visual isolation, permitting larger numbers of fish to live together without excessive territorial interactions.

Greater Dolly Varden numbers were related to increased cover provided by debris. There was little apparent competition between the species. An examination of microhabitat preferences showed that each of two coho and three Dolly Varden age classes was found in distinct areas. Coho occupied midwater positions that they defended from other fish. Dolly Varden were found on the stream bottom in dense cover. Analysis of stomach contents showed that coho selected most dietary items from the drift whereas Dolly Varden primarily exploited benthic prey.

Discriminant analysis showed that depth of focal point, depth of water, distance to nearest fish and distance to nearest cover were the most important variables accounting for separation of the five species-age class groups. Discriminant analysis using species as groups and incorporating the proportion of diet from terrestrial sources as an independent variable revealed that dietary differences also contributed to group separation. Stream cleaning in streams similar to those studied will likely be detrimental to anadromous Juvenile fish populations.

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APPROVAL

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Charles Andrew Dolloff

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Many small streams in Southeast Alaska contain both wood debris deposited by natural causes and/or logging and populations of juvenile salmonids. Resource managers have assumed that large amounts of wood debris were detrimental to fish populations and have recommended debris removal. This study was initiated to describe the effects of wood debris and debris removal on populations of juvenile coho salmon and Dolly Varden in four tributary streams of Staney Creek, Prince of Wales Island, Alaska during the summers of 1979-1981. Three streams were located in clearcuts and had debris removed from selected subsections by manual labor. A fourth stream was located in an uncut forest stand and provided information on fish populations under natural conditions. Population densities and production of both species were typically higher in subsections having debris accumulations intact. Production during the June-September period for age 0+ and age 1+ coho combined ranged from 0.464-2.496 g/square meter. Dolly Varden production ranged from 0.106-0.879 g/square meter. For coho, debris provided visual isolation, permitting larger numbers of fish to live together without excessive territorial interactions. Greater Dolly Varden numbers were related to increased cover provided by debris. There was little apparent competition between the species. An examination of microhabitat preferences showed that each of two coho and three Dolly Varden age classes was found in distinct areas. Coho occupied midwater positions that they defended from other fish. Dolly Varden were found on the stream bottom in dense cover. Analysis of stomach contents showed that coho selected most dietary items from the drift whereas Dolly Varden primarily exploited benthic prey. Discriminant analysis showed that depth of focal point, depth of water, distance to nearest fish and distance to nearest cover were the most important variables accounting for separation of the five species-age class groups. Discriminant analysis using species as groups and incorporating the proportion of diet from terrestrial sources as an independent variable revealed that dietary differences also contributed to group separation. Stream cleaning in streams similar to those studied will likely be detrimental to anadromous juvenile fish populations.

INTRODUCTION

The forests of Southeast Alaska contain many small streams that provide important spawning areas and rearing space for juvenile anadromous fishes. These streams typically contain large amounts of wood debris deposited by natural processes. In addition, logging operations frequently result in the additional deposition of slash and unmerchantable timber. When this occurs, resource management policies call for stream cleaning. While the intent of these policies is to restore affected streams to prelogging conditions, little is known about the role of wood debris in the structure of fish habitats and the consequences of stream cleaning on fish populations.

Stream cleaning operations in the United States have been conducted for over 100 years (Sedell and Luchessa 1982). In the past, it was generally assumed that large amounts of wood debris were detrimental to fish populations and the efficacy of stream cleaning operations was rarely questioned. Early studies were largely based on the belief that debris negatively affected fish populations and generally advocated drastic clearance of logs and debris from stream channels (Merrell 1951). One of California's first major stream clearance programs "...was deemed beneficial, although no satisfactory method was devised to evaluate results." (Holman and Evans 1964). Narver (1971) reviewed the environmental requirements of eight salmonid species and concluded that accumulations of logging debris could have serious negative consequences on their production in small streams. Au (1972) recommended a vigorous cleanup of Oregon streams to maintain coho salmon (*Oncorhynchus kisutch*) populations within normal ranges.

In recent years, however, some researchers have become more critical of the effects of stream cleaning. Wood debris accumulates naturally in forest streams where it strongly influences channel morphology and biological processes (Swanson et al. 1976). Many fishes have evolved in its presence; salmonids in particular have demonstrated a broad range of tolerance, if not adaptation, to varying amounts of debris (Sedell and Luchessa 1982). Recognizing these facts, Hall and Baker (1975) concluded that debris in stream systems could have positive as well as detrimental effects depending upon the particular stream and the extent of debris loading. Bustard and Narver (1975) suggested that overzealous stream cleaning may result in the loss of overwintering habitat and decreased survival in coho salmon and steelhead (*Salmo gairdneri*) populations. In Southeast Alaska, Elliott and Hubartt (1975) documented decreased Dolly Varden (*Salvelinus malma*) populations following debris removal.

The present study was undertaken to determine the relationships between wood debris and associated habitat features and salmonid populations in small southeast Alaska streams. The effects of stream cleaning on distributions, numbers, and the production of coho salmon and Dolly Varden were examined during the June-September field seasons from 1979 through 1981. Microhabitat use and resource partitioning were examined to account for interactions among the various age classes and species and habitat characteristics present. The findings of the study will be used to evaluate and develop management practices dealing with salmonid rearing habitat in Alaska.

DESCRIPTION OF STUDY AREA

The Staney Creek Drainage lies in the Tongass National Forest on the west side of Prince of Wales Island in Southeast Alaska (Figure 1). The Tongass is part of the Northwestern Pacific needle-leaf forest -- an environment characterized by cool, cloudy weather and dense stands of old growth coniferous trees. The mean annual temperature recorded at the U.S. Forest Service station at Ketchikan, approximately 135 kilometers (km) southeast of Staney Creek, is 8.0 Celsius (C) and annual precipitation ranges from 225 to over 500 centimeters (cm) (Louis Bartos, personnal communication). Western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*) are the principal codominant tree species with mountain hemlock (*Chamaecyparis nootkatensis*) and western redcedar (*Thuja plicata*) present on many sites. Red alder (*Alnus rubra*) is common along stream margins and on disturbed soils.

Logging in the drainage has produced a mosaic of clearcuts interspersed with virgin timber stands. Clearcuts ranged in size from 10 to over 1,000 hectares (ha). Revegetation in clearcuts occured in dense patches with Sitka spruce and western hemlock dominating shrub communities variously composed of salal (*Gaultheria shallon*), salmonberry (*Rubus spectabilis*), blueberry (*Vaccinium* spp.), and currant (*Ribes* spp.).

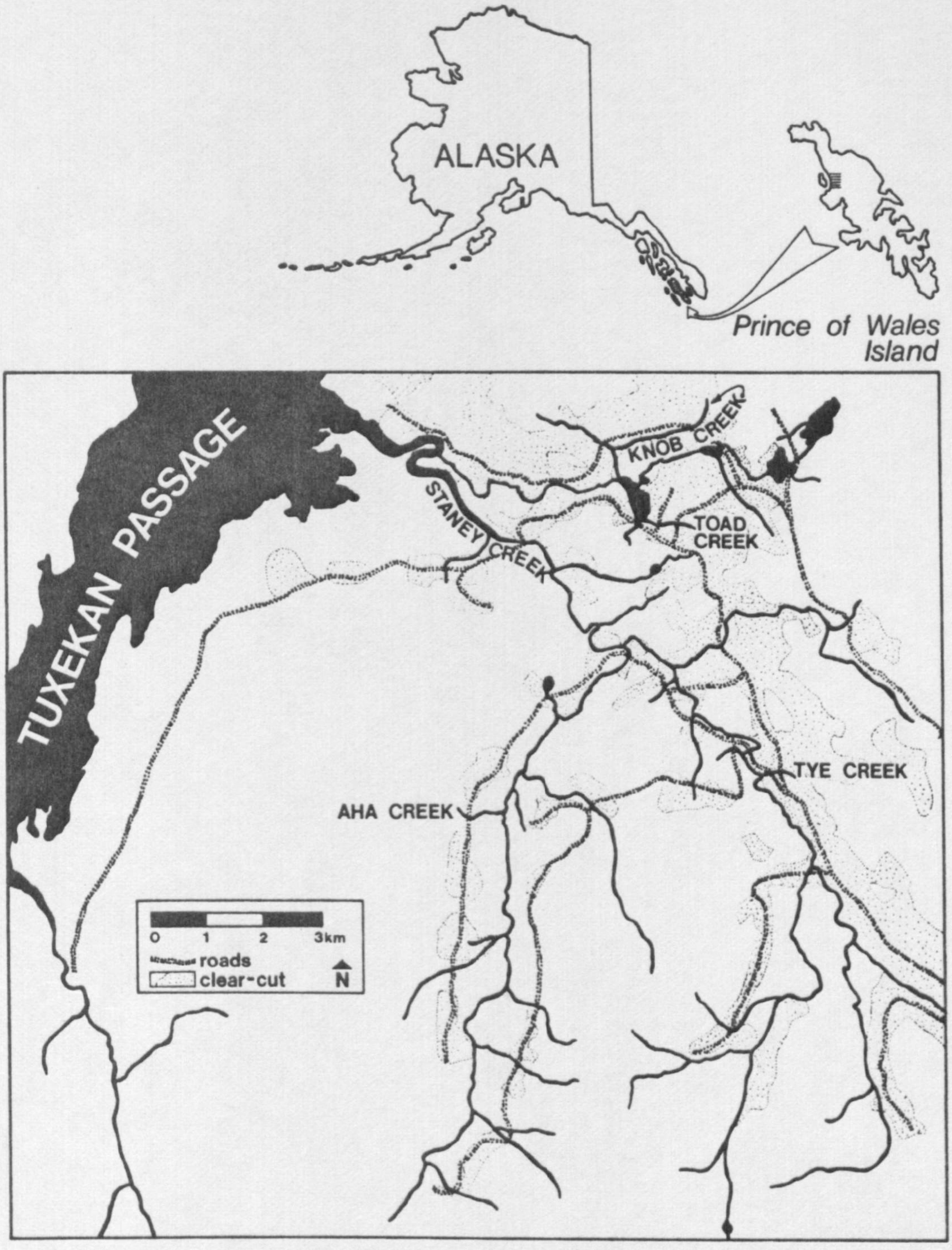

Figure 1. Map of Staney Creek Drainage, Prince of Wales Island, Alaska and the location of study streams.

Four tributaries to Staney Creek were selected for study (Figure 1). All streams were approximately 2 meters (m) wide and contained wood debris deposited as a result of logging and/or natural processes. Selected chemical characteristics were measured monthly during 1980 and 1981 (Table 1). The observed ranges of alkalinities and conductivities were representative of similar streams in Southeast Alaska (Louis Bartos, personal communication).

Tye Creek was located in a clearcut created in 1967 and emptied into the South Fork of Staney Creek. Summer low flow in Tye Creek during 1979 was approximately 0.0003 cubic meters per second. A 170 m study section on Tye Creek was enclosed by two-way fish traps (Figure 2).

Toad Creek drained into a pond which in turn emptied into the East Fork of Staney Creek. The 340 m study section on Toad Creek, located in an area clearcut in 1971, also was enclosed by two-way fish traps (Figure 2).

Debris was removed from the lower half of Tye Creek and the upper half of Toad Creek study sections during July 1979 by a Forest Service stream cleaning crew using hand tools. The remaining subsections in both streams were not cleaned and served as controls.

Knob Creek drained an area logged in 1972 and paralleled a logging road to its juncture with the East Fork of Staney Creek. Within the 260 m study section on Knob Creek, 100 m at the upstream end were totally cleared

Table 1. Monthly measurements of selected water chemistry parameters from 4 Southeast Alaska streams, 1980-1981.

Month Stream	pH		Alkalinity (mg/l)		Conductivity (umhos/cm @25 C)		NO3 (mg/l)	
	Year							
	1980	1981	1980	1981	1980	1981	1980	1981
June								
Tye	7.80	7.02		40	140	98	1.5	1.2
Toad	7.00	6.93	45	35	112	78	1.5	2.2
Knob	7.80	7.80	125	130	230	270	1.5	1.3
Aha	7.50	6.99	30	15	63	68	1.5	0.9
July								
Tye	6.87	7.15	50	55	104	110	0.7	1.3
Toad	6.64	7.49	25	55	60	91	0.5	0.7
Knob	6.90	8.00	135	145	260	275	0.6	0.6
Aha	6.75	7.10	20	35	52	76	0.4	1.0
August								
Tye	7.55	7.17	55	45	121	120	1.6	1.6
Toad	7.00	6.30	35	20	80	60	0.7	0.8
Knob	7.90	7.00	140	145	290	280	1.1	1.7
Aha	7.00	7.84	25	30	73	82	1.5	2.7
September								
Tye	7.35		50		110		0.6	
Toad	6.95		35		82		0.7	
Knob	7.60		145		300		0.7	
Aha	7.02		35		70		0.6	

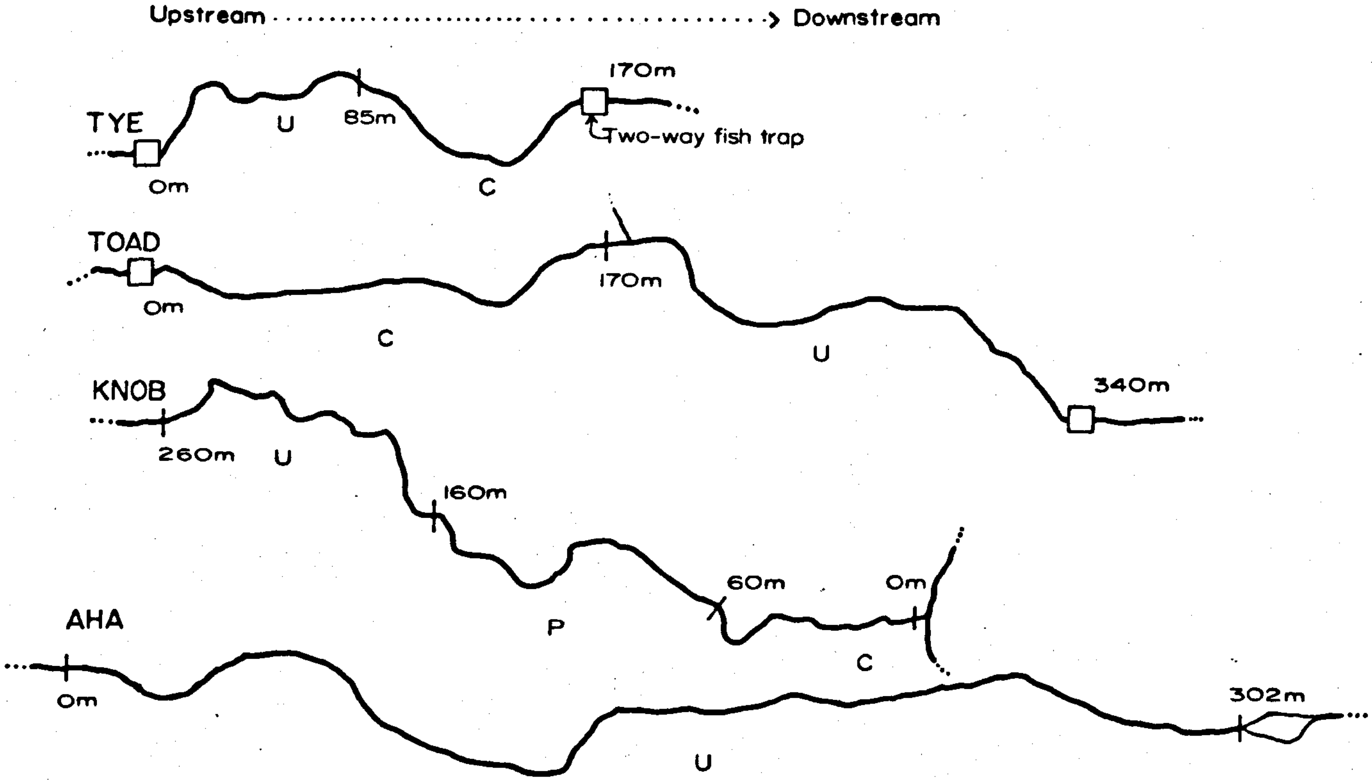

Figure 2. Location of the totally cleaned (C), partially cleaned (P) and uncleaned (U) subsections on the 4 study streams in Southeast Alaska.

of debris, 100 m from the middle were partially cleared and 60 m at the downstream end were left with debris accumulations intact. In total cleaning, all logging debris was removed from the stream channel, while only the debris that could readily be taken out by hand was removed from the partially cleaned subsection. Knob Creek was cleaned in 1977.

Aha Creek was located in an uncut forest stand along the West Fork of Staney Creek. The 304 m study section on Aha Creek provided information on debris-fish population relationships under natural conditions.

Coho salmon and Dolly Varden were present in all study streams. Cutthroat trout (*Salmo clarki*) were found in Toad and Knob Creeks, while steelhead were found in Tye Creek only. Coastrange sculpin (*Cottus aleuticus*) were captured in all study streams but Aha Creek.

MATERIALS AND METHODS

Establishment of Stations

The study sections on all streams were divided into consecutively numbered stations to assess fish movements. Tye Creek included 7 stations at 20 m intervals with 1 30 m station at the downstream end. Toad Creek contained eight stations of 40 m with a 20 m station at the downstream end. Aha Creek had seven 40 m stations and a 20 m station at the upstream end. Six 40 m stations with one 20 m station at the upstream end were established on Knob Creek.

Transect Location and Measurements

Transects were established to measure selected characteristics of the channel at each trapsite and at 10 m intervals throughout the study sections on each stream. Transects were established perpendicular to the thalweg and depth measurements were made at 0.3 m intervals once during each field season. Wooden staff gauges placed at each transect site in 1980 and 1981 showed that aside from occasional freshets, stream channel depth was relatively stable during the period of sampling in 1980 and 1981. Estimates of stream surface areas were made using maps derived from transect data and a digitizing planimeter.

Fish Population Sampling

Fish populations in each subsection were estimated monthly from June-September using mark-recapture techniques. Fish were captured in baited minnow traps, anaesthetized with tricaine methanesulfonate (MS-222), measured to the nearest millimeter (mm) for total length (TL) and fork length (FL), marked and released at the site of capture. Traps had a 0.6 cm mesh and were baited with boraxed salmon eggs contained in perforated Whirl-pac plastic bags which allowed odors to escape but prevented fish from eating the bait. Traps were set in all locations with water depth sufficient to submerge at least one entry funnel.

Fish 50 mm TL or greater were marked with a freeze brand (Bryant and Walkotten 1980) indicating both the month and station at the time of marking. Fish less than 50 mm TL received a fin punch mark that indicated the month but not the station of capture. One week after marking, fish were again captured, measured and all marks recorded. During the recapture period in 1980 and 1981, approximately five fish per species in each 5 mm size group from each stream subsection were weighed to the nearest 0.05 gram (g) using a triple beam balance. Monthly average weights were derived using mean fork lengths in logarithmic regressions of length on weight. Weights for fish in each subsection during 1979 were estimated using length-weight regression equations from the appropriate pooled 1980 and 1981 data.

Population estimates (N) for each species and age class in each subsection were made using the Chapman modification of the Petersen formula (Ricker 1975) and were converted to density estimates (N/m^2). If population estimates did not decline over the season, density estimates were derived from regression equations. Population estimates for 1978 were based on data from Cardinal (unpublished data). Age classes were determined by length-frequency distributions.

Monthly production (P) estimates were computed according to the formula P=GB, where G is the instantaneous growth coefficient and B is the average biomass during the period of measurement. The instantaneous growth coefficient was estimated by the equation,

$$G=\ln(w_{t+1})-\ln(w_t),$$

where w is the mean weight of individuals in a time period (Chapman 1978). Mean weight and population estimates were smoothed by regression techniques prior to use in production calculations taking into account confidence intervals and sample sizes. Average biomass was computed as the mean of the product wxN in successive samplings.

Microhabitat Sampling

Microhabitat sampling was conducted in 1980 and 1981 on rain-free, windless days between 0900 and 1500 hrs. Sites were selected by walking upstream to where a discrete stream area could be observed.

After selecting a site, the observer positioned himself on a stream bank and remained as motionless as possible. If disturbed by the observer's approach, fish appeared to resume normal activity after approximately 10 minutes (min). The observer watched until he was satisfied that the all fish occupying focal points had been identified and their locations recorded on a field sketch (Figure 3). This typically required observation periods of from 60 to 180 min. Painted and numbered markers corresponding to the different species and size classes present were placed on the stream bottom under the focal point of each fish. Fish not having specific focal points also were noted and markers were placed at the locations they most frequently occupied. Following an additional 10-20 min observation period to verify the placement of markers, focal point characteristics including water depth, velocity, substrate type and size and type of cover were measured. Descriptions of the cover and substrate categories are given in Tables 2 and 3, respectively. The distance to and species of nearest fish also were recorded

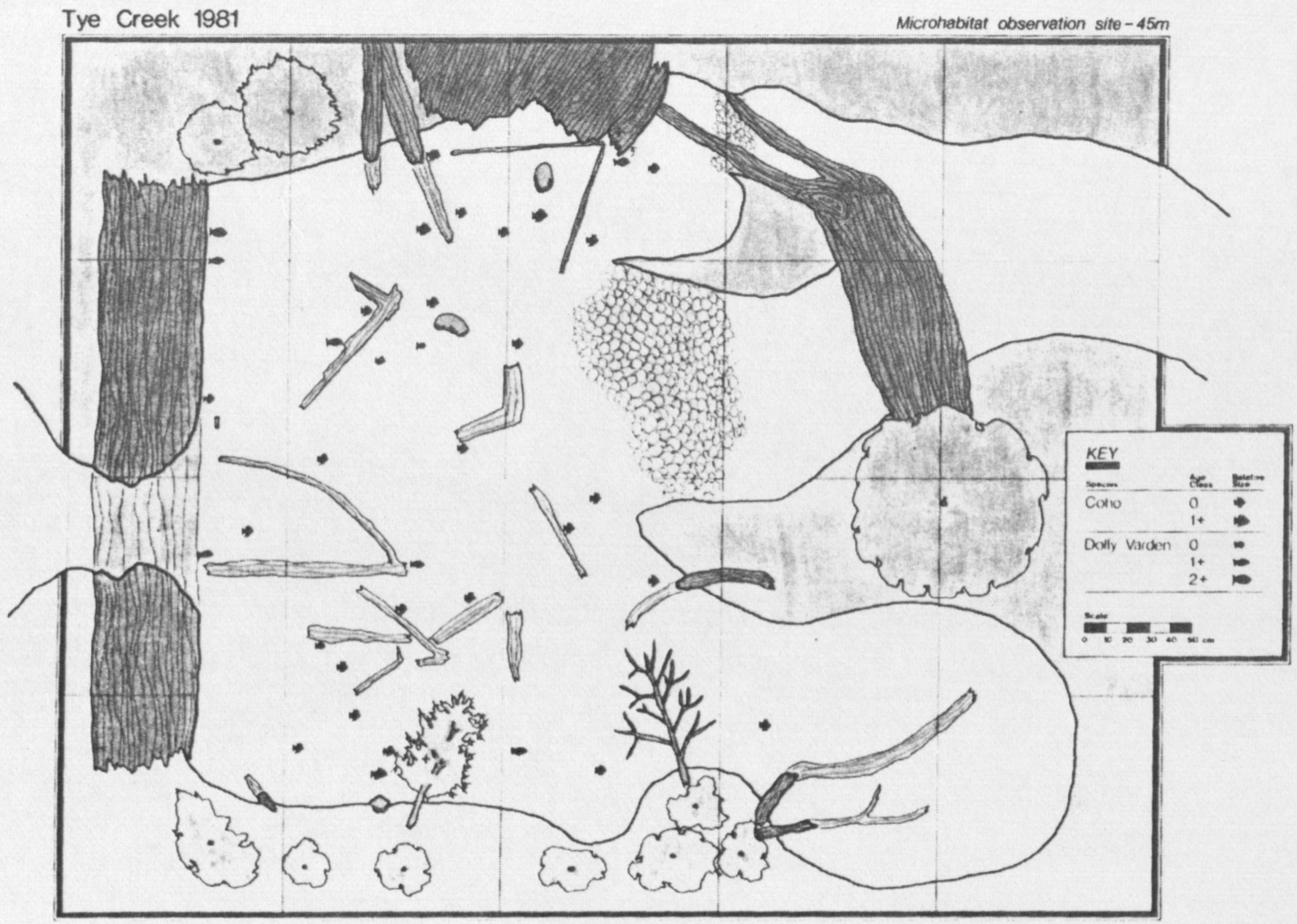

Figure 3. Sketch of a microhabitat study observation site.

Table 2. Descriptions of 11 cover categories utilized in the microhabitats of juvenile coho salmon and Dolly Varden in 4 Southeast Alaska streams.

Cover category	Description
Cobble	Rocks of approximately 100-300 mm diameter on the streambed.
Boulder	Rocks larger than cobble with space underneath suitable for hiding.
Log	Wood debris ranging from approximately 10 cm to 1 m in diameter.
Branches	Wood debris <10 cm anchored to the streambed.
Debris + overhead cover	Stream bank vegetation intertwined with branches.
Fine debris	Loose collection of wood and other debris.
Debris + undercut bank	Branches forming the base for or extending from an earth bank.
Overhead vegetation	Trees and/or other vegetation extending over the water surface.
Aquatic vegetation	Primarily leaves of Symplocarpus sp. (skunk cabbage)
Undercut bank	Overhanging earth bank carved by water current.
Overhead vegetation + undercut bank	Vegetation and earth bank.

Table 3. Descriptions of 10 substrate categories found at the focal points of juvenile coho salmon and Dolly Varden in 4 Southeast Alaska streams.

Substrate category	Description
Silt	Floculent particles≤0.06 mm.
Sand	Particle size > silt and ≤2 mm.
Small gravel	Particle size > sand and ≤12 mm.
Medium gravel	Particle size > small gravel and ≤100 mm.
Large gravel	Particle size > medium gravel and ≤300 mm.
Rock	Particle size > large gravel but not embedded in the stream bottom.
Ledge	Shelf of embedded rock.
Fine debris	Wood and vegetative debris particles.
Clay	Smooth earth surface, no rock.
Log	Wood debris ≥10 cm diameter.

as was the distance to nearest cover. The site was then photographed and its areal dimensions and essential habitat features recorded on the field sketch. Additional observation sites were chosen by walking upstream from the previous site.

Where feasible, fish at each site were captured with a backpack electrofisher to analyse food habits and verify species and age classes. The stomach contents were taken from samples of fish representing the range of species and size classes at the site by a flushing technique (Meehan and Miller 1978) and immediately preserved in 10% formalin. Food items were identified by Taxon, Inc. Aquatic Consultants, Corvallis, Oregon. Estimates of food item volume were computed from length-width measurements, after assigning a spheroidal or cylindrical shape to individual food items.

The initial analysis of continuous microhabitat variables was based on paired comparisons between all age classes and species. The Kolmogorov-Smirnov (K-S) two-sample test for identical distributions (Conover 1971) was used to detect differences in microhabitat use between pairs.

Niche breadth and pairwise overlap in resource use were evaluated for substrate, cover type and food. Niche breadth,

$$B_{xi}=1/\Sigma(p_{xi}^2)$$

was calculated for each age class and species where p_{xi} was the proportion of a given species (x) utilizing resource category (i) (Levins 1968). Three measures of resource overlap, defined here as the overlap in use of a common resource between two species or different size groups of the same species, were calculated. The first was Schoener's (1968) index,

$$O_{xy}=1-0.5\sum|p_{xi}-p_{yi}|,$$

where p_{xi} and p_{yi} are the proportional utilizations of resource category i by species x and y, respectively. Horn's (1966) modification of Morisita's index,

$$C_{xy}=2\Sigma(p_{xi}p_{yi})/(\Sigma p_{xi}^2)+(\Sigma p_{yi}^2)$$

was also calculated as it has proved to be more accurate than Schoener's index where overlap exceeds 85% (Linton et al. 1981). A third index, the sample correlation coefficient, r_{xy} (Snedecor and Cochran 1970) also was calculated and compared to values for Schoener's and Horn's measures.

Stepwise discriminant analysis was used to identify interactions between and to determine the relative importance of resource categories in distinguishing micro-habitat use by species and size class. This and all statistics were computed with either the SPSS (Nie et al. 1975) or BMDP (Dixon 1981) statistical packages at the Montana State University Computor Center.

RESULTS

Width, Depth and Wetted Perimeter

Mean width, depth and wetted perimeter measurements for all subsections in Tye, Toad, Knob, and Aha creeks from 1979-1981 are presented in Tables 4-7, respectively. No consistent pattern related to stream cleaning could be detected in these parameters during the sampling seasons (t-test; $p<0.05$). The lack of observed differences in stream channel characteristics was probably due to the dynamic nature of stream channel formation and the choice of transects for measurement. Transects were established at all trapsites thus favoring deeper areas. Due to this bias for deep sites, the differences in width, depth and wetted perimeter between subsections were relatively small and did not appear to reflect changes in fish habitat.

Water Surface Area

Water surface areas tended to be stable in all streams within the sampling seasons. In the cleaned subsection of Tye Creek, water surface areas decreased by 3% one week after cleaning (Table 8). Most of the reduction in surface area was due to the loss of small pool areas formed by logs and tree branches. Tye Creek surface area in the cleaned subsection decreased 17% in 1980 and remained at this level

Table 4. Mean ±95% CI for width, depth and wetted perimeter during the sampling seasons in Tye Creek from 1979 through 1981. Number of transects in parenthesis.

Year Subsection	Width (m)	Depth (cm)	Wetted perimeter (m)
1979			
Cleaned	1.78±0.34 (25)	0.09±0.02 (25)	1.82±0.29 (25)
Uncleaned	1.89±0.41 (22)	0.09±0.02 (22)	1.72±0.41 (22)
1980			
Cleaned	1.56±0.41 (18)	0.09±0.02 (20)	1.93±0.46 (18)
Uncleaned	1.72±0.42 (13)	0.07±0.01 (16)	1.66±0.39 (13)
1981			
Cleaned	1.70±0.36 (24)	0.09±0.02 (24)	1.84±0.37 (23)
Uncleaned	1.60±0.33 (20)	0.09±0.03 (20)	1.72±0.39 (19)

Table 5. Mean ±95% CI for width, depth and wetted perimeter during the sampling seasons in Toad Creek from 1979 through 1981. Number of transects in parenthesis.

Year Subsection	Width (m)	Depth (cm)	Wetted perimeter (m)
1979			
Cleaned	1.77±0.27 (26)	0.14±0.02 (25)	1.93±0.30 (25)
Uncleaned	1.71±0.17 (27)	0.12±0.02 (27)	1.89±0.27 (27)
1980			
Cleaned	1.96±0.26 (36)	0.10±0.01 (36)	1.80±0.24 (36)
Uncleaned	1.89±0.39 (17)	0.09±0.02 (39)	1.58±0.18 (38)
1981			
Cleaned	1.49±0.25 (40)	0.09±0.02 (41)	1.66±0.24 (40)
Uncleaned	1.73±0.63 (42)	0.09±0.02 (43)	1.73±0.18 (42)

Table 6. Mean ±95% CI for width, depth and wetted perimeter in Knob Creek during the sampling seasons in 1980 and 1981. Numbers of transects in parenthesis.

Year Subsection	Width (m)	Depth (cm)	Wetted perimeter (m)
1980			
Cleaned (C)	2.06±0.30 (20)	0.15±0.01 (20)	2.17±0.32 (20)
Partial (P)	1.81±0.35 (16)	0.13±0.02 (16)	1.85±0.33 (16)
Uncleaned (U)	1.81±0.54 (9)	0.14±0.04 (9)	2.17±0.34 (9)
1981			
Cleaned (C)	1.65±0.25 (31)	0.09±0.02 (31)	1.72±0.26 (31)
Partial (P)	1.70±0.24 (27)	0.12±0.02 (27)	1.80±0.26 (27)
Uncleaned (U)	1.92±0.21 (17)	0.13±0.03 (17)	1.80±0.22 (17)

Table 7. Mean ±95% CI for width, depth and wetted perimeter in Aha Creek during the sampling seasons in 1979 through 1981. Number of transects in parenthesis.

Year Subsection	Width (m)	Depth (cm)	Wetted perimeter (m)
1979			
0-302m	2.11±0.75 (47)	0.07±0.17 (48)	2.40±0.32 (47)
1980			
0-302m	2.30±0.24 (63)	0.09±0.01 (59)	2.26±0.23 (57)
1981			
0-302m	2.87±0.37 (34)	0.14±0.03 (33)	2.70±0.34 (33)

Table 8. Water surface areas (m^2) in subsections of 4 study streams in Southeast Alaska.

Stream Subsection	1979	1980	1981
Tye			
Cleaned			
Precleaning	157.6		
Postcleaning	153.9*	130.6	129.9
Uncleaned	136.5	136.6	136.2
Toad			
Cleaned			
Precleaning	292.7		
Postcleaning	262.3*	272.8	280.7
Uncleaned	281.6	254.5	301.5
Knob			
Partially cleaned		154.6	150.0
Cleaned		169.8	156.4
Uncleaned		92.2	105.9
Aha	690.7	808.8	755.2

* Water surface area one week after stream cleaning.

in 1981. Toad Creek surface area in the cleaned subsection decreased by 10% one week after cleaning but increased 4% in 1980 and 2% in 1981 as fewer but larger pools were formed behind large debris logs not removed by cleaning and accumulations of leaves and other litter from stream-side vegetation. Surface areas in the uncleaned subsection of Toad Creek decreased in 1980 but increased in 1981 probably due to the destruction and reformation of transient pools. Surface areas in the Knob Creek study sections remained relatively stable during 1980 and 1981, while Aha Creek surface area fluctuated widely between years. Many of the pools in Aha Creek were formed by gravel accumulations rather than debris and thus tended to be unstable at high flows occurring in the fall.

Population Movements

Young-of-the-year (YOY) were recruited to the coho population in May and June. Downstream emigration was the only significant movement by age 0+ coho (Figure 4). In 1979 and 1981, emigration was 95% complete in Tye Creek and 98% complete in Toad Creek prior to the first population census in June. Emergence of coho fry was apparently later in 1980 however, as emigration was only 80% complete in Tye and 81% complete in Toad Creek before population censusing began. In the 6-day interval between the June marking and recapture period, 2,395 YOY coho representing 14% of the total emigration passed through the downstream fish trap on Tye Creek and left the study section. At the same time, 330 YOY coho (16% of the total emigration) emigrated from Toad Creek. Recruitment to the yearling coho age class depended primarily upon overwintering survival of the previous year's fry and to a lesser extent on immigration. Though yearling coho moved both into and out of the study sections, most movement was completed prior to each year's June census (Figure 5).

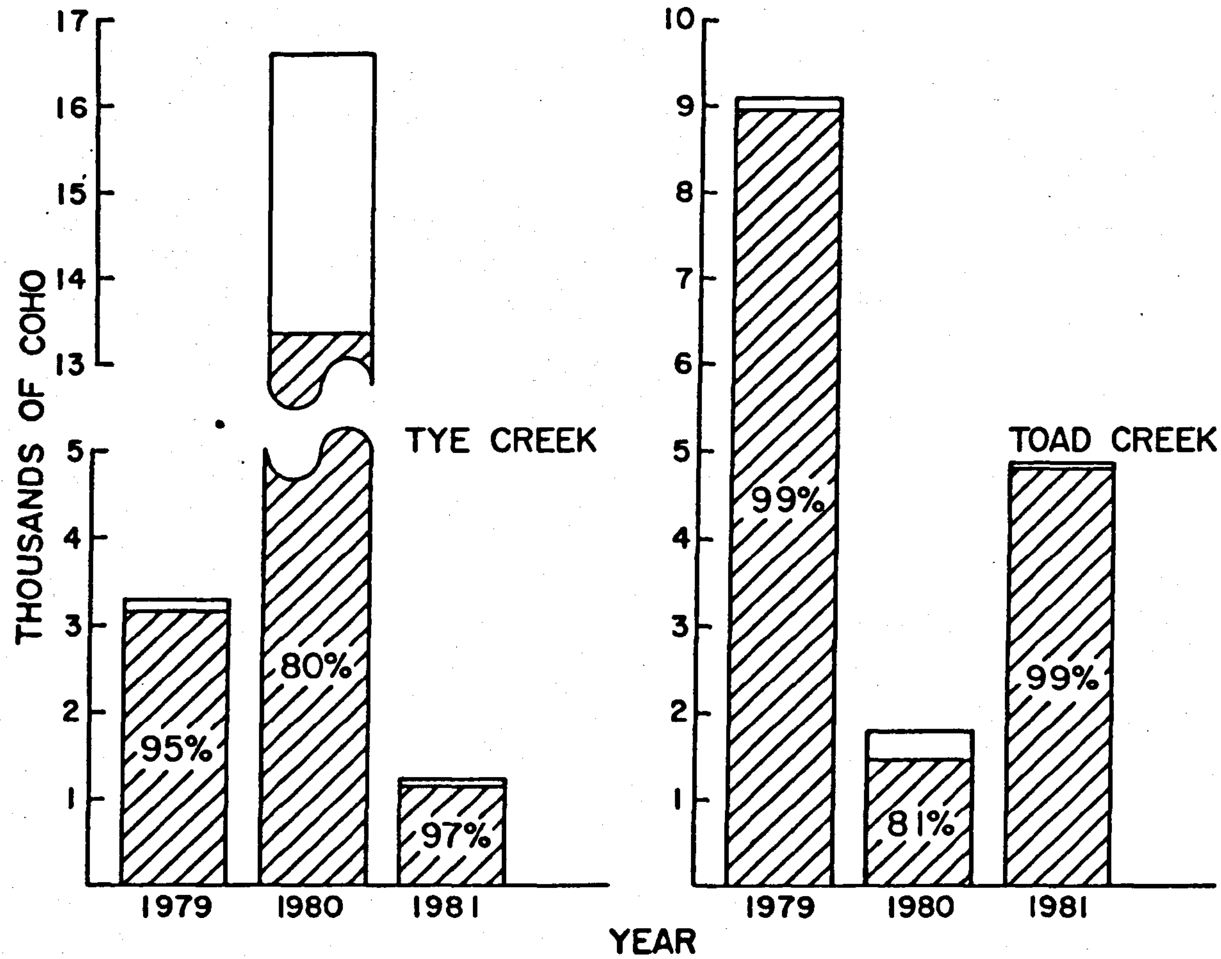

Figure 4. Total numbers of age 0+ coho emigrating downstream from the study sections of Tye and Toad creeks and the number leaving before the first population estimate (cross-hatching) during 1979-1981.

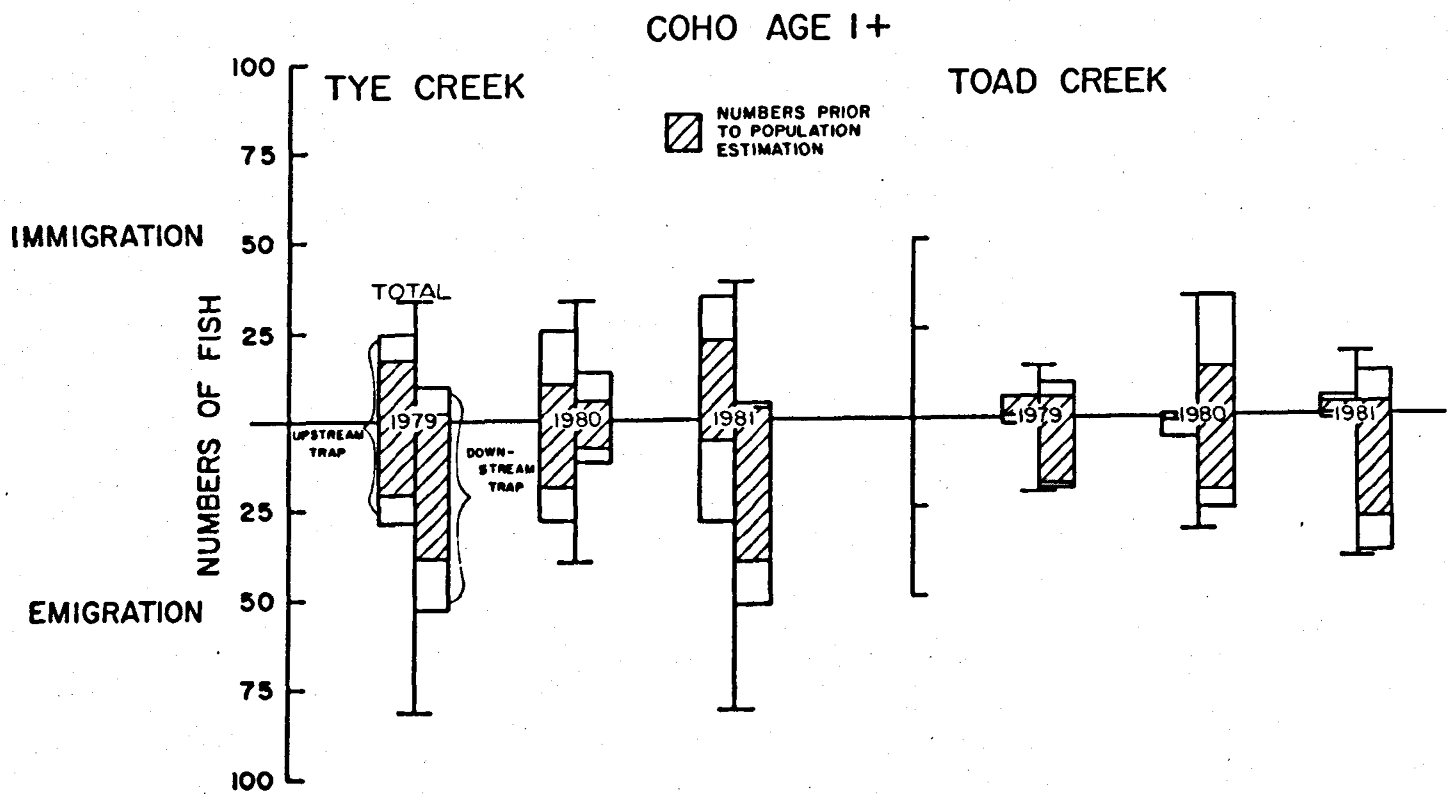

Figure 5. Total numbers of yearling coho immigrating to and emigrating from Tye and Toad creeks during 1979-1981.

Dolly Varden YOY movements were not evaluated in this study. Due to their small size (<30 mm), many Dolly Varden fry passed through the two-way traps and escaped. Like yearling coho, yearling and older-aged Dolly Varden moved into and out of the study sections (Figure 6). Late August and September Dolly Varden movements primarily consisted of immigration and seemingly random movements by individuals in spawning condition.

Inter-station movements by yearling coho and yearling and older Dolly Varden during 1979-1981 are summarized in Tables 9-11, respectively. Fish tended to remain throughout the sampling season within the station at which they were marked. In each of the three field seasons, greater than 93% of the recaptured coho and Dolly Varden had remained within the station at which they were marked. Among those fish moving, approximately equal numbers of coho went upstream and downstream while twice as many Dolly Varden moved downstream as up. The lack of movement greatly simplified population estimation and the estimation of growth and mortality rates for populations within subsections.

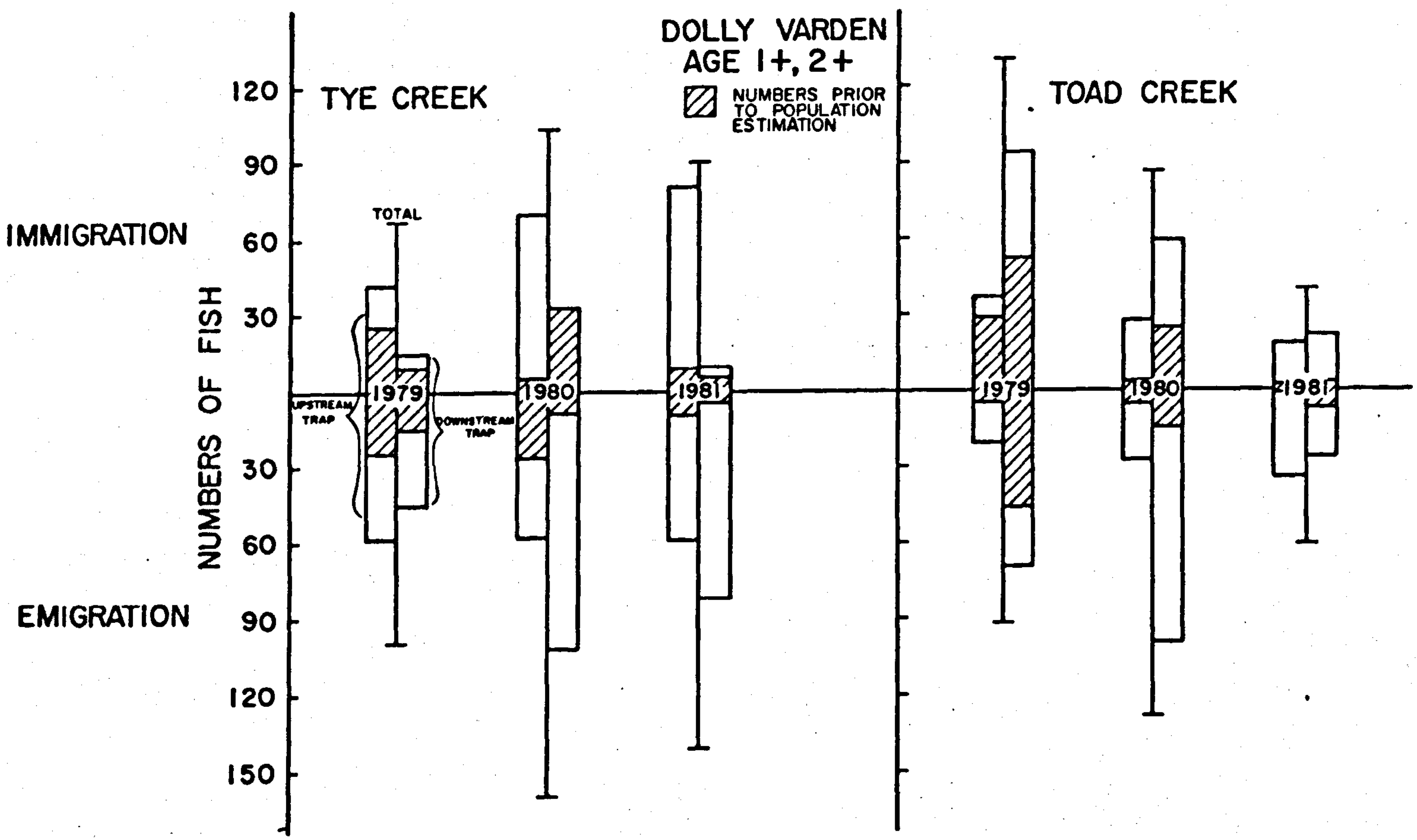

Figure 6. Total numbers of age 1+ and age 2+ Dolly Varden immigrating to and emigrating from Tye and Toad creeks during 1979-1981.

Table 9. Direction and distance (m) of interstation movements by juvenile coho and Dolly Varden in 3 study streams during 1979. Station numbers in parenthesis.

	Coho		Dolly Varden	
	Direction			
Stream	Up	Down	Up	Down
Tye Creek				
No. fish recaptured and % recaptures that moved	88(10.0%)		38(11.0%)	
Distance	40(7-5)	40(3-5)	40(7-5)	100(3-8)
	40(6-4)	40(4-6)	40(3-1)	
	40(5-3)	40(2-4)	80(7-3)	
	60(7-4)	80(4-8)		
	80(7-3)			
Toad Creek				
No. fish recaptured and % recaptures that moved	139(4.0%)		182(9.0%)	
Distance	20(9-8)	40(4-5)	80(7-5)	40(4-5)
	40(8-7)	40(4-5)		4@40(3-4)
	40(3-2)	80(2-4)		5@80(2-4)
				2@80(7-9)
				120(6-9)
				160(4-8)
				280(1-8)
Aha Creek				
No. fish recaptured and % recaptures that moved	89(7.0%)		50(6.0%)	
Distance	40(4-3)	80(1-3)	80(4-2)	200(1-6)
	40(3-2)	80(3-5)	80(6-4)	
		120(3-6)		
		280(1-8)		

Table 10. Direction and distance (m) of interstation movements by juvenile coho and Dolly Varden in 3 study streams during 1980. Station numbers in parenthesis.

	Coho		Dolly Varden	
	Direction			
Stream	Up	Down	Up	Down
Tye Creek				
No. fish recaptured and % recaptures that moved	134(9.0%)		49(14.0%)	
Distance	40(6-4)	2@40(1-3)	40(7-5)	40(1-3)
	40(3-1)	2@60(5-8)	60(8-5)	80(4-8)
		4@80(4-8)	80(7-3)	2@100(3-8)
		120(1-7)		
		140(1-8)		
Toad Creek				
No. fish recaptures and % recaptured that moved	231(5.0%)		217(7.0%)	
Distance	3@120(4-1)	40(5-6)	80(4-2)	40(2-3)
		40(7-8)	2@120(7-4)	120(5-8)
		80(2-4)		160(4-8)
		80(4-6)		200(4-9)
		80(6-8)		
		100(3-8)		
		120(4-7)		
		160(3-7)		
		160(4-8)		
Aha Creek				
No. fish recaptured and % recaptures that moved	163(9.0%)		187(6.0%)	
Distance	60(8-6)	40(1-2)	2@80(5-3)	40(3-4)
	2@80(5-3)	80(5-7)	3@120(6-3)	80(1-3)
	80(6-4)	120(5-8)	120(8-5)	80(3-5)
	5@120(6-3)	240(2-8)		80(6-8)
	160(8-4)			120(3-6)
				200(3-8)
Knob Creek				
No. fish recaptured and % recaptures that moved	207(4.0%)		55(2.0%)	
Distance	3@40(5-4)	120(4-7)		80(1-3)
	40(2-1)			
	40(3-2)			
	80(4-2)			
	80(6-4)			
	200(6-1)			

Table 11. Direction and distance (m) of interstation movements by juvenile coho and Dolly Varden in 3 study streams during 1981. Station numbers in parenthesis.

	Coho		Dolly Varden	
		Direction		
Stream	Up	Down	Up	Down
Tye Creek				
No. fish recaptured and % recaptures that moved	61(8.0%)		28(7.0%)	
Distance	60(7-4)	40(5-7)	40(3-1)	
	80(7-3)	100(3-8)	40(7-5)	
	100(8-3)			
Toad Creek				
No. fish recaptured and % recaptures that moved	93(0.0%)		137(5.0%)	
Distance			80(7-5)	80(2-4)
				120(1-4)
				4@120(4-7)
Aha Creek				
No. fish recaptured and % recaptures that moved	172(9.0%)		104(3.0%)	
Distance	80(8-6)	3@80(4-6)		80(6-8)
	80(7-5)	80(6-8)		120(2-5)
	80(4-2)	2@120(5-8)		200(1-6)
	120(8-5)	120(4-7)		
Knob Creek				
No. fish recaptured and % recaptures that moved	60(17.0%)		37(11.0%)	
Distance	40(3-2)	120(2-5)	80(3-1)	80(1-3)
	40(7-6)	2@120(4-7)	120(5-2)	120(3-6)
	80(3-1)	160(3-7)		
	80(6-4)			
	120(5-2)			
	160(6-2)			

Population Abundance

Population estimates for age 0+ and age 1+ coho and age 1+ and age 2+ Dolly Varden in Tye, Toad, Knob and Aha creeks are presented in Appendix Tables 1-6. It was not possible to calculate population estimates for age 0+ Dolly Varden or cutthroat trout and steelhead of any age; Dolly Varden because of small size and cutthroat and steelhead because of insufficient numbers. Sampling was not conducted during September, 1979 and no Petersen estimates were calculated for that month. However, point estimates for September were derived by extrapolation of the trend in previous months using regression techniques.

Tables 12-15 contain population density estimates for coho and Dolly Varden in Tye, Toad, Knob, and Aha creeks, respectively . Densities of fish within a subsection generally declined between monthly sampling periods and varied relatively little from year to year. Though initial densities of YOY coho were frequently high, emigration and mortality quickly reduced their numbers to comparable levels among years. The June 1980 density estimates for YOY coho in Tye Creek (Table 12) were the highest recorded for any group due to the inclusion of fish that were soon to emigrate. These inflated estimates were therefore not representative of the YOY coho population densities that the stream could support.

Table 12. Density (N/m^2) of fish in cleaned (C) and uncleaned (U) subsections of Tye Creek, 1978-1981.

Species, age class Month	1978 C	1978 U	1979 C	1979 U	1980 C	1980 U	1981 C	1981 U
Coho 0+								
June			2.20	2.86	35.57	18.33	0.82	1.36
July	0.90	2.33	1.42	2.13	3.98	3.94	0.68	1.23
August			0.93	1.60	1.10	1.60	0.59	1.17
September	0.73	1.31	0.60	1.19	0.44	0.85	0.53	1.12
Coho 1+								
June			0.41	0.56	0.25	0.43	0.25	0.28
July	0.32	0.40	0.36	0.51	0.21	0.37	0.22	0.26
August			0.32	0.45	0.19	0.31	0.21	0.25
September	0.25	0.37	0.29	0.42	0.17	0.26	0.20	0.23
Dolly Varden 1+								
June			0.36	0.43	0.17	0.34	0.37	0.22
July	0.32	0.65	0.36	0.40	0.16	0.30	0.35	0.21
August			0.35	0.38	0.15	0.26	0.32	0.20
September	0.41	0.51	0.34	0.36	0.15	0.23	0.30	0.18
Dolly Varden 2+								
June			0.26	0.39	0.19	0.19	0.11	0.10
July	0.21	0.55	0.25	0.37	0.18	0.18	0.08	0.09
August			0.25	0.36	0.17	0.15	0.07	0.08
September	0.15	0.25	0.24	0.35	0.16	0.15	0.05	0.07

Uncleaned stream subsections in Tye and Toad Creeks had either greater or similar densities of fish as cleaned subsections (Tables 12 and 13). The only exception to this general relationship occurred in Tye Creek during the 1981 season when September age 1+ Dolly Varden densities were lower in the uncleared than in the cleared subsection.

Table 13. Density (N/m^2) of fish in cleaned (C) and uncleaned (U) subsections of Toad Creek, 1978-1981.

Species, age class / Month	1978 C	1978 U	1979 C	1979 U	1980 C	1980 U	1981 C	1981 U
Coho 0+								
June			1.13	1.02	0.66	2.39	1.83	2.29
July	0.69	0.20	0.56	0.60	0.43	0.84	1.39	1.68
August			0.41	0.44	0.33	0.46	1.13	1.33
September	0.14	0.49	0.30	0.36	0.28	0.30	0.94	1.08
Coho 1+								
June			0.22	0.30	0.22	0.42	0.11	0.25
July	0.21	0.33	0.21	0.27	0.22	0.42	0.10	0.23
August			0.22	0.25	0.22	0.41	0.10	0.22
September	0.22	0.24	0.21	0.23	0.21	0.41	0.10	0.20
Dolly Varden 1+								
June			0.31	0.33	0.31	0.28	0.31	0.29
July	0.36	0.32	0.28	0.31	0.29	0.27	0.29	0.29
August			0.27	0.28	0.27	0.26	0.28	0.28
September	0.32	0.44	0.24	0.26	0.25	0.26	0.27	0.28
Dolly Varden 2+								
June			0.31	0.58	0.19	0.59	0.32	0.37
July	0.25	0.34	0.29	0.49	0.18	0.55	0.32	0.35
August			0.30	0.41	0.17	0.51	0.31	0.34
September	0.17	0.27	0.28	0.34	0.16	0.47	0.30	0.33

The relationship of debris removal to fish densities was less distinct in Knob Creek (Table 14). In 1980 densities of coho and Dolly Varden were greatest where there was no debris removal. This relationship changed in 1981; the uncleaned subsection supported fewer age 0+ coho and both age classes of Dolly Varden, but more age 1+ coho

Table 14. Density (N/m^2) of fish in totally cleaned (C), partially cleaned (P) and uncleaned subsections of Knob Creek, 1980-1981.

Species, age class Month	Year Subsection					
	1980			1981		
	C	P	U	C	P	U
Coho 0+						
June	0.35	0.58	0.61	1.41	1.25	0.76
July	0.33	0.51	0.55	1.35	1.19	0.76
August	0.31	0.45	0.52	1.28	1.15	0.76
September	0.29	0.40	0.50	1.22	1.10	0.76
Coho 1+						
June	0.35	0.50	0.60	0.22	0.19	0.34
July	0.34	0.47	0.55	0.22	0.18	0.32
August	0.32	0.45	0.51	0.20	0.17	0.29
September	0.30	0.43	0.47	0.20	0.17	0.27
Dolly Varden 1+						
June	0.21	0.10	0.29	0.38	0.12	0.16
July	0.20	0.10	0.28	0.35	0.12	0.15
August	0.20	0.10	0.27	0.32	0.12	0.15
September	0.19	0.10	0.26	0.29	0.11	0.14
Dolly Varden 2+						
June	0.26	0.24	0.40	0.35	0.11	0.31
July	0.25	0.24	0.38	0.33	0.09	0.29
August	0.24	0.23	0.37	0.31	0.08	0.27
September	0.23	0.23	0.36	0.29	0.07	0.25

than in the uncleaned subsection. Coho densities in the partially cleaned subsection were intermediate between the totally cleaned and uncleaned subsections except for yearlings in 1981. Dolly Varden densities always were lowest in the partially cleaned subsection.

Table 15. Density (N/m^2) of fish in Aha Creek, 1979-1981.

Species, age class Month	Year 1979	 1980	 1981
Coho 0+			
June	4.32	5.48	0.84
July	1.13	1.53	0.72
August	0.52	0.73	0.64
September	0.30	0.43	0.59
Coho 1+			
June	0.16	0.13	0.19
July	0.15	0.13	0.17
August	0.14	0.13	0.16
September	0.14	0.12	0.14
Dolly Varden 1+			
June	0.32	0.23	0.24
July	0.30	0.23	0.24
August	0.29	0.22	0.23
September	0.28	0.21	0.23
Dolly Varden 2+			
June	0.10	0.13	0.20
July	0.07	0.13	0.20
August	0.05	0.13	0.19
September	0.04	0.12	0.19

Population densities in Aha were usually lower than in the other streams (Table 15). The June, 1979 and 1980 estimates for age 0+ coho, however, were among the largest observed in any stream. This may have been due to the presence of emigrating or soon to emigrate individuals. No two-way traps were used on Aha Creek to explicitly evaluate this possibility, but emigration from Tye and Toad creeks at least in 1980 was incomplete during the same time period.

Fish Weights

The parameter estimates from the regressions of $\log_{10}$ length on $\log_{10}$ weight for coho and Dolly Varden are presented in Appendix Tables 7-8, respectively. Separate regressions were calculated for each subsection in 1980 and 1981. Length-weight regressions for 1979 were based on data from 1980 and 1981 pooled by species.

Mean monthly weights for each species and age class in cleaned and uncleaned subsections of Tye and Toad creeks are presented in Tables 16 and 17 respectively. Mean weights for age 0+ and age 1+ coho were greater in cleaned subsections with the exception of age 1+ coho in Toad during 1981. Before cleaning in 1979, mean weights for coho showed no relation to stream subsection. Weights of Dolly Varden from Tye and Toad creeks did not appear to be related to stream cleaning.

In Knob Creek coho weights were greater in the partially or totally cleaned subsections; in contrast, Dolly Varden weights were generally greater in undisturbed subsections (Table 18). Mean weights for fish in Aha Creek (Table 19) were within the range found in the other study streams.

Table 16. Mean weights of fish (g) in cleaned (C) and uncleaned (U) subsections of Tye Creek, 1979-1981.

Species, age class Month	1979 C	1979 U	1980 C	1980 U	1981 C	1981 U
Coho 0+						
June	0.42	0.42	0.34	0.36	0.53	0.55
July	0.51	0.52	0.44	0.44	0.65	0.63
August	0.62	0.63	0.57	0.54	0.79	0.73
September	0.74	0.77	0.74	0.67	0.86	0.83
Coho 1+						
June	2.76	2.58	3.30	2.79	2.73	2.31
July	2.84	2.82	3.70	3.16	3.03	2.69
August	2.92	3.09	4.15	3.57	3.36	3.12
September	3.01	3.38	4.65	4.03	3.73	3.62
Dolly Varden 1+						
June	1.27	1.17	1.82	1.79	1.70	1.61
July	1.40	1.37	2.07	1.96	1.77	1.68
August	1.55	1.61	2.36	2.15	1.83	1.76
September	1.71	1.88	2.69	2.35	1.90	1.85
Dolly Varden 2+						
June	5.08	5.25	9.07	9.48	5.62	6.12
July	5.36	5.76	9.49	10.10	5.85	6.42
August	5.66	6.31	9.94	10.75	6.09	6.73
September	5.98	6.92	10.40	11.45	6.35	7.06

Table 17. Mean weights of fish (g) in cleaned (C) and uncleaned (U) subsections of Toad Creek, 1979-1981.

Species, age class Month	1979 C	1979 U	1980 C	1980 U	1981 C	1981 U
Coho 0+						
June	0.70	0.56	0.72	0.57	0.85	0.68
July	0.88	0.76	0.88	0.73	1.02	0.80
August	1.11	1.02	1.07	0.92	1.22	0.95
September	1.39	1.36	1.30	1.17	1.45	1.12
Coho 1+						
June	3.99	4.07	3.78	3.62	3.24	3.38
July	4.47	4.41	4.17	3.99	3.54	3.75
August	5.02	4.78	4.60	4.40	3.87	4.16
September	5.63	5.17	5.07	4.84	4.23	4.61
Dolly Varden 1+						
June	1.84	1.97	2.35	2.17	1.96	2.26
July	1.98	2.26	2.55	2.40	2.07	2.44
August	2.14	2.58	2.77	2.65	2.19	2.63
September	2.31	2.95	3.01	2.93	2.31	2.84
Dolly Varden 2+						
June	5.91	6.63	6.22	6.12	6.26	6.39
July	6.18	6.91	6.77	6.53	6.48	6.63
August	6.47	7.19	7.37	6.96	6.70	6.89
September	6.77	7.49	8.03	7.42	6.92	7.15

Table 18. Mean weights (g) of fish in totally cleaned (C), partially cleaned (P), and uncleaned (U) subsections of Knob Creek, 1980-1981.

Species, age class Month	Year Subsection					
	1980			1981		
	C	P	U	C	P	U
Coho 0+						
June	1.27	1.28	1.43	0.93	0.91	0.92
July	1.54	1.58	1.57	1.16	1.21	1.15
August	1.87	1.96	1.72	1.44	1.61	1.45
September	2.26	2.42	1.89	1.79	2.14	1.81
Coho 1+						
June	4.32	4.20	4.10	4.85	3.99	4.10
July	4.95	4.64	4.47	5.17	4.64	4.62
August	5.66	5.14	4.87	5.51	5.41	5.21
September	6.49	5.68	5.31	5.88	6.30	5.88
Dolly Varden 1+						
June	2.39	2.21	2.51	2.54	2.81	2.87
July	2.54	2.45	2.62	2.80	2.94	3.08
August	2.70	2.72	2.73	3.09	3.08	3.31
September	2.87	3.03	2.84	3.41	3.22	3.55
Dolly Varden 2+						
June	5.88	4.85	5.59	5.15	6.42	6.46
July	6.51	5.28	5.93	5.61	6.59	6.69
August	7.22	5.75	6.28	6.11	6.77	6.94
September	8.01	6.26	6.66	6.65	6.95	7.20

Table 19. Mean weights of fish (g) in Aha Creek, 1979-1981.

Species, age class Month	Year Subsection		
	1979	1980	1981
Coho 0+			
June	0.49	0.54	0.63
July	0.64	0.71	0.74
August	0.83	0.95	0.88
September	1.08	1.26	1.03
Coho 1+			
June	2.95	3.29	2.65
July	3.30	3.77	3.02
August	3.68	4.33	3.43
September	4.11	4.97	3.90
Dolly Varden 1+			
June	1.58	1.65	1.71
July	1.82	1.91	1.87
August	2.09	2.21	2.04
September	2.40	2.56	2.23
Dolly Varden 2+			
June	5.36	5.93	4.94
July	5.88	6.71	5.41
August	6.44	7.59	5.93
September	7.06	8.60	6.49

Production

Production is probably the most comprehensive population parameter by which a species performance can be evaluated in a given environment (LeCren 1969). Estimates of population size, mortality and the growth rates and sizes of individuals within a population are reflected in production estimates. Monthly growth rates and biomass and production estimates per m^2 for Tye, Toad, Knob and Aha creeks appear in Appendix Tables 9-10, 11-12, 12-14 and 15, respectively.

In 1979 and 1981, the total seasonal production in Tye Creek was greater in the uncleaned than in the cleaned subsection (Table 20). Total production in 1980 was greater in the cleaned subsection, however, due to the high June population estimate for age 0+ coho which included fish that had not yet emigrated. Densities of age 0+ coho in the cleaned declined faster than in the uncleaned subsection (Table 12) and by September, production was greater in the latter (Appendix Table 9). Yearling Dolly Varden production during 1981 was greater in the cleaned subsection primarily because of greater fish density (Table 12) and to a lesser degree greater fish weight (Table 16).

The pattern of total seasonal fish production from 1979-1981 in Toad Creek (Table 21) was similar to that in Tye Creek and demonstrated greater production by all groups in the uncleaned subsections. In 1979 yearling and in 1981 subyearling coho production was greater in the cleaned subsection. The higher yearling production in 1979 supports the contention that stream cleaning was responsible for the lower production in the cleaned subsection in subsequent years. In 1981, greater production by age 0+ coho in the cleaned subsection primarily resulted from larger fish size (Table 21). Dolly

Table 20. Summary of June-September production in g/m^2 by coho salmon and Dolly Varden in cleaned (C) and uncleaned (U) subsections of Tye Creek.

Species and age class	Production g/m^2 Year 1979		1980		1981	
Subsection	C	U	C	U	C	U
Coho 0+	0.376	0.636	2.234	1.252	0.272	0.345
Coho 1+	0.088	0.384	0.262	0.412	0.211	0.336
subtotal	0.464	1.020	2.496	1.664	0.483	0.681
Dolly Varden 1+	0.157	0.280	0.136	0.156	0.066	0.048
Dolly Varden 2+	0.210	0.599	0.256	0.310	0.042	0.083
subtotal	0.367	0.879	0.392	0.466	0.108	0.131
Total	0.831	1.899	2.888	2.130	0.591	0.812

Varden production was always greater in the uncleaned subsection.

The relationship of stream cleaning to production in Knob Creek (Table 22) was the opposite of that in Tye and Toad creeks with total production greatest where at least some stream cleaning had been performed. Total coho production was always lowest in the uncleaned and highest in the partially cleaned subsections. Production by age 0+ coho was greatest in the partially cleaned and lowest in the uncleaned subsection during both 1980 and 81. Production by age 1+ coho was greatest in the uncleaned subsection during 1981 but lowest during 1980. However, the difference between the highest and lowest yearling coho production in 1980 was only 0.043 g/m^2. The pattern of Dolly Varden production also was less distinct in Knob Creek, with production in the uncleaned subsection intermediate between the partially cleaned (lowest) and totally cleaned (highest) subsections.

Table 21. Summary of June-September production in g/m^2 by coho salmon and Dolly Varden in cleaned (C) and uncleaned (U) subsections of Toad Creek.

Species and age class	Production g/m^2 Year 1979		1980		1981	
Subsection	C	U	C	U	C	U
Coho 0+	0.359	0.417	0.226	0.452	0.751	0.652
Coho 1+	0.360	0.288	0.288	0.515	0.102	0.267
subtotal	0.719	0.705	0.514	0.967	0.853	0.919
Dolly Varden 1+	0.133	0.283	0.177	0.201	0.097	0.167
Dolly Varden 2+	0.267	0.381	0.312	0.637	0.185	0.282
subtotal	0.400	0.664	0.489	0.838	0.282	0.449
Total	1.119	1.369	1.003	1.805	1.135	1.368

Production values in Aha Creek were similar to those in the other study streams (Table 23). Total production in 1979 and 1980 was affected by high age 0+ coho population densities (Table 15), which resulted from incomplete emigration noted in the population density section.

Table 22. Summary of June-September production in g/m^2 by coho salmon and Dolly Varden in totally cleaned (C), partially cleaned (P) and uncleaned (U) subsections of Knob Creek.

Species and age class	Production g/m^2 Year 1980			1981		
Subsection	C	P	U	C	P	U
Coho 0+	0.312	0.535	0.240	1.135	1.426	0.667
Coho 1+	0.710	0.678	0.667	0.198	0.401	0.551
subtotal	1.022	1.213	0.907	1.333	1.827	1.218
Dolly Varden 1+	0.094	0.079	0.089	0.296	0.053	0.101
Dolly Varden 2+	0.500	0.326	0.413	0.509	0.053	0.231
subtotal	0.594	0.405	0.502	0.805	0.106	0.332
Total	1.616	1.618	1.409	2.138	1.933	1.550

Table 23. Summary of June-September production in g/m² by coho salmon and Dolly Varden in the study section on Aha Creek.

Species and age class	Production g/m² Year 1979	1980	1981
Coho 0+	0.631	0.976	0.272
Coho 1+	0.168	0.220	0.208
subtotal	0.799	1.196	0.480
Dolly Varden 1+	0.242	0.206	0.124
Dolly Varden 2+	0.106	0.331	0.298
subtotal	0.348	0.537	0.422
Total	1.147	1.733	0.902

Microhabitat

Preliminary K-S tests showed that there were only minor differences in values of microhabitat variables between streams. Data from all microhabitat sites were therefore pooled for subsequent analyses.

Frequency distributions for water depth (D) and depth of water at focal points (FPD) showed that both age classes of coho usually were found at specific midwater locations with age 1+ coho occupying sites in deeper water (Figure 7). Subyearling Dolly Varden did not occupy specific focal points but were typically observed in shallow water on the

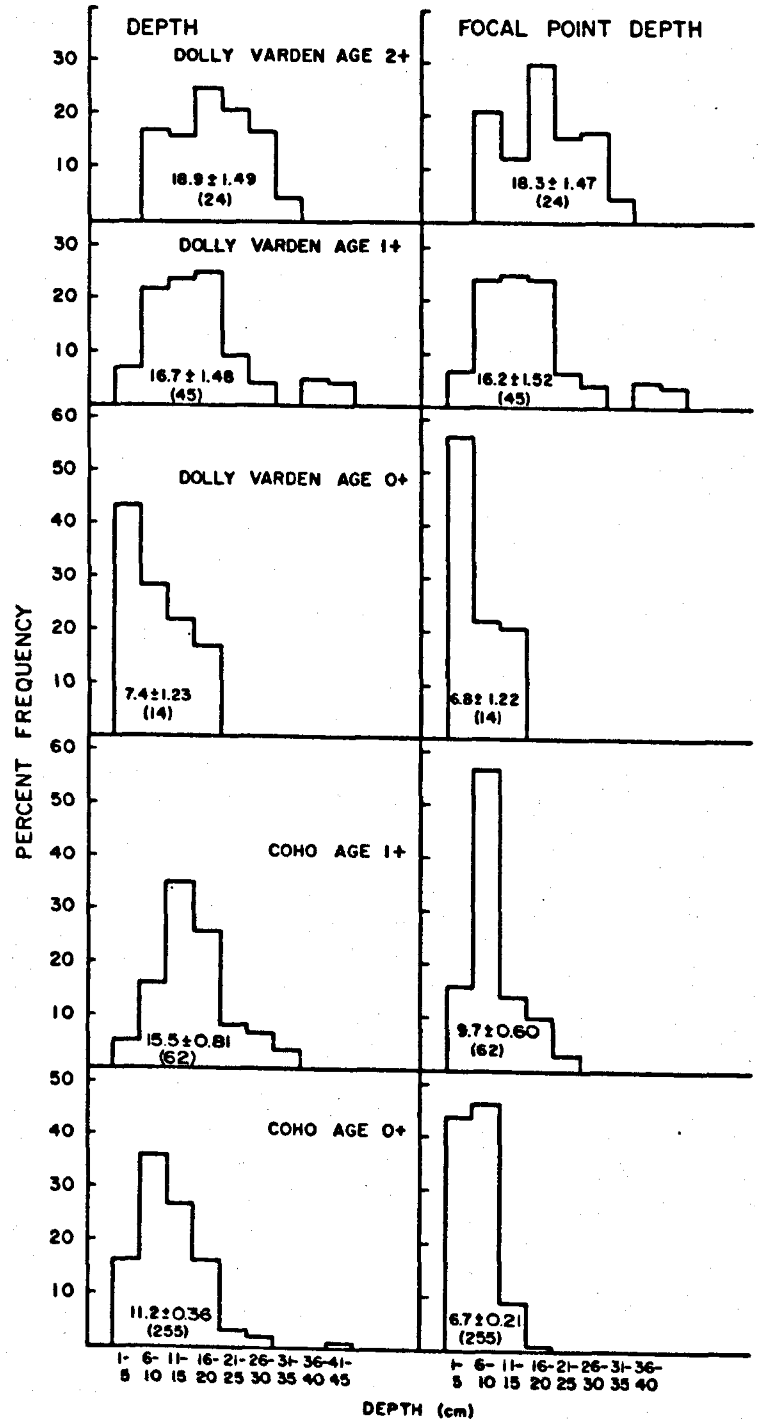

Figure 7. Frequency distributions, means and standard errors for water depths and focal point depths occupied by coho and Dolly Varden in 4 Southeast Alaska streams.

stream bottom. Older Dolly Varden occupied focal points located in the deepest water on or near the streambed.

The probabilities that values for D and FPD were equally distributed for any species-age class pair are presented in Table 24. With few exceptions, the use of D and FPD differed and appeared to be partitioned among the groups. Yearling coho and Dolly Varden were observed at similar D's but the Dolly Varden had deeper FPD's. Age 0+ coho and Dolly Varden apparently utilized similar D's and FPD's. However, the shallow focal point depths assigned to the Dolly Varden were related to the shallow depth of water. Age 1+ and 2+ Dolly Varden utilized similar D's and FPD's.

The distance to nearest cover (DTNC) from fish focal points decreased for both species with increasing age (Figure 8). The affinity for cover was most apparent in the yearling and age 2+ Dolly Varden of which 53% and 88%, respectively, were found in cover (DTNC=0). Differences between species were more pronounced than differences within species (Table 25).

The distance to nearest fish was used as a generalized indicator of agonistic tendencies. Tolerance towards other fish as measured by the DTNF was greatest for subyearling Dolly Varden and least for yearling coho. For coho, the DTNF increased with fish size. The DTNF and fish size were

Table 24. Kolmogorov-Smirnov 2-tailed test p-value for differences in use of water depths and depths of focal points among groups of coho and Dolly Varden in 4 Southeast Alaska streams.

Species and age class	Water depth	Focal point depth
Coho 0+ and 1+	<0.001	<0.001
Coho 0+, Dolly Varden 0+	0.081	0.889
Coho 0+, Dolly Varden 1+	0.007	<0.001
Coho 0+, Dolly Varden 2+	<0.001	<0.001
Coho 1+, Dolly Varden 0+	0.003	0.043
Coho 1+, Dolly Varden 1+	0.836	<0.001
Coho 1+, Dolly Varden 2+	0.024	<0.001
Dolly Varden 0+ and 1+	0.014	0.005
Dolly Varden 0+ and 2+	0.002	0.001
Dolly Varden 1+ and 2+	0.055	0.347

not related for Dolly Varden. As was the case for DTNC, the differences in DTNF were more pronounced between species than among age classes (Table 25).

The distance to nearest conspecific fish (DTNCF) was measured to obtain an indication of the degree of territorial behavior exhibited by a fish towards other fish of the same species and age class (Figure 8). For all groups, DTNCF was greater than DTNF, indicating greater aggression towards conspecifics. However, due to complications introduced by the local abundance of conspecific fish and the physical characteristics of a site, the DTNCF did not accurately reflect territoriality. The distribution of values for the DTNCF maintained by yearling coho suggests that while these fish were highly

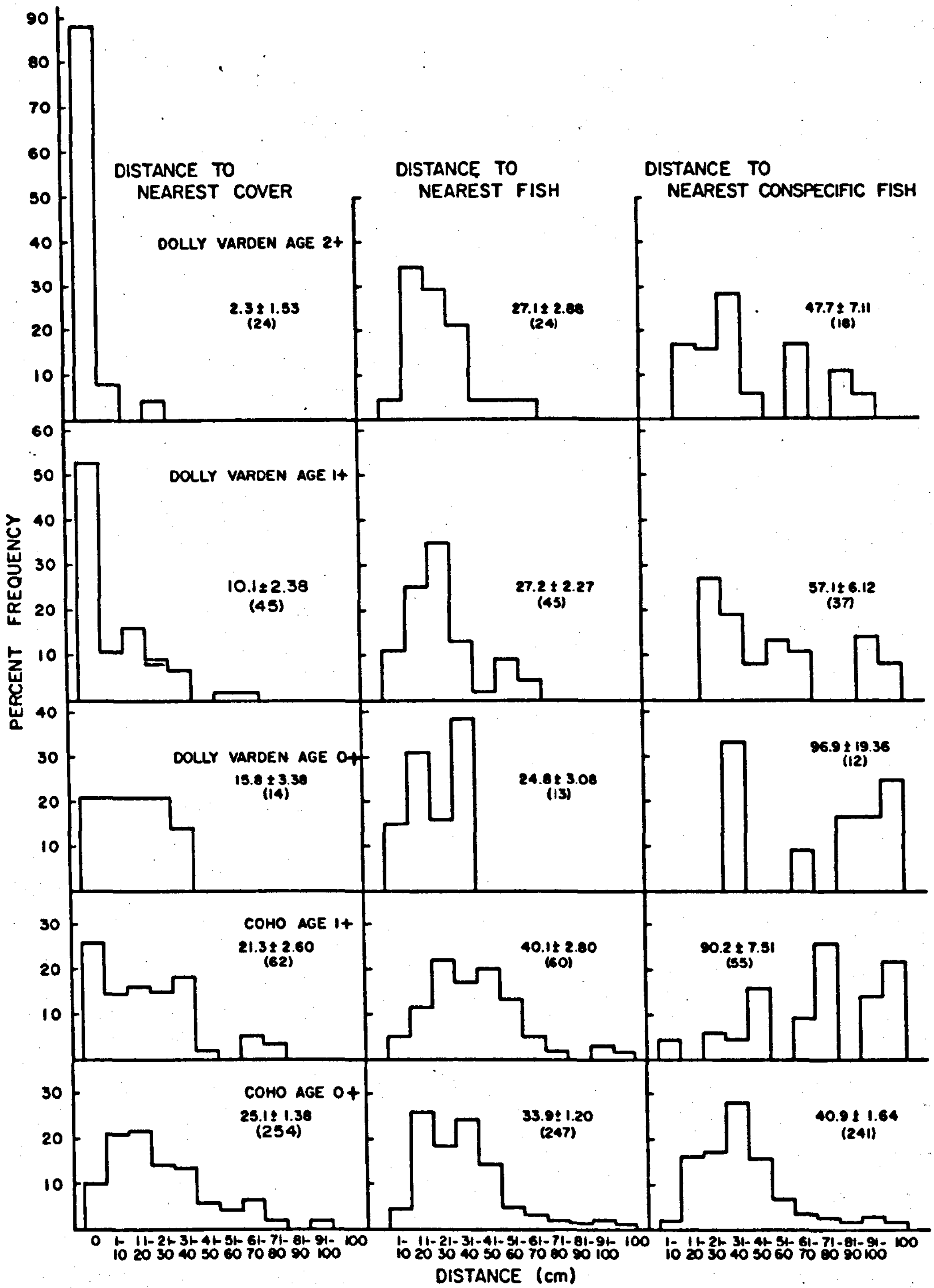

Figure 8. Frequency distributions, means, and standard errors for distance to nearest cover, distance to nearest fish and distance to nearest conspecific fish for coho and Dolly Varden in 4 Southeast Alaska streams.

territorial, at least a few tolerated conspecifics at close range. For yearling coho, the DTNCF may have been influenced both by the local abundance of conspecifics and by the degree of visual isolation between territories. At several sites, visual isolation was provided by wood debris or streambed topography, thereby allowing adjacent territory holders to coexist despite their proximity. Subyearling Dolly Varden appeared to be highly territorial because their average DTNCF exceeded all others (Figure 8). But the distribution of values for the DTNCF was related to the relative scarcity of sub-yearling Dolly Varden at individual sites and not territoriality. Aggression between these fish and fish of any other group was never observed. The DTNCF was therefore not considered in further analyses.

Table 25. Kolmogorov-Smirnov 2-tailed test p-value for differences in distance to nearest cover, fish and conspecific fish among groups of coho and Dolly Varden in 4 Southeast Alaska streams.

Species and age class	Distance to nearest cover	fish	conspecific fish
Coho 0+ and 1+	0.198	0.010	<0.001
Coho 0+, Dolly Varden 0+	0.393	0.218	0.003
Coho 0+, Dolly Varden 1+	<0.001	0.012	0.020
Coho 0+, Dolly Varden 2+	<0.001	0.270	0.293
Coho 1+, Dolly Varden 0+	0.697	0.005	0.609
Coho 1+, Dolly Varden 1+	0.001	0.001	<0.001
Coho 1+, Dolly Varden 2+	0.001	0.007	0.003
Dolly Varden 0+ and 1+	0.057	0.882	0.051
Dolly Varden 0+ and 2+	0.001	0.988	0.164
Dolly Varden 1+ and 2+	0.052	0.912	0.308

Water velocities at focal points were placed into three categories: zero; greater than zero but less than 9.0 cm/sec; and greater than or equal to 9.0 cm/sec (Figure 9). While velocities of less than approximately 9.0 cm/sec were difficult to measure, over 85% of the coho and 95% of the Dolly Varden occupied focal points where the velocity was between 0.0 and 9.0 cm/sec. Similar preferences by coho for areas having low water velocity were reported by Bustard and Narver (1975) in coastal British Columbia streams where 86% of the age 0+ and 84% of the age 1+ fish observed had focal point velocities between 0.0 and 15.0 cm/sec.

Cover

The percent of use of 11 cover categories are shown in Figure 10. In several instances it was not possible to assign a unique cover type to a fish observation which neccessitated the use of joint cover designations. These joint categories were treated as distinct cover types in this analysis.

Logs, branches, undercut banks, dense overhead vegetation, and large boulders undercut by current were the primary types of cover closest to fish of both species. These cover types had in common the ability to completely conceal fish at least from a streambank vantage point and were termed "superior" cover.

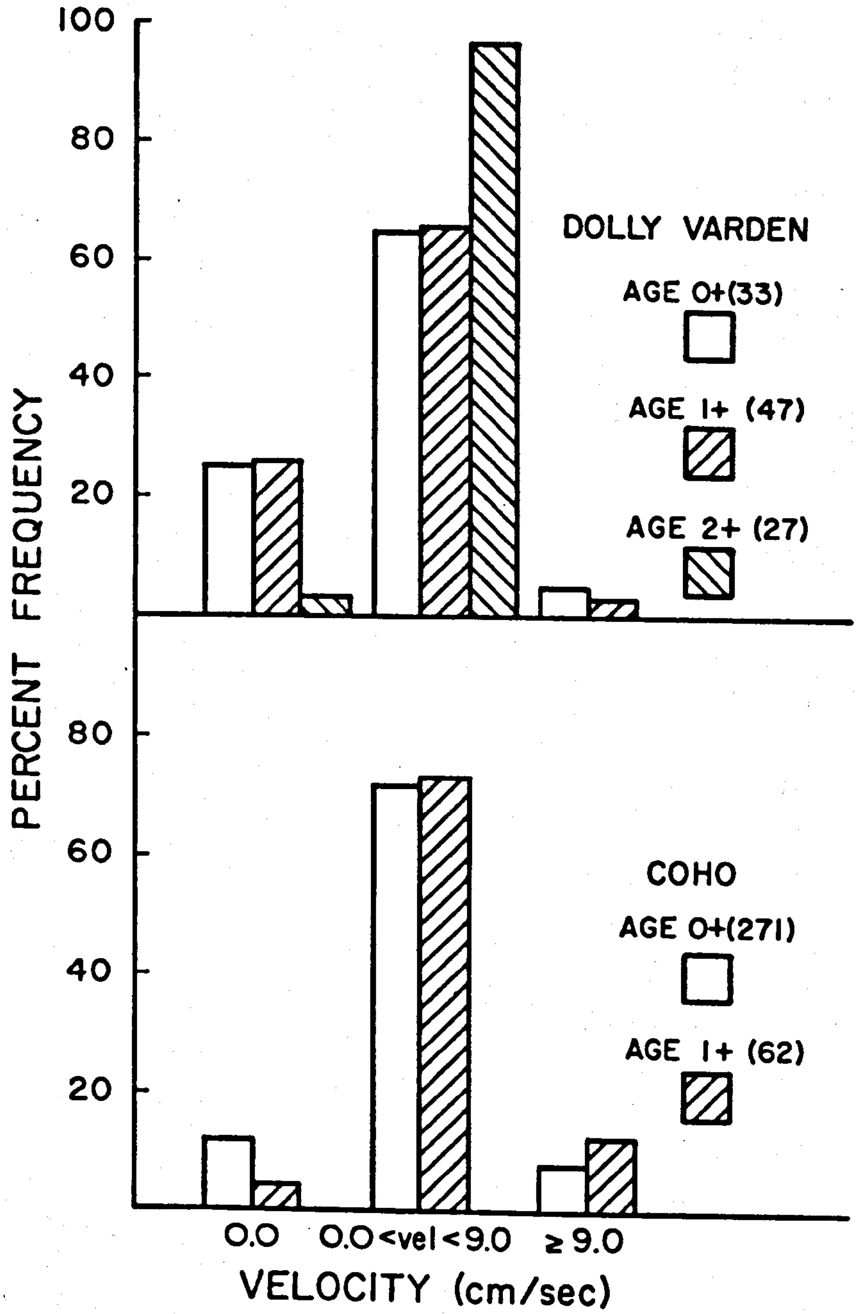

Figure 9. Frequency distribution for water current velocity at the focal points of coho and Dolly Varden in 4 Southeast Alaska streams.

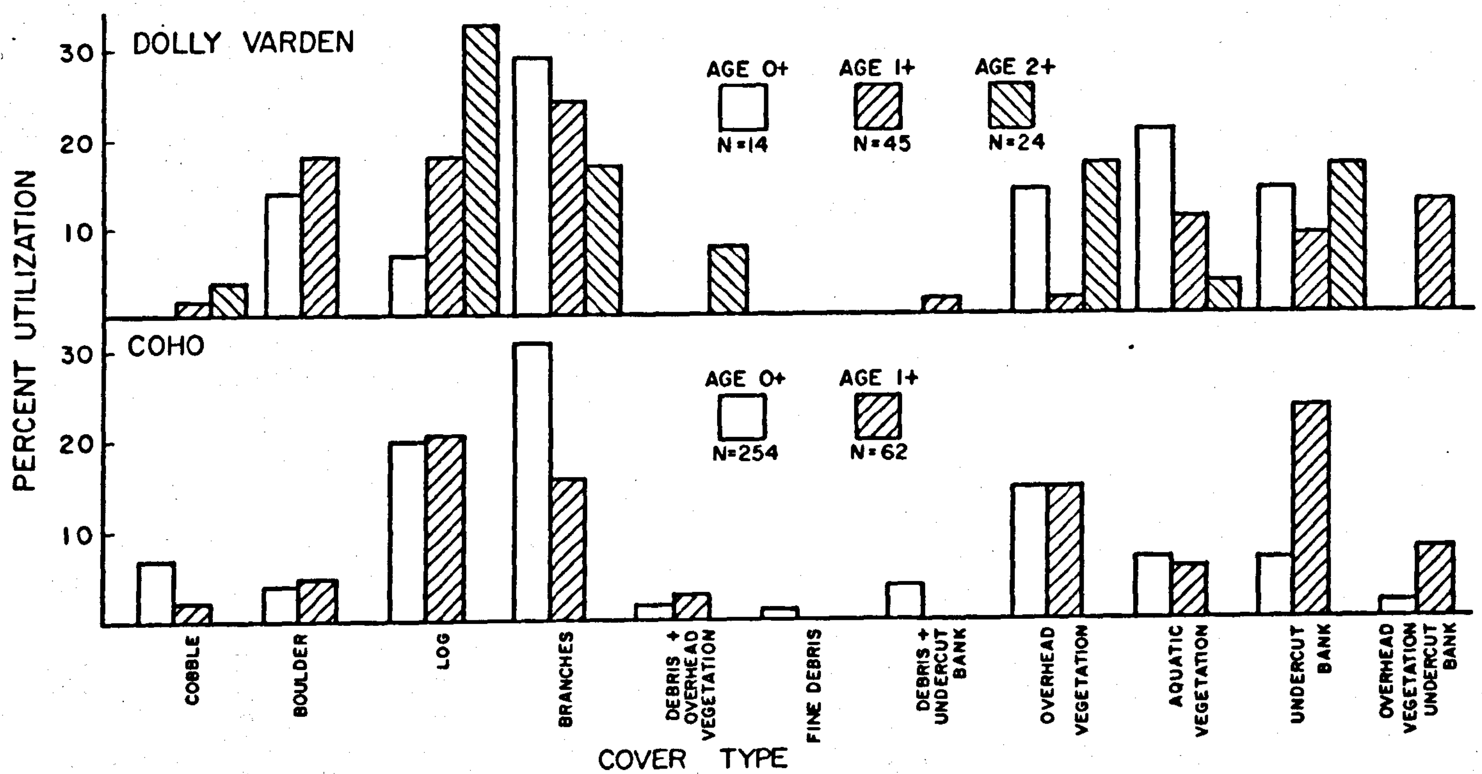

Figure 10. Percent usage of 11 cover types by coho and Dolly Varden in 4 Southeast Alaska streams.

Logs and branches alone comprized over 50% of the cover utilized by age 0+ coho (Figure 10). Logs and branches also were important to yearling coho. Along with undercut banks, these cover types accounted for over 60% of the cover used by yearling coho. The use of superior cover by yearling coho was, however, even greater than that indicated by the percent utilization figures. When yearling coho were disturbed, for example, by sudden movements of the observer on the streambank, they usually attempted to conceal themselves by darting to cover. In several instances these yearling coho by-passed the nearest cover and, instead, utilized more distant superior cover.

Branches and aquatic vegetation comprized 49% of the cover used by age 0+ Dolly Varden. Yearling and older Dolly Varden made the most extensive use of superior cover types with over 70% of the age 1+ and 85% of the age 2+ fish utilizing superior cover.

Larger values for cover niche breadth (Table 26) indicate utilization of diverse cover types, while smaller values indicate preference to a few cover types. Cover niche breaths were similar among the subyearlings and subyearlins of both species. The relatively narrow cover niche breadth for age 2+ Dolly Varden demonstrated their preference for superior cover.

Table 26. Niche breadth for utilization of 11 cover categories by juvenile coho and Dolly Varden.

Species and age class	Cover
Coho 0+	5.64
Coho 1+	6.11
Dolly Varden 0+	5.21
Dolly Varden 1+	6.22
Dolly Varden 2+	4.87

The three niche overlap indices yielded different overlap values for the cover data (Table 27) though the patterns of overlap within each index were similar. Values computed with any one index indicated overlap among at 80% of the species-age class pairs. The greatest overlap occurred between the largest body sized coho (age 1+) and Dolly Varden (age 2+) (Table 28). In contrast, the least overlap occurred between the smallest and largest groups: age 0+ and age 2+ Dolly Varden.

Substrate

Sixty-five percent of the age 0+ and 55% of the age 1+ coho were found over small and medium gravel (Figure 11). Similarly, 61% of the age 1+ and 55% of the age 2+ Dolly Varden used small and medium gravel. Age 0+ Dolly Varden were found over small gravel which together with rock and fine debris comprized their total substrate use. The narrow substrate niche breadth (Table 29) for age 0+ Dolly Varden demonstrated this limited use of substrate types.

Table 27. Overlap in utilization of 11 cover type categories for juvenile coho and Dolly Varden in 4 Southeast Alaska streams. O_{xy}=Schoener's measure, C_{xy}=Horn's measure, r_{xy}=correlation coefficient.

Species and age class	Cover		
	O_{xy}	C_{xy}	r_{xy}
Coho 0+ and 1+	0.74	0.83	0.66
Coho 0+, Dolly Varden 0+	0.69	0.84	0.71
Coho 0+, Dolly Varden 1+	0.69	0.82	0.66
Coho 0+, Dolly Varden 2+	0.69	0.85	0.75
Coho 1+, Dolly Varden 0+	0.63	0.76	0.56
Coho 1+, Dolly Varden 1+	0.67	0.78	0.56
Coho 1+, Dolly Varden 2+	0.78	0.91	0.86
Dolly Varden 0+ and 1+	0.68	0.83	0.69
Dolly Varden 0+ and 2+	0.57	0.65	0.40
Dolly Varden 1+ and 2+	0.53	0.68	0.42

Table 28. Means and standard errors for total lengths of a sample of juvenile salmonids in 4 Southeast Alaska streams.

Species and age class	Sample size	Mean total length	Standard error
Coho 0+	209	50.6	0.40
Coho 1+	53	75.3	1.50
Dolly Varden 0+	32	39.2	0.74
Dolly Varden 1+	31	70.7	1.82
Dolly Varden 2+	24	101.6	2.57

Table 29. Niche breadth for utilization of 10 substrate categories by juvenile coho and Dolly Varden.

Species and age class	Substrate
Coho 0+	3.61
Coho 1+	4.64
Dolly Varden 0+	2.79
Dolly Varden 1+	4.42
Dolly Varden 2+	3.81

As was the case for cover types, the values computed with the three niche overlap indices for substrate types were different but the patterns of overlap were similar (Table 30). All species-age class pairs demonstrated overlap in substrate use.

Table 30. Overlap in utilization of 10 substrate categories for juvenile coho and Dolly Varden. O_{xy}=Schoener's measure, C_{xy}=Horn's measure, r_{xy}=correlation coefficient.

Species and age class	Substrate		
	O_{xy}	C_{xy}	r_{xy}
Coho 0+ and 1+	0.86	0.95	0.95
Coho 0+, Dolly Varden 0+	0.70	0.86	0.81
Coho 0+, Dolly Varden 1+	0.76	0.91	0.87
Coho 0+, Dolly Varden 2+	0.58	0.67	0.48
Coho 1+, Dolly Varden 0+	0.73	0.88	0.88
Coho 1+, Dolly Varden 1+	0.85	0.96	0.93
Coho 1+, Dolly Varden 2+	0.69	0.82	0.70
Dolly Varden 0+ and 1+	0.81	0.95	0.98
Dolly Varden 0+ and 2+	0.76	0.87	0.84
Dolly Varden 1+ and 2+	0.71	0.87	0.79

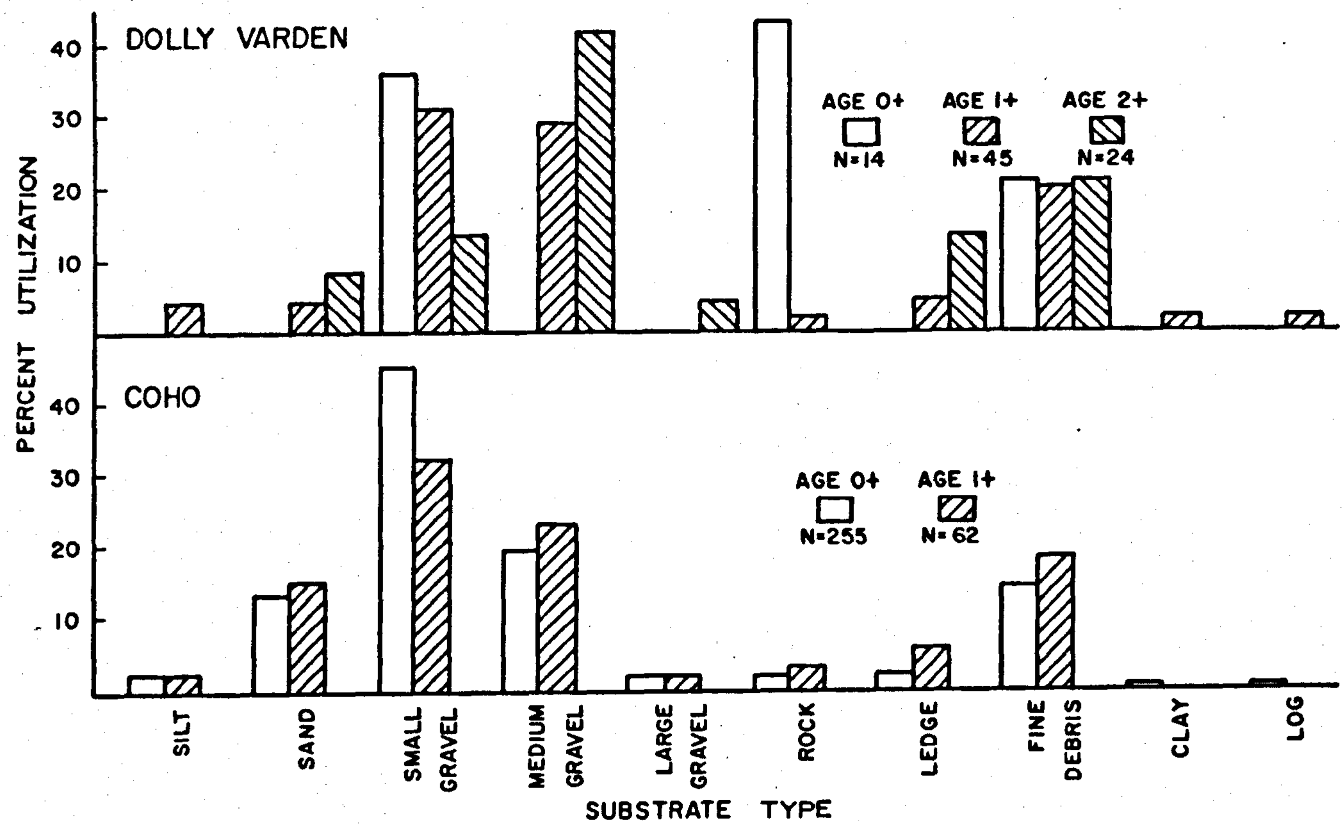

Figure 11. Percent usage of 10 substrate types by coho and Dolly Varden in 4 Southeast Alaska streams.

Discriminant Analysis--Physical Microhabitat Variables

The results of stepwise discriminant anaylsis on variables measured in the microhabitats of two age groups of coho and three age groups of Dolly Varden showed that all seven variables contributed to the separation and were retained by the stepwise procedure (Table 31). Four discriminant functions were computed; however, over 96% of the discriminatory power was contained in the first two which form the basis for the following discussion.

Table 31. Results from a 5-group discriminant analysis. Grouping and sample size (N) were coho age 0+ (246) coho age 1+ (60), Dolly Varden age 0+ (13), Dolly Varden age 1+ (45), Dolly Varden age 2+ (25).

	Discriminant function			
	I	II	III	IV
Percent of variance	88.16%	8.14%	3.32%	0.38%
Variable	Standardized discriminant function coefficients			
Depth (D)	1.675	1.293	-0.246	-0.592
Focal point depth (FPD)	-2.088	-0.426	0.094	0.387
Distance to nearest cover (DTNC)	0.344	-0.060	-0.140	0.450
Distance to nearest fish (DTNF)	0.136	0.581	-0.023	0.140
Velocity (V)	0.036	0.078	0.809	-0.424
Cover (C)	0.030	0.084	0.654	0.620
Substrate (S)	-0.120	-0.128	0.276	0.083

The absolute values of the standardized discriminant function coefficients listed in Table 31 show that in order of decreasing importance, FPD, D, DTNC, and DTNF contributed the most to group separation in the first discriminant function. The discriminant score centroids and ranges along the discriminant axis were plotted in Figure 12. A centroid represents the mean position of an individual group along the discriminant axis, while the range encompasses all the discriminant scores computed for each group. Differences among centroids represent the degree of separation along the function. Generalized gradients for the four variables dominating this function appear under the discriminant axis.

The first discriminant function primarily demonstrated differences between species. Compared to Dolly Varden, coho of both age classes were: higher in the water column; in shallower water; further from the nearest cover; and further from other fish. Within species differences also were apparent. The age classes of coho and Dolly Varden separate with regard to the variable gradients except for the DTNF for coho. This occurred because the DTNF was the fourth most important variable in the first function and therefore had less influence relative to the first three in distinguishing group differences.

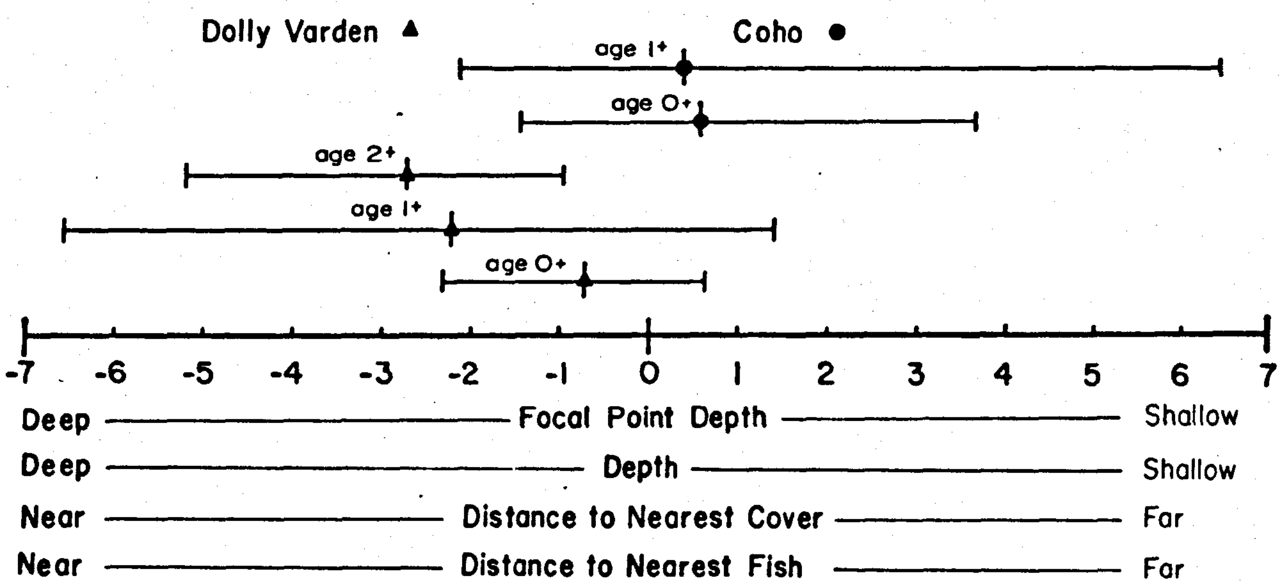

Figure 12. Mean and ranges of positions on the first discriminant axis for 5 groups of coho and Dolly Varden in 4 Southeast Alaska streams.

The most important variables in the second function were D, DTNF and FPD (Table 31). This function accurately described intraspecies differences observed for both species. Within both coho and Dolly Varden groups, the older fish were in deeper water further from other fish and had deeper focal point depths. However, the function did not make a clear distinction between species as evidenced by the position of the centroid for subyearling coho relative to those for age 1+ and 2+ Dolly Varden (Figure 13). Depth was the most important variable in this function but the distance to nearest fish was probably responsible for the more positive position of yearling coho in relation to all other groups. Centroids on the second axis were necessarily closer than on the first as the second function contained only 8% of the total discriminatory power.

Another useful feature of the discriminant analysis technique is the ability to predict group membership based on the group classification functions and values of the original variables (Klecka 1975). The classification matrix shown in Table 33 gives the proportion of cases correctly classified and distribution of incorrect classifications by group. The percent classification by group demonstrates the major separation by species with less distinction between individual age classes. Subyearling coho were most frequently misclassified as

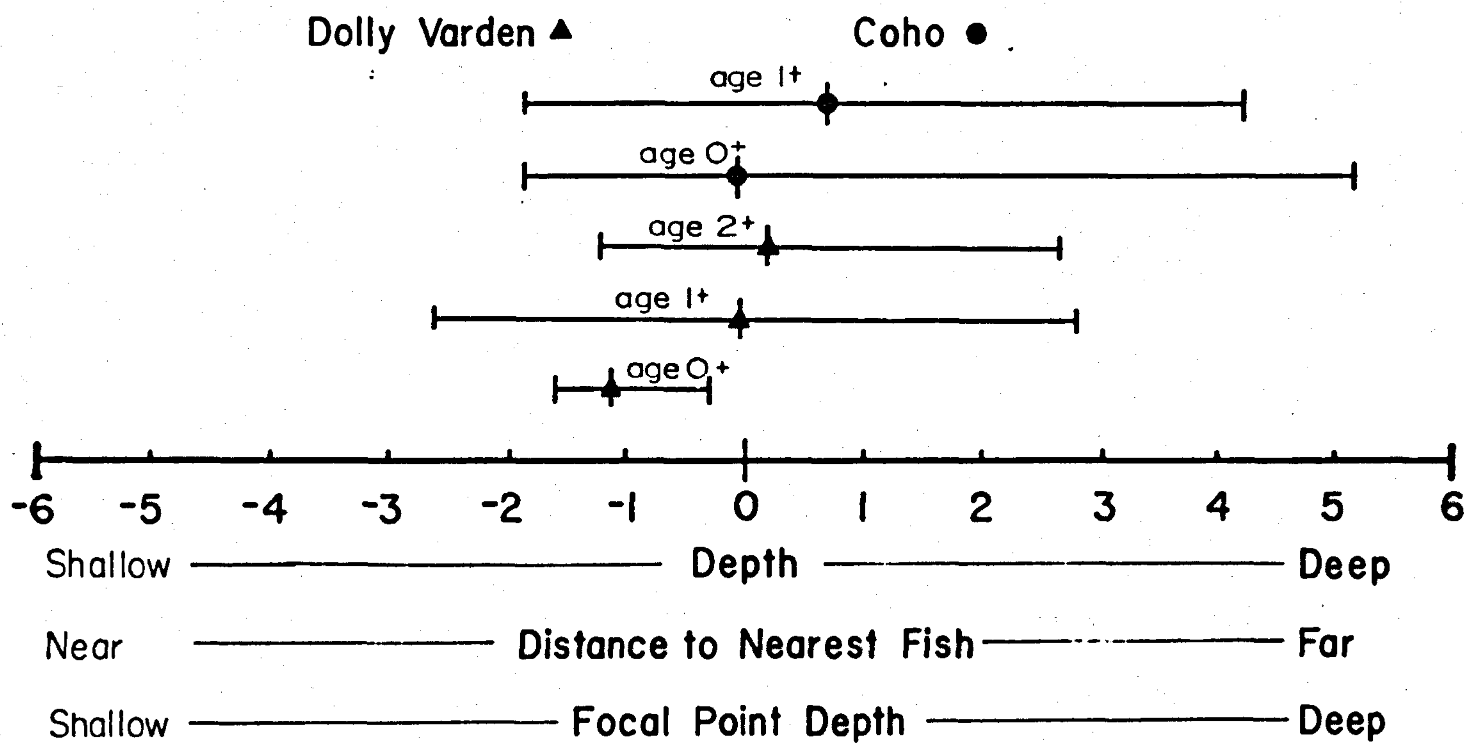

Figure 13. Mean and ranges of positions on the second discriminant axis for 5 groups of coho and Dolly Varden in 4 Southeast Alaska streams.

yearling coho and vice-versa. Over 85% of all coho were classified correctly. Likewise, Dolly Varden misclassifications mostly fell into other Dolly Varden groups. No age 2+ Dolly Varden were misclassified as coho and only 11.1% of age 1+ Dolly Varden were misclassified as subyearling and yearling coho.

Table 32. Predicted group membership based on classification functions derived from a discriminant analysis on 5 groups of juvenile salmonids from four Southeast Alaska streams. Actual numbers in parenthesis.

	Sample Size	Predicted Group Membership				
Actual Group	N	CO 0+	CO 1+	DV 0+	DV 1+	DV 2+
Coho age 0+ (CO 0+)	246	62.2% (153)	22.8% (56)	13.8% (34)	1.2% (3)	0.0% (0)
Coho age 1+ (CO 1+)	60	31.7% (19)	55.0% (33)	8.3% (5)	3.3% (2)	1.7% (1)
Dolly Varden age 0+ (DV 0+)	13	7.7% (1)	0.0% (0)	69.2% (9)	23.1% (3)	0.0% (0)
Dolly Varden age 1+ (DV 1+)	45	6.7% (3)	4.4% (2)	22.2% (10)	37.8% (17)	28.9% (13)
Dolly Varden age 2+ (DV 2+)	24	0.0% (0)	0.0% (0)	20.8% (5)	20.8% (5)	58.3% (14)

The discriminant function plots and classification matrix suggest that while differences exist among all five groups, the principal separation occurs between species. Age classes within a species merely occupied different locations on what was essentially a species continuum. To demonstrate this relationship, a two group (species) discriminant analysis was conducted using the combined age classes of both species. The results from this analysis appear in Table 33.

Table 33. Results from a 2-group discriminant analysis. Grouping and sample size (N) were coho (307) and Dolly Varden (82).

	Discriminant Function I
Percent of variance	100.00%
Variable	Standardized discriminant function coefficients
Depth (D)	1.892
Focal point depth (FPD)	-2.217
Distance to nearest cover (DTNC)	0.327
Distance to nearest fish (DTNF)	0.207
Substrate (S)	-0.152

Only 5 of the original 7 variables were required to account for all of the variance associated with the single discriminant function. The order of variable importance was the same as for the first discriminant function in the preceeding five-group analysis (Table 31), namely FPD, D, DTNC and DTNF. Coho occupied focal points that were higher in the water column, in deeper water, and further from cover and other fish than Dolly Varden. The plot of species discriminant score centroids and ranges illustrates the separation between species and reflects the overlap in computed discriminant scores along gradients of the four most important variables (Figure 14). The dashed vertical line represents the dividing line separating the zone of coho prediction from that for Dolly Varden. The right-facing arrow indicates those Dolly Varden that were misclassified as coho while the left arrow shows coho that were predicted to be Dolly Varden. The overlap along this multidimensional axis was 5.7%. The classification matrix (Table 34) illustrates the high degree of discrimination between species with over 96% of the coho and 85% of the Dolly Varden correctly classified.

Table 34. Predicted group membership based on classification functions derived from a discriminant analysis on two groups of juvenile salmonids from four Southeast Alaska streams. Actual classification numbers in parenthesis.

	Sample size	Predicted group membership	
Actual group	N	Coho	Dolly Varden
Coho	307	96.7% (297)	3.3% (10)
Dolly Varden	82	14.6% (12)	85.4% (70)

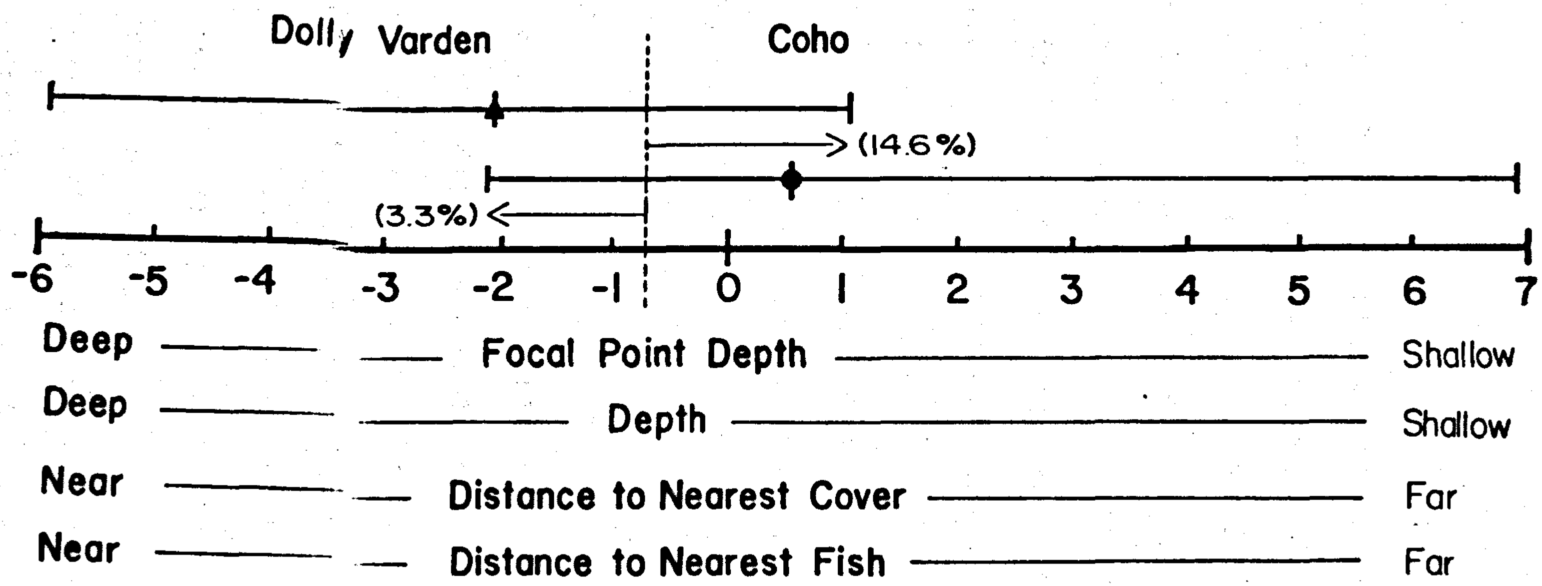

Figure 14. Mean positions and ranges along the discriminant axis for coho and Dolly Varden, age classes combined in 4 Southeast Alaska streams.

Food Resources

Prey Type

A total of 2,244 prey items was recovered from the stomachs of 162 juvenile salmonids. Only three fish, a subyearling coho, a yearling Dolly Varden and an age 2+ Dolly Varden, had empty stomachs. The breakdown of major prey taxa into 27 categories by percent number and volume is presented in Table 35. A prey type was considered as a separate category if it comprised 0.5% by number or volume of the diet of at least one group of fish. Most taxa were grouped at the ordinal level for ease of interpretation. Because all sampling was conducted during a single, 6-week interval, the data from all the streams were combined for all analyses.

Items from aquatic sources made up from 78%-92% by number of the fishes' diet (Table 35). Larval chironomidae, Collembola and larval Ephemeroptera comprized 51% and 46% of the stomach contents of both age 0+ and age 1+ coho, respectively. Adult Diptera from terrestrial sources and chironomidae were more prominent in the diets of yearling coho than subyearlings, indicating the greater success of the former group in exploiting drift or surface prey. Chironomid larvae and larval ephemeropterans comprized 70% and 43% respectively of the diets of age 1+ and age 2+

Table 35. Food resource categories from aquatic and terrestrial sources by percent number and percent volume for coho and Dolly Varden from 4 Southeast Alaska streams during July and August, 1981. N=number of stomachs sampled, A=adult, L=larvae.

Food category	CO Age 0+ N=68		CO Age 1+ N=42		DV Age 0+ N=3		DV Age 1+ N=26		DV Age 2+ N=23	
	%No.	%Vol.	%No.	%Vol.	%No.	%Vol.	%No.	%Vol.	%No.	%Vol.
Aquatic sources										
Acarina	7.28	2.88	3.97	0.83			1.36	0.37	1.18	0.01
Oligochaeta	1.17	1.73	0.15	0.74			0.34	0.19		
Ostracoda	7.19	1.40	0.15	0.01			1.02	0.28	1.78	0.00
Nematoda	0.27	0.01	2.14	0.06			1.34	0.02	5.33	0.18
Diptera A.	1.26	1.34	2.29	1.00					0.59	0.03
L.	5.49	4.04	2.90	2.39			1.69	0.93	1.78	0.03
Collembolla	10.52	2.32	17.71	3.23			0.68	0.06	4.14	0.13
Emphemeroptera										
A.	0.27	1.47	0.92	0.68			0.34	0.76	0.37	0.32
L.	9.26	9.98	10.84	4.09	38.46	74.50	30.17	34.11	23.08	1.66
Plecoptera A.	0.09	0.21	0.46	0.24						
L.	2.43	2.42	1.07	2.53	7.69	14.68	3.05	2.65	3.55	0.48
Trichoptera										
A.	0.18	0.06	1.22	6.68						
L.	3.42	17.93	1.98	15.97	7.69	3.55	5.08	30.90	9.47	19.48
Coleoptera	0.99	1.82	3.97	12.26			1.02	8.51	3.55	1.11
Chironomidae										
A.	4.05	0.21	11.45	0.49	15.38	1.55			5.92	0.07
L.	31.21	3.08	17.10	1.35	23.08	4.64	42.37	6.48	20.12	0.38
Miscellaneous	1.53	0.14							1.78	0.39
subtotal	86.58	50.03	78.32	50.54	92.30	98.92	88.46	85.26	84.64	24.27
Terrestrial sources										
Araneae	1.53	7.24	1.98	2.73			7.80	1.28	3.55	2.14
Diptera A.	2.43	2.58	6.41	2.78	7.69	1.08	0.68	0.61	2.37	0.22
Cercopidae	1.71	30.33	1.83	26.33					1.18	5.49
Cicadidae	0.27	2.01	1.22	4.51					1.78	0.53
Aphididae	3.15	1.46	4.12	1.24			1.69	0.44	2.96	0.20
Homoptera	0.72	0.22	0.61	0.56						
Hymenoptera	1.26	0.49	3.21	4.16			0.34	10.51	0.59	0.02
Lepidoptera	0.36	0.52	0.46	1.73			0.34	0.42		
Stylomatophora	0.09	1.21							1.78	65.80
Miscellaneous	1.89	3.92	11.83	5.43			0.68	1.48	1.18	1.30
subtotal	13.52	49.97	21.68	49.46	7.69	1.08	11.51	14.74	15.38	75.70
Total	100	100	100	100	100	100	100	100	100	100

Dolly Varden, illustrating the greater dependence of these fish on benthic prey production.

The dietary contribution of each taxa by percent volume presents a somewhat different picture than percent by number. Small items such as Chironomidae and Collembola made large numeric contributions, but the larger, less frequently encountered items such as Trichoptera and Coleoptera larvae and Homoptera together comprised the bulk of the stomach contents. Coho diets included approximately equal volumes of aquatic and terrestrial foods, with adult Homoptera and Trichoptera larvae comprising approximately 50% of the stomach contents. Ephemeroptera larvae were the most important in age 0+ and age 1+ Dolly Varden diets in terms of volume. Age 0+ and age 1+ Dolly Varden derived over 98% and 85% of their diet from aquatic sources. Terrestrial sources comprised over 75% of the diets of age 2+ Dolly Varden due to the inclusion of a small number of large slugs (Stylomatophora).

Food Niche Breadths and Overlaps

Food niche breadths and overlaps are presented in Table 36. Yearling coho had the largest niche breadth for both numbers and volume per prey taxa, indicating the most diverse diet.

Table 36. Niche breadth for utilization of 27 prey categories occurring in stomach samples of juvenile coho and Dolly Varden from 4 Southeast Alaska streams by percent number and volume.

Species and age class	Number	Volume
Coho 0+	7.28	6.75
Coho 1+	13.80	9.45
Dolly Varden 0+	4.12	1.72
Dolly Varden 1+	3.55	4.24
Dolly Varden 2+	8.38	2.11

Yearling and subyearling coho had considerable overlap in volume consumed per taxa (Table 37). They did not exhibit overlap in numbers per taxa, however, since yearling coho captured proportionally more individual prey items from terrestrial sources (Table 35).

Table 37. Overlap in 27 categories of prey by percent number and volume occurring in stomach samples of juvenile coho and Dolly Varden from 4 Southeast Alaska streams. O_{xy}=Schoener's measure, C_{xy}=Horn's r_{xy}=correlation coefficient.

Species and age class	Number			Volume		
	O_{xy}	C_{xy}	r_{xy}	O_{xy}	C_{xy}	r_{xy}
Coho 0+ and 1+	0.59	0.51	0.32	0.67	0.85	0.80
Coho 0+, Dolly Varden 0+	0.45	0.63	0.58	0.20	0.24	0.20
Coho 0+, Dolly Varden 1+	0.58	0.80	0.84	0.42	0.50	0.40
Coho 0+, Dolly Varden 2+	0.61	0.79	0.71	0.33	0.21	0.12
Coho 1+, Dolly Varden 0+	0.40	0.47	0.43	0.16	0.10	0.01
Coho 1+, Dolly Varden 1+	0.35	0.30	0.20	0.36	0.31	0.15
Coho 1+, Dolly Varden 2+	0.54	0.59	0.39	0.26	0.11	-0.01
Dolly Varden 0+ and 1+	0.62	0.84	0.82	0.46	0.67	0.72
Dolly Varden 0+ and 2+	0.62	0.86	0.92	0.06	0.04	-0.03
Dolly Varden 1+ and 2+	0.65	0.83	0.91	0.27	0.19	0.10

The diets of all Dolly Varden groups exhibited overlap by number per taxa but, with the exception of yearlings and subyearlings, not by volume. The lack of overlap by volume was partly attributable to a few large slugs in the diet of age 2+ Dolly Varden.

Subyearling coho diets showed overlap in numbers per taxa with both age 1+ and age 2+ Dolly Varden. Yearling coho did not exhibit dietary overlap with any Dolly Varden group.

Prey Size Selection

Individual prey items were grouped into 10 size categories ignoring their source or taxonomic affiliation. Size categories were chosen to reflect the volume of individual prey items occurring in stomach samples of each fish group. The cumulative percentages of prey volume in these size categories show that while prey appeared to be allocated according to fish size, with larger fish capturing larger items, large fish also utilized prey from the small end of the size spectrum (Figure 15). Prey size utilization by species appeared to be virtually identical (Figure 16).

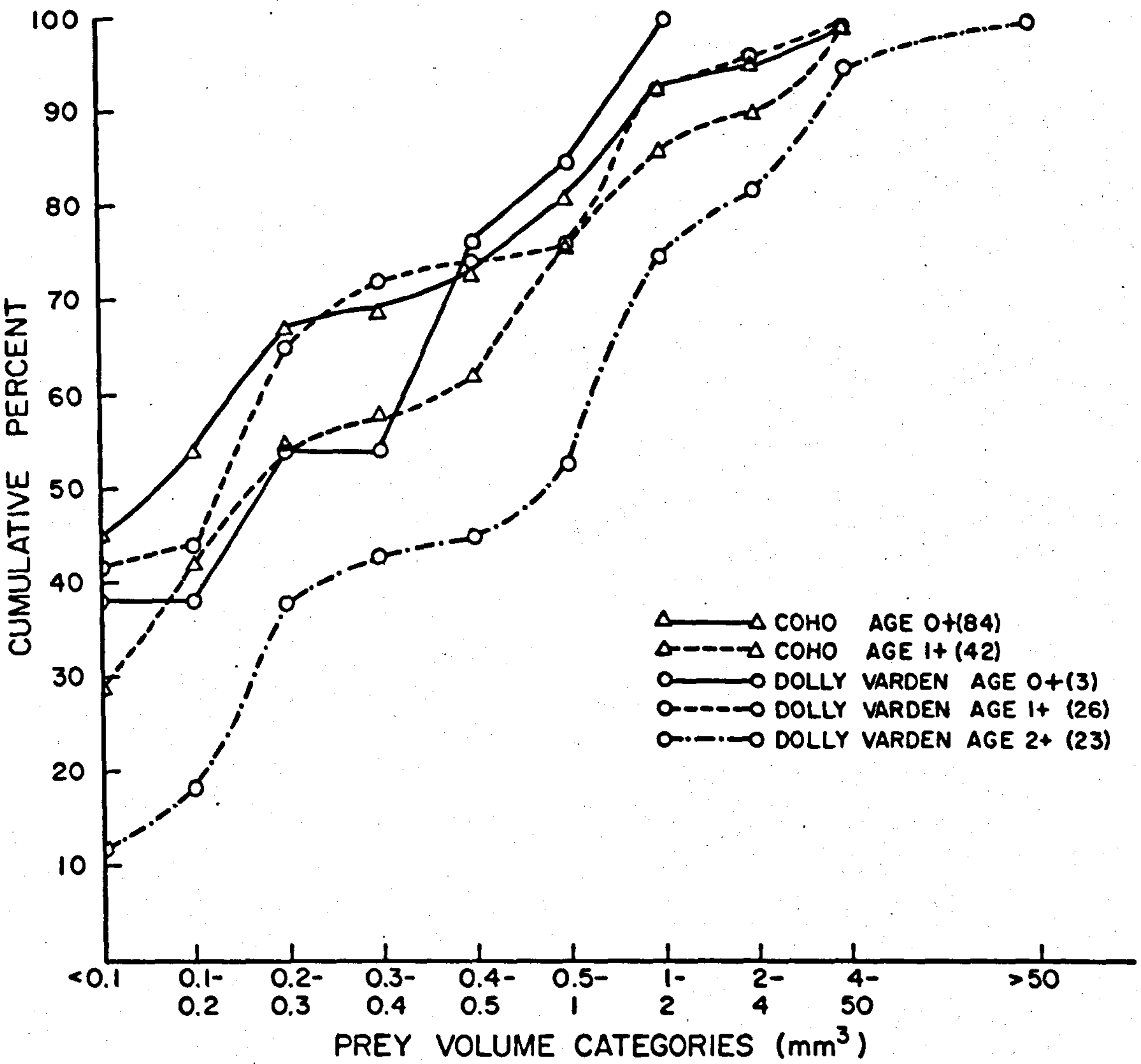

Figure 15. Cumulative percent of food in 10 size categories by 5 groups of juvenile coho and Dolly Varden in 4 Southeast Alaska streams.

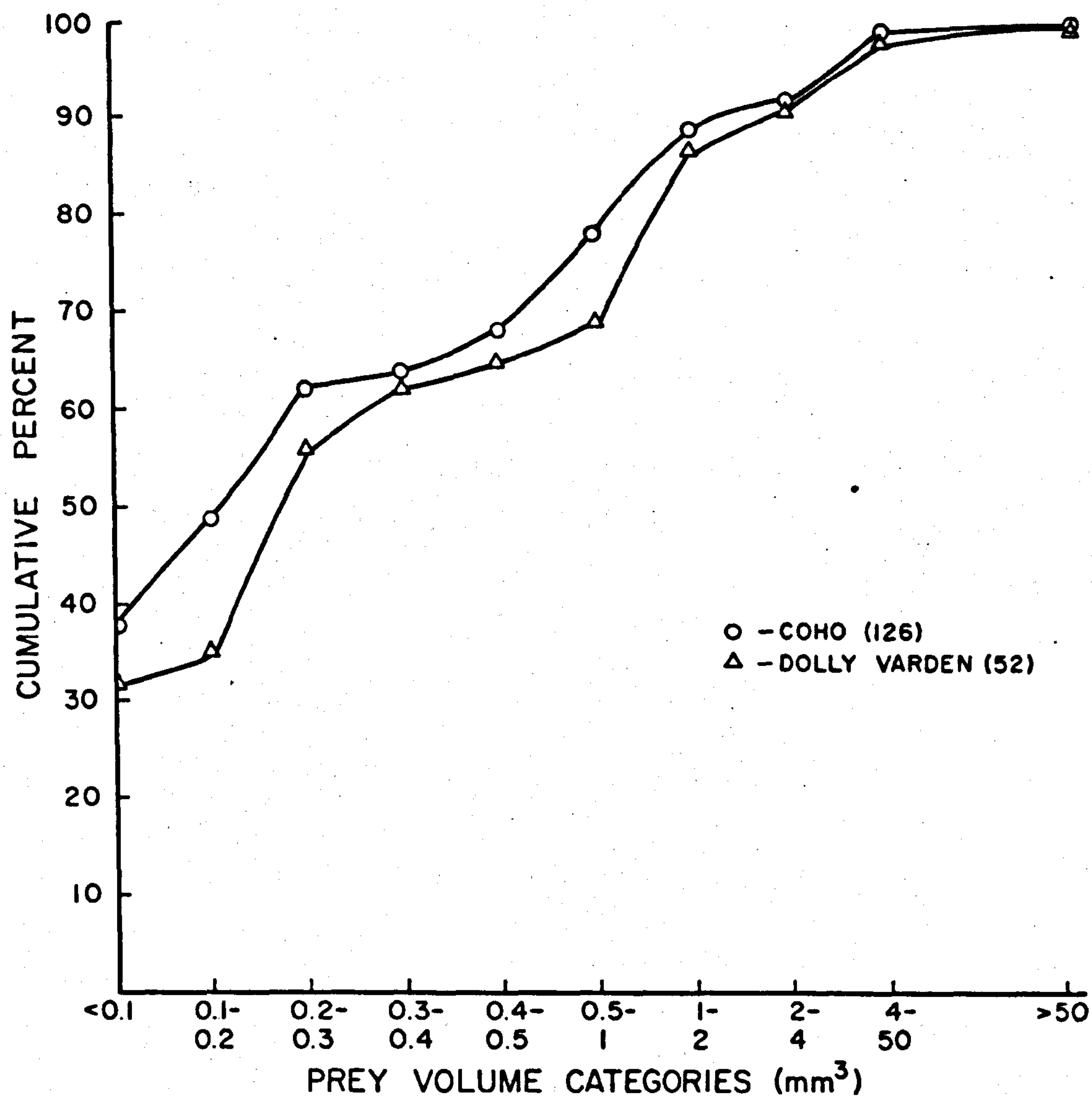

Figure 16. Cumulative percent of food in 10 size categories by 2 groups of coho and Dolly Varden in 4 Southeast Alaska streams.

Discriminant Analysis--Microhabitat and Food

In the preceding discriminant analysis (Table 33) a high degree of separation was achieved by coho and Dolly Varden along multidimensional gradients of physical microhabitat variables. Such differences in microhabitat preferences also contribute to dietary specialization. Being more closely associated with the substrate (Figure 7), Dolly Varden relied more heavliy on benthic food production than coho, as indicated by the high proportion of food from aquatic sources in their diets (Table 35). To determine the relative importance of dietary differences, a third discriminant analysis was conducted incorporating the proportion of food from terrestrial sources occurring in individual stomach samples (TERP) as a new variable.

Despite the fact that this analysis was based on a much reduced data set, the standardized discriminant function coefficients were selected in nearly the same order as in the previous analyses (Table 38). The new variable TERP was rated fourth in importance, slightly behind DTNF, and the DTNC, a highly rated variable in earlier models, was rated less important. The percentage overlap in discriminant scores between species was 5.5% (Figure 17) a marginal improvement over the 5.7% (Figure 14) observed when diet was not considered.

Table 38. Results from a 2-group discriminant analysis. Grouping and sample size (N) were coho (117) and Dolly Varden (46).

	Discriminant function I
Percent of variance	100.00%
Variable	Standardized discriminant function coefficients
Depth (D)	1.858
Focal point depth (FPD)	-2.250
Distance to nearest cover (DTNC)	0.108
Distance to nearest fish (DTNF)	0.289
Velocity (V)	0.186
Substrate (S)	-0.111
Proportion of food from terrestrial sources (TERP)	0.287

The percentages of correct classifications (Table 39) were slightly higher in the previous two-group discriminant analysis (Table 35) with 97% of the coho and 87% of the Dolly Varden cases correctly classified.

Table 39. Predicted group membership based on classification functions derived from a discriminant analysis on 2 groups of juvenile salmonids from 4 Southeast Alaska streams. Actual classification numbers in parenthesis.

	Sample size	Predicted group membership	
Actual Group	N	Coho	DollyVarden
Coho	117	97.4% (114)	2.6% (3)
Dolly Varden	46	13.0% (6)	87.0% (40)

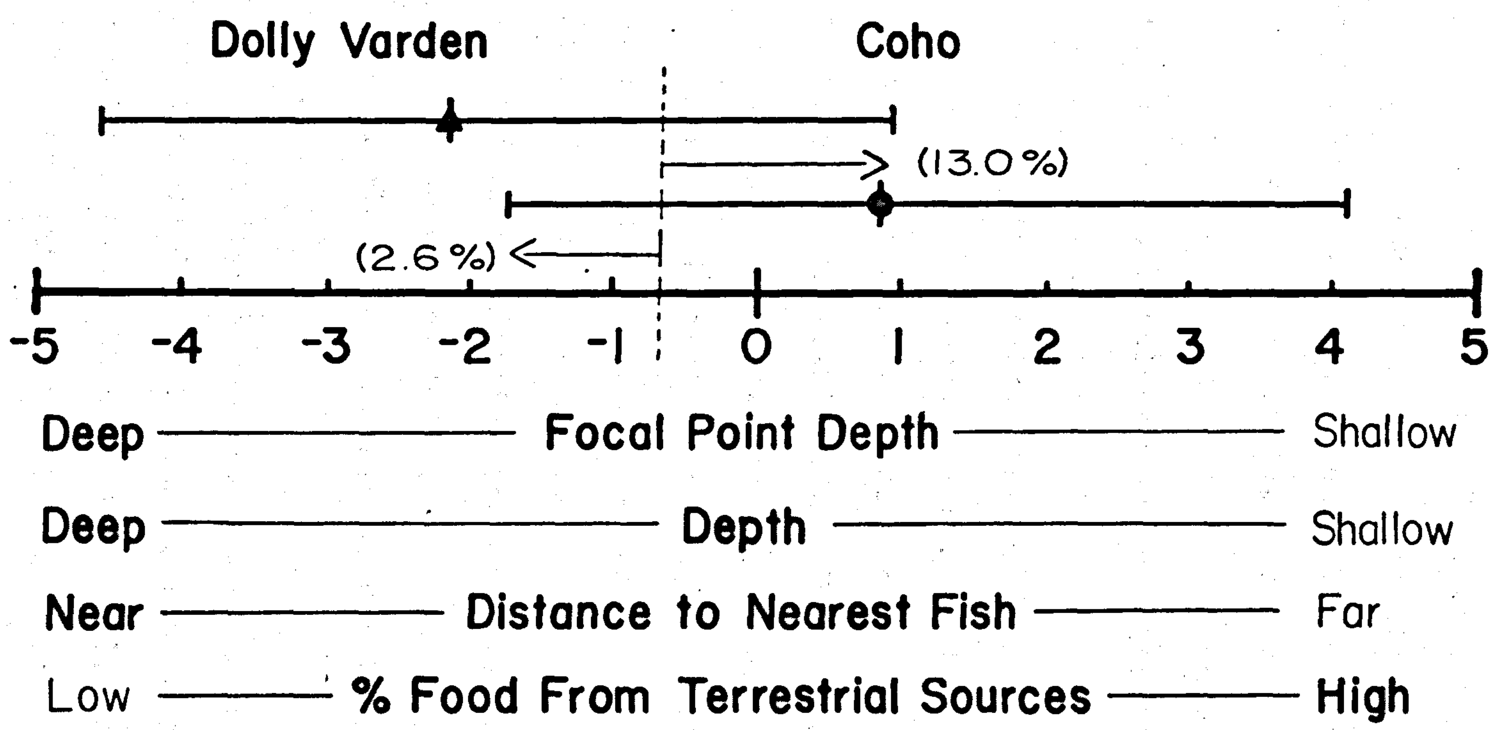

Figure 17. Mean positions and ranges along the discriminant axis for coho and Dolly Varden, age classes combined, in 4 Southeast Alaska streams with the proportion of food from terrestrial sources as a variable.

DISCUSSION

Wood debris in small Southeast Alaska streams was an important component in the habitats of juvenile coho and Dolly Varden, and its removal from stream channels generally resulted in lowered carrying capacities for both species. Population densities and production values in uncleaned subsections were greater than or equal to those in cleaned subsections of Tye and Toad creeks. Population densities in a third stream, Knob Creek, were greatest in the uncleaned subsection during 1980 but not 1981, and no relationship between stream cleaning and production could be established (Table 22). Fish in Knob Creek, the most chemically productive of the three streams (Table 1), generally had greater growth rates than fish in the other streams which may have masked or overridden the effects of stream cleaning on production. In addition, 3 years had elapsed since cleaning on Knob Creek. During this time, cover such as undercut banks and overhead vegetation may have developed to compensate for that lost with debris removal.

Wood debris made direct contributions to fish habitat. Small pools formed behind debris dams providing space that might otherwise have been unavailable due to shallow water depth or high velocity in an unimpacted stream channel. The older age classes of both species were typically found in the deepest water (Figure 7) available at a site and all groups preferred slower water velocities (Figure 9). Debris also provided cover, with the larger fish being more closely associated with cover than their smaller conspecifics (Table 26). Gordon and MacCrimmon (1982) demonstrated the importance of instream logs and brush, and permanent bank cover to density and biomass of juvenile coho salmon, rainbow and brown trout. Similar relationships for juvenile salmonids were noted by Boussu (1954) and Hartman (1963).

Debris also may have affected coho populations by reducing the frequency of aggressive interactions. Juvenile coho and other species employ aggressive territorial behavior as a mechanism to regulate population densities (Hoar 1951; Hartman 1965; Chapman 1962). Territorial defense prevents overcrowding in areas where food resources are available in limited quantities. Larger fish dominate their smaller conspecifics, forcing the latter to reside in suboptimal habitat or to emigrate (Chapman 1962). Territoriality thus ensures that larger, more aggressive individuals have the best access to food and other resources (Morse 1974). This is advantageous from the standpoint of relative individual fitness; the larger a fish is when it emigrates and begins its marine existance, the more likely it is to survive and return to spawn (Bilton 1978).

Territory size, however, may be larger than that neccessary to satisfy the requirements of territory holders (Dill 1978a). While territory size has been shown to be inversely correlated with benthic food abundance (Dill et al. 1981), territorial behavior may continue even in the presence of excess food (Chapman 1966). The minimum area defended is therefore constrained by innate spatial requirements irrespective of food abundance (Dill 1978b). This suggests that in streams where food is not limiting, territorial behavior may restrict carrying capacities to levels below what might otherwise be sustained. Because territorial defense is initiated by sight (Kalleberg 1958), wood debris visual barriers may isolate individuals, reduce the frequency of aggressive interactions and lead to greater fish densities and production.

No attempt was made in this study to evaluate food availability or delineate territories. However, with few exceptions fish in uncleaned subsections were greater in number, smaller in average size and displayed faster growth than fish in cleaned subsections. This may have been the result of greater visual isolation in the uncleaned subsections. Greater numbers of smaller fish remained in the uncleaned subsections due to the increased availability of territory space, while small fish in the cleaned subsections failed to become established and were forced to emigrate. The mean size of fish in the uncleaned subsections was less because of the greater numbers of smaller fish that also were present. The slower growth rate of fish in the cleaned subsection may have been a reflection of the greater energy cost of territorial maintenance in suboptimal habitats (Dill 1978a). With greater territory size, fish in the cleaned subsections may have expended greater amounts of time and energy in territorial defense and maintenance that might otherwise have gone into foraging and growth.

Age 1+ and 2+ Dolly Varden densities and production also were greater in the uncleaned subsections of Tye and Toad creeks. Territorial defense was apparently less important to Dolly Varden. Aggression, vis-a-vis territoriality, was rarely observed. Dolly Varden typically were observed in deeper water closely associated with cover, and other nearby fish were usually tolerated regardless of species. Dolly Varden numbers and production were probably enhanced in uncleaned subsections by the availability of suitable cover such as that provided by debris. While debris per se was not preferred over any other cover type, it comprised a significant portion of the available cover at most sites. Saunders and Smith (1955) and Elwood and Waters (1969) have demonstrated the dependence of brook trout (Salvelinus fontinalis) standing crops on the availability of hiding places.

Interspecific interactions also may have influenced population densities and production. If, for example, coho and Dolly Varden competed for food or space, populations of one or the the other may have been depressed, leading to decreased overall production.

Coho and Dolly Varden coexistance in all study streams was explained by differences in microhabitat utilization and dietary preferences. The segregation between species was apparently more of the selective as opposed to the interactive type (Nilsson 1967). Selective segregation occurs when for genetic reasons one species occupies different microhabitats or exploits resources not "selected" by the other. Interactive segregation occurs when use of a resource by one species precludes or inhibits the use of that resource by another species. Interactive segregation has been described for coho and rainbow trout by Hartman (1965) and coho and cutthroat by Glova (1978). Despite overlap in several niche parameters, particularly as related to specific items in the diet, observed microhabitat distributions and foraging patterns indicated that each species was primarily exploiting food resources not readily available to or selected by the other.

The existance of inter- and intraspecific size groups also may have contributed to microhabitat partitioning and selective segregation. Large differences in total lengths (Table 29) were noted for all groups except for the yearlings of both species. Considering all microhabitat variables simultaneously with discriminant analysis, the greatest group segregation occurred between the smallest coho group (age 0+) and the largest Dolly Varden group (age 2+) (Figure 13). None of individuals in these groups was ever misclassified as belonging to the other group (Table 33). Everest and Chapman (1972) attributed segregation of juvenile chinook (Oncorhynchus tshawytshcha) and steelhead in Idaho to size related spatial requirements. These fish had similar habitat preferences at a given size but avoided severe interactions by varying times of emergence and smoltification. Similar habitat segregation by size has been described for juvenile chinook and coho (Lister and Genoe 1970) and single species populations of juvenile Atlantic salmon (Salmo salar) (Saunders and Gee 1964; Symons and Heland 1978; Wankowski and Thorpe 1979) and brook trout (Saunders and Smith 1955).

Evidence for or against interactive segregation must come from more detailed studies. Only sympatric populations were observed and it is possible that interactive segregation was undetected by the methods of investigation used in this study. Detailed observations over all seasons and habitats coupled with species addition-removal experiments (or sympatry vs. allopatry observations) may reveal that interspecific interactions occur and have an impact on community organization. The mode of segregation notwithstanding, the consequence of coexistance was more complete utilization of the available habitat and probably greater total production than would be possible by either species alone.

Conclusions and Recommendations

The results of this study suggest that cleaning in streams similar to those studied will decrease carrying capacities for juvenile salmonids. However, where debris blocks the movements of fish into suitable habitat, limited stream cleaning to improve fish passage may be justified and desirable. But determinations of blocks to fish passage based on appearances alone can be misleading. Despite what appeared to be impassable amounts of debris, adult coho and Dolly Varden were able to enter all four study streams as evidenced by the springtime presence of fry above suspected debris blocks.

The addition of debris may even enhance stream carrying capacities. The simplest method would involve leaving buffer strips of timber along stream courses, thereby providing for debris "recruitment" by natural means such as windthrow and bank undercutting.

It also may be desirable to deliberately place debris in stream channels that lack essential habitat features such as a series of small pools. Coho frequently inhabit small backwater pools and side channels (Hartman 1965). Where these pools are separated from the stream channel they may be subject to drying during periods of low flow. Pools in the channel are less likely to dry up and, thus, should result in greater survival over the low flow season (Mundie 1969).

Many small pools are preferrable to a few large pools. Glova (1978) found a negative correlation between coho and cutthroat trout biomass/m^2 and pool surface area. He attributed this relationship to competition among the fish for choice feeding positions at the head of pools. Fish density decreased in the remaining area of any pool, with proportionally fewer fish in larger pools.

New pools should be constructed from materials (debris) available on site to minimize cost. Pool design and placement should be supervised by both a fishery biologist and a hydrologist knowledgable in stream mechanics to ensure maximum useful life and a minimum of maintenance.

Finally, consideration must be given to the cost-effectiveness of any habitat improvement program. Stream cleaning is expensive. The cost of cleaning a 1.0 km long, 2.5 m wide stream section in the Tongass National Forest ranged from approximately $2,550 to over $9,500 during the late 1970s (Michael Pease, Personnal Communication).

Obviously, stream cleaning in streams such as those examined in this study cannot be justified on economic grounds considering its negative biological impacts.

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APPENDIX

Appendix Table 1. Petersen population estimates and 95% confidence limits (N±2SE) for coho salmon in Tye Creek, 1978-1981.

Month / Subsection	1978*	1979	1980	1981
		Coho Age 0+		
June				
Cleaned		136±108	4644	113± 99
Uncleaned		365±178	2504	179± 91
July				
Cleaned	153± 59	396±144	550±127	54± 22
Uncleaned	247± 70	332±144	546± 87	138± 41
August				
Cleaned		132± 43	126± 26	75± 41
Uncleaned		204±107	211± 33	160± 27
September				
Cleaned	124± 27	92	63± 42	76± 30
Uncleaned	139± 38	162	118± 30	146± 22
		Coho Age 1+		
June				
Cleaned		91± 50	29± 15	41± 23
Uncleaned		103± 30	59± 26	48± 29
July				
Cleaned	54± 3	55± 17	32± 7	15± 4
Uncleaned	42± 5	64± 22	52± 7	23± 4
August				
Cleaned		50± 17	28± 6	22± 8
Uncleaned		51± 20	42± 6	29± 10
September				
Cleaned	43± 13	45	18± 5	20± 8
Uncleaned	39± 9	57	37± 6	29± 5

(Header: Month / Subsection; Year / Species-age class)

*Estimated from data from Cardinal

Appendix Table 2. Petersen population estimates and 95% confidence limits (N±2SE) for Dolly Varden in Tye Creek, 1978-1981.

Month Subsection	Year Species-age class			
	1978*	1979	1980	1981
		Dolly Varden Age 1+		
June				
Cleaned		168±227	40±53	5± 6
Uncleaned		111± 90	70±56	24±20
July				
Cleaned	55± 6	127±132	21±17	10± 8
Uncleaned	69±12	43± 28	41±21	28±37
August				
Cleaned		48± 34	16± 9	30±39
Uncleaned		85± 77	35±20	12± 6
September				
Cleaned	69±15	52	8± 4	39±22
Uncleaned	54±19	49	32±17	25± 8
		Dolly Varden Age 2+		
June				
Cleaned		61± 33	12±14	13± 9
Uncleaned		136± 96	27±25	14±14
July				
Cleaned	35± 0	75± 77	8± 5	12±12
Uncleaned	58± 3	41± 18	22±22	6± 6
August				
Cleaned		28± 24	20±10	5± 0
Uncleaned		27± 6	16± 9	5± 3
September				
Cleaned	26± 3	40	23±13	7± 0
Uncleaned	26± 6	48	20±12	9± 5

*Estimated from data from Cardinal

Appendix Table 3. Petersen population estimates and 95% confidence limits (N±2SE) for coho salmon in Toad Creek, 1978-1981.

Month Subsection	Year Species-age class			
	1978*	1979	1980	1981
		Coho Age 0+		
June				
Cleaned		353±248	183± 69	509±195
Uncleaned		300±215	667±268	696±681
July				
Cleaned	203±51	135± 29	112± 25	400± 91
Uncleaned	57±17	150± 84	186± 64	496±158
August				
Cleaned		101± 28	92± 19	270± 70
Uncleaned		108± 49	105± 33	324± 86
September				
Cleaned	40±11	79	77± 23	259± 70
Uncleaned	139±39	101	88± 33	331± 91
		Coho Age 1+		
June				
Cleaned		65± 15	55± 18	33± 20
Uncleaned		88± 27	105± 21	52± 29
July				
Cleaned	61±15	62± 12	72± 16	24± 7
Uncleaned	94±18	68± 15	113± 19	75± 22
August				
Cleaned		53± 13	54± 12	28± 11
Uncleaned		63± 18	93± 21	40± 7
September				
Cleaned	64±11	55	57± 15	30± 12
Uncleaned	68±10	65	110± 26	57± 16

*Estimated from data from Cardinal

Appendix Table 4. Petersen population estimates and 95% confidence limits (N±2SE) for Dolly Varden in Toad Creek, 1978-1981.

Month Subsection	Year Species-age class			
	1978*	1979	1980	1981
		Dolly Varden Age 1+		
June				
Cleaned		102± 70	78±43	58±42
Uncleaned		196±215	46±22	33±34
July				
Cleaned	106±56	81± 43	65±25	69±46
Uncleaned	90±27	86± 31	85±51	75±70
August				
Cleaned		72± 37	68±45	69±61
Uncleaned		79± 50	40±19	65±67
September				
Cleaned	95±21	63	90±42	86±66
Uncleaned	125±52	73	77±80	86±37
		Dolly Varden Age 2+		
June				
Cleaned		112± 41	44±14	78±34
Uncleaned		243± 79	141±43	122±95
July				
Cleaned	74±17	77± 24	38±11	111±47
Uncleaned	96±18	126± 25	157±25	92±33
August				
Cleaned		57± 19	57±42	32±13
Uncleaned		96± 19	89±21	54±30
September				
Cleaned	51± 6	73	44±20	78±28
Uncleaned	75±15	96	87±29	104±24

*Estimated from data from Cardinal

Appendix Table 5. Petersen estimates and 95% confidence limits (N±2SE) for coho salmon and Dolly Varden in Knob Creek, 1980-1981.

Month Subsection	Year Species-age class			
	1980	1981	1980	1981
	Coho 0+		Coho 1+	
June				
Cleaned	60±48	155±113	49±13	35±46
Partial	34±24	88± 96	75±62	14±11
Uncleaned	30±27	43± 39	71±45	29±24
July				
Cleaned	55±15	259±120	53±10	35±17
Partial	58±21	252±346	67±11	28±27
Uncleaned	27±11	81± 63	51±12	42±31
August				
Cleaned	53±16	219± 64	56±10	20± 6
Partial	70±26	179± 63	89±23	32±16
Uncleaned	48±22	82± 27	47±11	36±15
September				
Cleaned	38±21	264± 99	72±36	25± 9
Partial	62±28	160± 55	58±24	21± 7
Uncleaned	46±32	80± 34	29±12	27± 8
	Dolly Varden 1+		Dolly Varden 2+	
June				
Cleaned	30±39	42± 44	42±54	25±26
Partial		4± 4	50±67	25±24
Uncleaned	6± 4	7± 9	45±49	18±18
July				
Cleaned	37±33	110±131	22±23	72±44
Partial	15±10	12± 13	22±13	28±34
Uncleaned	8± 6	18± 21	26± 9	33±38
August				
Cleaned	29±20	96±124	40±22	34±21
Partial	15±14	21± 20	42±41	24±32
Uncleaned	24±19	13± 30	20±11	29±12
September				
Cleaned	36±20	42± 34	27±11	45±20
Partial	24±31	40± 40	39±28	9± 6
Uncleaned	25±32	21± 24	36±26	17±11

Appendix Table 6. Petersen population estimates and 95% confidence limits (N±2SE) for coho salmon and Dolly Varden in Aha Creek, 1979-1981.

Month	Year		
	1979	1980	1981
		Coho Age 0+	
June	3257±1578	4787±966	600±239
July	616± 197	1044±117	595±273
August	415± 54	612± 55	517± 68
September	207	366± 64	389± 69
		Coho Age 1+	
June	101± 33	98± 24	134± 47
July	119± 44	93± 11	142± 25
August	88± 8	103± 15	130± 18
September	97	101± 25	98± 13
		Dolly Varden Age 1+	
June	183± 105	288±222	170±228
July	297± 253	182± 39	185± 71
August	167± 45	192± 59	192± 87
September	193	125± 37	160± 53
		Dolly Varden Age 2+	
June	68± 53	96± 55	107± 80
July	61± 49	76± 19	235± 67
August	30± 7	140± 37	157± 66
September	28	101± 24	117± 26

Appendix Table 7. Length-weight regressions for coho salmon in the subsections of 4 study streams in Southeast Alaska, 1979-1981.

Stream, Year	Subsection	Sample size N	Slope b	Intercept a	r^2
Tye Creek					
1979					
	Cleaned and uncleaned*	430	3.554	-5.985	0.970
1980					
	Cleaned	146	3.621	-6.101	0.970
	Uncleaned	144	3.521	-5.933	0.955
1981					
	Cleaned	70	3.205	-5.374	0.962
	Uncleaned	72	3.267	-5.466	0.945
Toad Creek					
1979					
	Cleaned and uncleaned*	497	3.209	-5.355	0.969
1980					
	Cleaned	110	3.185	-5.301	0.965
	Uncleaned	168	3.308	-5.548	0.978
1981					
	Cleaned	83	2.942	-4.847	0.960
	Uncleaned	136	3.215	-5.372	0.976
Knob Creek					
1980					
	Uncleaned	102	3.073	-5.089	0.980
	Partial	63	3.319	-5.560	0.967
	Cleaned	49	3.265	-5.456	0.986
1981					
	Uncleaned	66	3.129	-5.217	0.983
	Partial	35	3.263	-5.456	0.986
	Cleaned	77	3.223	-5.384	0.957
Aha Creek					
1979	0-302m	421	3.207	-5.342	0.966
1980		224	3.271	-5.434	0.964
1981		196	3.073	-5.127	0.942

*Based on 1980 and 1981 data from the combined cleaned and uncleaned subsections.

Appendix Table 8. Length-weight regressions for Dolly Varden in subsections of 4 study streams in Southeast Alaska, 1979-1981.

Stream Year	Subsection	Sample size N	Slope b	Intercept a	r^2
Tye Creek					
1979					
	Cleaned and uncleaned*	210	3.338	-5.686	0.958
1980					
	Cleaned	46	3.147	-5.288	0.964
	Uncleaned	80	3.330	-5.656	0.977
1981					
	Cleaned	40	3.086	-5.251	0.959
	Uncleaned	43	3.437	-5.884	0.919
Toad Creek					
1979					
	Cleaned and Uncleaned*	397	2.876	-4.782	0.979
1980					
	Cleaned	79	2.848	-4.722	0.988
	Uncleaned	114	3.004	-5.025	0.975
1981					
	Cleaned	73	2.875	-4.776	0.990
	Uncleaned	131	2.848	-4.735	0.966
Knob Creek					
1980					
	Cleaned	55	3.218	-5.426	0.972
	Partial	38	3.080	-5.175	0.983
	Uncleaned	43	2.873	-4.874	0.924
1981					
	Cleaned	74	3.057	-5.155	0.962
	Partial	25	3.042	-5.116	0.986
	Uncleaned	25	3.168	-5.352	0.981
Aha Creek					
1979	0-302m	397	3.192	-5.396	0.971
1980		194	3.113	-5.220	0.981
1981		204	3.271	-5.568	0.976

*Based on 1980 and 1981 data from the combined cleaned and uncleaned sections.

Appendix Table 9. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for coho in Tye Creek, 1979-1981.

Age class Subsection Month	1979 G	 B	 P	Year 1980 G	 B	 P	1981 G	 B	 P
Age 0+									
Cleaned									
June		0.922			12.094			0.436	
July	0.194	0.722	0.156	0.258	1.753	1.800	0.204	0.440	0.088
August	0.195	0.576	0.128	0.259	0.629	0.310	0.195	0.468	0.091
September	0.177	0.442	0.092	0.261	0.329	0.124	0.195	0.510	0.093
Uncleaned									
June		1.200			6.605			0.747	
July	0.214	1.109	0.242	0.201	1.735	0.834	0.136	0.777	0.107
August	0.192	1.006	0.201	0.205	0.867	0.260	0.147	0.852	0.122
September	0.201	0.920	0.193	0.216	0.570	0.158	0.128	0.926	0.116
Age 1+									
Cleaned									
June		1.139			0.810			0.672	
July	0.029	1.027	0.032	0.114	0.794	0.088	0.104	0.676	0.067
August	0.028	0.949	0.029	0.115	0.795	0.087	0.104	0.746	0.072
September	0.030	0.861	0.027	0.114	0.784	0.087	0.104	0.746	0.072
Uncleaned									
June		1.456			1.206			0.645	
July	0.089	1.426	0.130	0.125	1.181	0.143	0.152	0.711	0.102
August	0.091	1.404	0.127	0.122	1.124	0.138	0.148	0.779	0.112
September	0.090	1.412	0.127	0.121	1.063	0.131	0.149	0.851	0.122

Appendix Table 10. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for Dolly Varden in Tye Creek, 1979-1981.

Age class Subsection Month	1979 G	1979 B	1979 P	1980 G	1980 B	1980 P	1981 G	1981 B	1981 P
Age 1+									
Cleaned									
June		0.459			0.307			0.628	
July	0.097	0.498	0.048	0.129	0.333	0.042	0.040	0.613	0.025
August	0.102	0.531	0.053	0.131	0.362	0.045	0.033	0.592	0.018
September	0.098	0.564	0.056	0.131	0.391	0.049	0.038	0.570	0.023
Uncleaned									
June		0.497			0.603			0.355	
July	0.158	0.537	0.084	0.089	0.588	0.054	0.043	0.345	0.014
August	0.161	0.613	0.093	0.093	0.566	0.052	0.047	0.349	0.017
September	0.155	0.675	0.103	0.091	0.550	0.050	0.050	0.340	0.017
Age 2+									
Cleaned									
June		1.322			1.737			0.606	
July	0.054	1.361	0.067	0.045	1.745	0.087	0.040	0.495	0.017
August	0.054	1.435	0.071	0.046	1.675	0.085	0.040	0.422	0.014
September	0.055	1.438	0.072	0.045	1.673	0.084	0.042	0.342	0.011
Uncleaned									
June		2.039			1.804			0.629	
July	0.093	2.153	0.189	0.063	1.774	0.107	0.048	0.566	0.030
August	0.091	2.266	0.199	0.062	1.652	0.103	0.047	0.544	0.028
September	0.092	2.434	0.211	0.063	1.676	0.100	0.048	0.467	0.025

Appendix Table 11. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for coho in Toad Creek, 1979-1981.

Age class Subsection Month	1979 G	 B	 P	Year 1980 G	 B	 P	1981 G	 B	 P
Age 0+									
Cleaned									
June		0.789			0.475			1.556	
July	0.229	0.490	0.147	0.201	0.377	0.085	0.182	1.413	0.267
August	0.232	0.457	0.115	0.195	0.357	0.073	0.179	1.373	0.251
September	0.225	0.424	0.097	0.195	0.362	0.068	0.173	1.364	0.233
Uncleaned									
June		0.571			1.362			1.556	
July	0.305	0.459	0.149	0.247	0.614	0.247	0.163	1.348	0.232
August	0.294	0.453	0.132	0.231	0.419	0.119	0.172	1.264	0.222
September	0.283	0.488	0.136	0.240	0.349	0.092	0.165	1.207	0.198
Age 1+									
Cleaned									
June		0.886			0.845			0.346	
July	0.114	0.947	0.101	0.098	0.917	0.088	0.089	0.366	0.032
August	0.116	1.129	0.131	0.098	0.995	0.096	0.089	0.386	0.034
September	0.115	1.202	0.128	0.097	1.078	0.104	0.089	0.422	0.036
Uncleaned									
June		1.229			1.507			0.852	
July	0.078	1.206	0.097	0.097	1.662	0.158	0.103	0.871	0.086
August	0.081	1.188	0.096	0.098	1.815	0.174	0.104	0.912	0.089
September	0.078	1.175	0.095	0.095	1.978	0.190	0.104	0.933	0.092

Appendix Table 12. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for Dolly Varden in Toad Creek, 1979-1981.

Age class Subsection Month	1979 G	 B	 P	Year 1980 G	 B	 P	1981 G	 B	 P
Age 1+									
Cleaned									
June		0.572			0.724			0.600	
July	0.073	0.548	0.039	0.082	0.729	0.058	0.055	0.605	0.030
August	0.078	0.587	0.048	0.083	0.741	0.059	0.056	0.613	0.036
September	0.076	0.564	0.046	0.083	0.761	0.060	0.053	0.617	0.031
Uncleaned									
June		0.658			0.597			0.652	
July	0.137	0.690	0.094	0.101	0.641	0.062	0.077	0.696	0.054
August	0.132	0.724	0.092	0.099	0.698	0.067	0.075	0.750	0.051
September	0.134	0.765	0.097	0.100	0.748	0.072	0.077	0.801	0.062
Age 2+									
Cleaned									
June		1.817			1.185			2.029	
July	0.045	1.795	0.072	0.085	1.216	0.096	0.035	2.054	0.061
August	0.046	1.948	0.099	0.085	1.270	0.099	0.033	2.053	0.062
September	0.045	1.910	0.096	0.086	1.324	0.117	0.032	2.071	0.062
Uncleaned									
June		3.862			3.582			2.353	
July	0.041	3.387	0.145	0.065	3.566	0.214	0.037	2.353	0.094
August	0.040	2.937	0.126	0.064	3.527	0.213	0.038	2.354	0.094
September	0.041	2.580	0.110	0.064	3.469	0.210	0.037	2.348	0.094

Appendix Table 13. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for coho in Knob Creek, 1980-1981.

Year Age class Month	Total			Subsection Partial			Uncleaned		
	G	B	P	G	B	P	G	B	P
1980									
Age 0+									
June		0.449			0.737			0.868	
July	0.193	0.508	0.091	0.211	0.808	0.162	0.093	0.868	0.078
August	0.194	0.584	0.104	0.216	0.888	0.178	0.091	0.895	0.079
September	0.189	0.652	0.117	0.211	0.971	0.195	0.094	0.943	0.083
Age 1+									
June		1.527			2.092			2.445	
July	0.136	1.662	0.223	0.100	2.191	0.214	0.086	2.472	0.221
August	0.134	1.800	0.225	0.102	2.328	0.226	0.086	2.482	0.223
September	0.137	1.949	0.262	0.100	2.425	0.238	0.086	2.476	0.223
1981									
Age 0+									
June		1.314			1.314			0.704	
July	0.221	1.565	0.317	0.285	1.444	0.361	0.223	0.879	0.174
August	0.216	1.841	0.375	0.286	1.846	0.477	0.232	1.109	0.219
September	0.218	2.186	0.443	0.285	2.345	0.588	0.222	1.384	0.274
Age 1+									
June		1.116			0.745			1.355	
July	0.064	1.124	0.067	0.151	0.835	0.119	0.119	1.483	0.170
August	0.064	1.092	0.066	0.154	0.938	0.133	0.120	1.574	0.183
September	0.065	1.090	0.065	0.152	1.050	0.149	0.121	1.721	0.198

Appendix Table 14. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for Dolly Varden in Knob Creek, 1980-1981.

Year				Subsection					
Age class	Total			Partial			Uncleaned		
Month	G	B	P	G	B	P	G	B	P
1980									
Age 1+									
June		0.493			0.214			0.735	
July	0.061	0.509	0.030	0.103	0.238	0.023	0.043	0.739	0.029
August	0.061	0.541	0.031	0.105	0.264	0.025	0.041	0.740	0.030
September	0.061	0.558	0.033	0.108	0.294	0.031	0.040	0.739	0.030
Age 2+									
June		1.524			1.161			2.243	
July	0.102	1.610	0.157	0.085	1.264	0.097	0.059	2.251	0.135
August	0.104	1.701	0.166	0.085	1.339	0.117	0.057	2.315	0.137
September	0.104	1.840	0.177	0.085	1.458	0.112	0.059	2.383	0.141
1981									
Age 1+									
June		0.958			0.337			0.461	
July	0.097	0.985	0.097	0.045	0.353	0.017	0.071	0.465	0.032
August	0.099	0.988	0.099	0.047	0.370	0.018	0.072	0.500	0.034
September	0.099	1.003	0.100	0.044	0.365	0.018	0.070	0.503	0.035
Age 2+									
June		1.811			0.727			2.013	
July	0.086	1.865	0.165	0.026	0.615	0.020	0.035	1.958	0.079
August	0.085	1.914	0.170	0.027	0.542	0.017	0.037	1.900	0.077
September	0.085	1.956	0.174	0.036	1.510	0.016	0.037	1.835	0.075

Appendix Table 15. Monthly instantaneous growth (G), biomass g/m^2 (B) and production g/m^2 (P) for coho and Dolly Varden in Aha Creek, 1979-1981.

Species Age class Month	1979 G	 B	 P	Year 1980 G	 B	 P	1981 G	 B	 P
Coho									
Age 0+									
June		2.116			2.958			0.531	
July	0.267	0.725	0.384	0.274	1.088	0.546	0.161	0.530	0.085
August	0.260	0.429	0.150	0.291	0.691	0.258	0.173	0.565	0.093
September	0.263	0.321	0.097	0.282	0.541	0.172	0.157	0.607	0.094
Age 1+									
June		0.461			0.435			0.502	
July	0.112	0.492	0.052	0.136	0.489	0.065	0.131	0.524	0.067
August	0.109	0.528	0.056	0.138	0.551	0.073	0.127	0.540	0.069
September	0.111	0.559	0.060	0.138	0.621	0.082	0.128	0.563	0.072
Dolly Varden									
Age 1+									
June		0.499			0.384			0.408	
July	0.141	0.551	0.073	0.146	0.430	0.061	0.089	0.441	0.038
August	0.138	0.602	0.081	0.146	0.481	0.068	0.087	0.475	0.041
September	0.138	0.660	0.088	0.147	0.541	0.077	0.089	0.514	0.045
Age 2+									
June		0.528			0.784			0.981	
July	0.093	0.426	0.043	0.124	0.871	0.099	0.091	1.060	0.092
August	0.091	0.345	0.035	0.123	0.967	0.110	0.092	1.146	0.099
September	0.092	0.276	0.028	0.125	1.074	0.122	0.090	1.237	0.107