Habitat Utilization, Density, and Growth of Steelhead Trout, Coho Salmon, and Pacific Giant Salamander in Relation to Habitat Types in a Small Coastal Redwood Stream

By

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ABSTRACT

Small Pacific northwestern coastal streams are nurseries for populations of young of the year coho salmon, steelhead trout, and the Pacific giant salamander larvae. Previous field studies suggest that the habitats of the juveniles of these species were similar to one another. Few habitat utilization studies focus on the juvenile stages of these species despite their important roles in northwestern coastal stream systems. To investigate species distributions and their habitat uses, I compared species density in different habitat types, measuring average species density found throughout the stream. I also examine species survival and growth in the habitat types. I found no significant difference between the total species densities and the habitat types. However, pools possessed the highest densities, riffles the least and runs intermediate. Coho salmon preferred pools and runs while avoiding riffle habitats. Coho densities were significantly greater in both pools and run habitats than riffles. Steelhead and larval salamanders demonstrated no habitat preference or avoidance and used most habitats available to them. There was no significant difference in steelhead and salamander density and the habitat types. I found no significant difference in species growth, and survival and the habitat categories. Coho had greater growth, survival, and lower densities than both steelhead and the larval salamanders. This study was part of a larger study, currently underway, on the effects of logging on salmonid production.

INTRODUCTION

During summer months, small Pacific northwestern coastal streams act as nurseries for populations of juvenile coho salmon *(Oncorhynchus kisutch), s*teelhead/rainbow trout (*O. mykiss*), and Pacific giant salamander larvae *(Dicamptodon tenebrosus*, formerly *D. ensatus* [Good 1989]). Previous field studies suggest that the habitats of these species are similar (Antonelli et. al. 1972, Hawkins et. al. 1983, Murphy and Hall 1981). However, few studies exist for these species while they coexist despite their potentially important roles in the Pacific northwestern stream systems.

Juvenile coho salmon and steelhead are ecologically similar (Hartman 1965). Both are anadromous, have similar habitat requirements, morphology, and behavior. They differ in the time they spend in stream residence. Coho juveniles typically spend one year in residence while steelhead juveniles spend one to two or three years prior to emigration.

Larval *D. tenebrosus* differ from the salmon juveniles by emerging from their subterranean nest as first year larvae. They transform into adults the following year (Stebbins 1951, Nussbaum and Clothier 1973). Salamanders are conspicuous and important components of the energy pathways of forest ecosystems and stream communities (Hawkins et. al. 1983). Antonelli et. al. (1972) considered the Pacific giant salamander and the rainbow trout to be ecologically similar. Both species occupied the same habitat and were opportunistic feeders with a considerable dietary overlap. They separated spatially since the trout's diet included many terrestrial animals found throughout the stream, while larval salamanders included many autochthonous sources, mostly benthos (Antonelli et. al. 1972).

Habitat use, behavior, and distributions of sympatric juvenile coho and steelhead have been described by previous workers (Hartman 1965, Chapman 1966, Fraser 1969, Burns 1971, Murphy et. al. 1981, Bisson et. al. 1982, Bisson et. al. 1988, Shirvell 1990, Bjornn et. al. 1991). Chapman (1966) observed that among stream dwelling salmonids, competition for space substituted for direct competition for other resources, such as food: Hartman (1965) demonstrated that young of the year (YOY) coho and trout segregate using agonistic displays. Coho juveniles tended to defend territories in pools while steelhead juveniles tended to defend territories in riffles.

The main factors regulating and limiting juvenile salmonid populations in streams are density-dependent factors. These factors result from territorial behavior and the amount of suitable juvenile rearing area (Le Cren 1973, Mortensen 1977). Fraser (1969) found growth and survival for juvenile coho salmon and steelhead trout inversely related to their intraspecific density. Murphy et. al. (1984) stated that the amount of summer habitat acting through density-dependent factors would set the upper limit on the yield of smolts. Bilby and Bisson (1987) found that habitat quality exerts a significant influence on local salmonid population densities. Mean weight of YOY steelhead juveniles was density dependent where overwinter survival was determined upon the fish reaching a minimum weight (Close and Anderson 1992). Growth varies among habitat types (Bilby and Bisson 1987, Dolloff 1987).

The implications of these relationships are that a specie's density in different habitat types is an indicator of its use, quality, and carrying capacity. The most common method to assess a stream's potential to produce salmonid juveniles was to apply a density estimate derived from the summer surface area (Columbia Basin Fish and Wildlife Authority 1989). However, this method assumes that all habitats have the same potential.

Current stream habitat classification and habitat inventory methods (Hankin and Reeves 1988, Bisson et. al. 1982) make it possible to quantify different types of habitat within a stream. The American Fisheries Society has approved their methodology for salmonid habitat inventory (Helm 1985, Hawkins et. al. 1993). Modern habitat classification makes fewer assumptions and assumes habitat quality based on surface area, density and habitat diversity. Kersner and Snider (1992) used Bisson's habitat types classification system to fine tune their habitat availability predictions from instream flow models. However, McCain et. al. (1989) warned about the tendency for habitat type expansion to occur based on a real or perceived need for more habitat classes. Habitat proliferation could lead to confounding comparison among streams. Hawkins et. al. (1993) proposed a hierarchical classification scheme where two additional habitat levels based on water speed and turbulence are arranged on to Bisson's classification system.

Few studies present data on distribution, density, and habitat use of the larval salamanders and other amphibians. Salamanders play important roles in the energy paths within stream communities (Hawkins et. al. 1983). Their densities are important indicators of habitat quality (Cory and Bury 1988, Hairston 1987). The Pacific giant salamander may substitute as the primary vertebrate predator in headwater streams lacking salmonids (Murphy and Hall 1981). Bury et. al. (1991) found that amphibians can be the dominant vertebrate in headwaters of the Pacific Northwest forest with the giant salamander being the most abundant one. Parker (1991) described the importance of instream cover to the abundance and distribution of larval *Dicamptodon* within a small redwood stream. Investigators probably overlook the Pacific giant and other salamanders due to their small commercial value and their primary dependence on first and second-order headwater streams that lack salmonids (Bury and Corn 1988).

Resource managers need information on habitat utilization, density, growth and survival of salmonids and larval salamanders during their stream residency. This information would allow biologists to relate the amount of habitat to population sizes. The use of different stream habitats by salmonids and salamanders fluctuates over time. Unless the densities of these species are measured and monitored, the importance of different stream habitats could easily be underestimated. If we measure these fluctuations on anadromous fish and salamander populations we may predict the effect of environmental changes to coastal streams, and manage them to reverse current population declines.

My purpose was to conduct a short-term investigation of the distributions, habitat use, and density of sympatric larval Pacific giant salamanders, coho salmon, and steelhead trout in Caspar Creek (Mendocino Co., CA). I compared species density in different habitat types based on average species densities found throughout the stream. My objectives were twofold. The first was to compare the use and availability of habitats to YOY steelhead, coho, and larval salamanders in Caspar Creek. The second was to compare the species densities, survival, and growth within the habitat types. This study was part of a United States Forest Service Pacific Southwest Forest and Range Experiment Station study, currently underway, on the effects of logging on salmonid production.

DESCRIPTION OF THE STUDY AREA

I conducted this study in the North and South Forks of Caspar Creek (Mendocino Co., CA). Caspar Creek is a small stream draining a secondary growth redwood/ Douglas fir forest. This creek lies within the Jackson State Forest, five miles south of Fort Bragg, California (Figure 1). California Department of Forestry (CDF) and the Pacific Southwest Forest and Range Experiment Station, (PSW) jointly established Caspar Creek as an experimental watershed. It was originally planned as a paired watershed investigation to study the effects of logging practices and road building on stream hydrology.

The North and South Fork have watershed areas of 1225 acres (508 ha) and 1047 acres (424 ha), respectively (Figure 1). The soils are Mendocino, overlying Cretaceous sedimentary rocks (Krammes and Burns 1973). The climate is one of mild summers with fog, and forty inches (1000 mm.) of average annual precipitation concentrated in October through April.

Stands of second growth redwood, Douglas Fir, hemlock, grand fir and some scattered hardwood cover both watersheds. Common understory plants include huckleberry, tanoak, sword fern and other species that associate with the redwood/ Douglas Fir forest. In the South Fork watershed, a logging

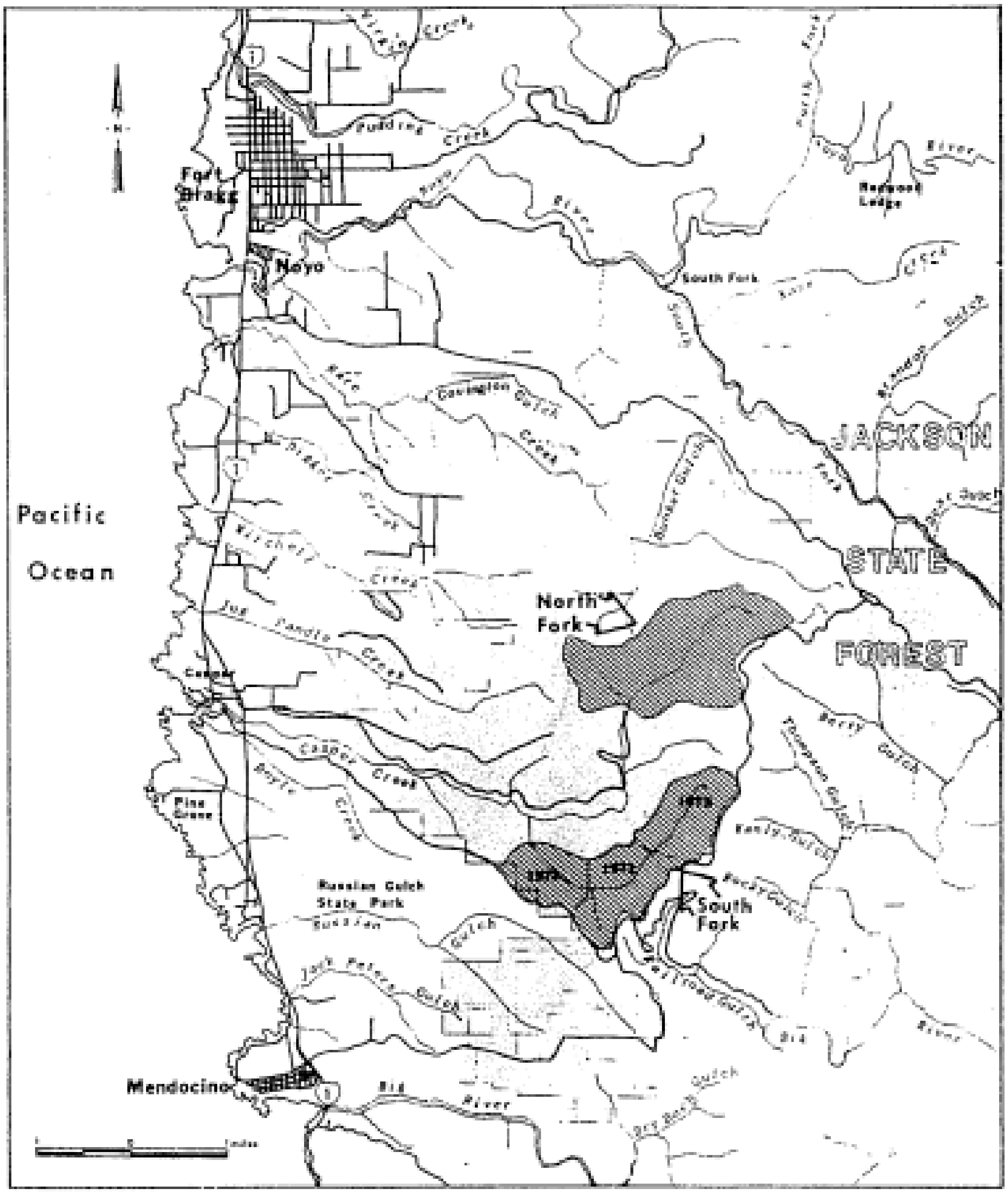


Figure 1. The two experimental watersheds, the North and South Forks of Caspar Creek, are on the Jackson State Forests, in Mendocino County.

road (7.0 km. (4.2 miles)) was constructed during the summer of 1967. The PSW and The California Department of Fish and Game evaluated the erosive effects of road construction on Caspar Creek's South Fork between 1971-1973 (Krammes and Burns 1973, Burns 1971, Rice et. al. 1979). Between 1971 and 1973, approximately sixty five percent of the South Fork's stand volume was removed by selective logging; the effects were monitored to 1976 (Rice et. al. 1979). Both watersheds were clear-cut and burned in the late 1880s. The North Fork watershed was not disturbed since, except some minor pole and piling cutting during World War II.

I established the study sites above the weir located on each fork. Each weir included a fish ladder that allowed anadromous fish to pass the streamflow and sediment gauging facilities. Above each weir, the creek formed a small pond. By angling, I found several larger and older juvenile steelhead in these ponds. However, I found few of the larger and older steelhead juveniles in the study sites above the ponds. In August 1969, these ponds supported about one percent of the stream's total salmonid population (Graves and Burns 1970). The shallow depth of both streams (averaging < 10 cm during summer base-flow) limited utilization by older and larger fish. Little or no angling occurred above the ponds. During summer months, low stream flows characterized both watersheds where base-flows were typically under 0.15 cfs (255 liters/min.). Both forks became intermittent above the study areas. The North Fork's flow was greater since it possessed the larger watershed.

Fish populations

Coho salmon and steelhead are the anadromous salmonids that inhabit Caspar Creek. The three-spined stickleback (*Gasterosteus aculeatus*) is common in the mainstem and the lower reaches of the South Fork. I found at least one species of sculpin (*Cottus sp.*) below the confluence of the North and South Fork, but not above the weirs.

The California Department of Fish and Game found that adult coho salmon and steelhead enter Caspar Creek from November through April (Kabel and German 1967). The coho run begins when fall rains raise water levels to where fish can proceed upstream. The steelhead run begins days or weeks afterward and continue later into the season. Caspar Creek's 1960-61 spawning escapement consisted of 322 coho salmon and 92 steelhead. The South Fork's escapement ranged from 33 to 111 coho salmon and 22 steelhead (Kabel and German 1967). No spawning escapement for the North Fork was available.

Participating agencies in this study included California Department of Forestry and the Pacific Southwest Forest and

Range Experiment Station. This study was part of a larger study on the effects of logging on salmonid production.

METHODS

Habitat Inventory

A methodology was needed to categorize Caspar Creek according to its various habitats. The terms 'riffles', 'pools', and 'runs' indicate relative water depth, current, and velocity. However, they have little meaning in relation to substrate, flow patterns, and cover. Fish utilization of these generalized categories may vary considerably within a stream (Allen 1969). We used an inventory method developed by Bisson et. al. (1982) to set objective criteria for habitat type identification. Bisson et. al. (1982) categorized riffles, pools, and runs based on their channel morphology, flow characteristics, substrate and cover criteria to classify habitats in finer detail (Table 1). This method has been effective in describing spatial segregation among similar coexisting fish populations (Bisson et. al. 1982, Bisson et. al. 1988, Murphy et. al. 1984, Hawkins et. al. 1993).

Researchers using Bisson's classification system agree on the names and definitions for most habitat types. However, characteristics that define a glide is in dispute. Glides are often transitional areas between fast and slow water (Hawkins et. al. 1993) or low-flow remnants of lateral scour

TABLE 1. Categories of major stream habitat types in Caspar Creek (after Bisson et. at. 1982).[a]

Habitat type	Formation and characteristics
Pools	
Plunge Pools	Streamflow drops vertically over channel obstructions into the streambed.
Lateral-scour pools	Channel obstructions deflect flow, causing lateral cutting and downcutting.
Riffles	
Low-gradient riffles	Shallow, moderately fast flow with surface turbulence; gradient less than 4%.
Runs	Even, nearly laminar flow over fine-grained substrate; often occur at tails of large pools, or reaches with little surface agitation and no major flow obstructions.

[a] I did not include several habitat types listed by Bisson et. al. (1982) that I did not encounter in this study.

pools under higher flow conditions (Lisle 1979). Due to this confusion, I eliminated the glide habitat type from this study.

Personnel (including myself) from the PSW Caspar Creek Watershed Study surveyed the North and South Fork stream channels using the techniques of Bisson et. al. (1982). I conducted this survey to find the abundance, frequency, and sequence of habitats available to fish in both the North and South Forks (Figure 1). We surveyed each fork on foot until we reached the upper limits of fish distribution. At each individual habitat type, personnel measured its length, depth, and width. Personnel then flagged each habitat with an identification number, and recorded its location in field notebooks.

This survey provided the basis to establish stratified random sampling of the habitats in Caspar Creek (Table 2). Stratified random sampling is where equal intensity sampling occurs, but with unequal sample sizes in each stratum. This sampling design works well in determining if differences in species abundance within different stratum (habitat types) of a stream exist (Schreck and Moyle 1990).

Table 2. Number of habitat types electroshocked in each fork of Caspar Creek, during July and September, 1987.

Habitat Type	North Fork		South Fork		Total	
	July	Sept.	July	Sept.	July	Sept.
Pools	12	8	7	9	19	17
Lateral Scour	7	6	4	6	11	12
Plunge	3	2	1	1	4	3
Secondary Channel	1	0	1	1	2	1
Backwater	1	0	1	1	2	1
Riffles	2	3	1	2	3	5
Runs	5	5	8	6	13	11

Population Estimates

Two crews consisting of three people each (myself and personnel from both the CDF and the PSW) sampled Caspar Creek by electroshocking. Each electroshocking team used a Coffelt Electronics Model BP-4 backpack D.C. electroshocker. The electroshocker operator adjusted the voltage for either 300 or 400 volts and the frequency settings on ninety or 120 pulses per second. The crew sampled vertebrate populations in each study site twice (July and September, 1987). We avoided repeated electroshocking to reduce the effect of shocking on the instantaneous growth rate of trout (Gatz et. al. 1986).

To prevent fish or salamanders from leaving the sampling area, the crews isolated each habitat by blocking its upper and lower ends with fine mesh seines. We placed both fish and larval salamanders captured from each pass in buckets in the shade along the stream margin prior to processing. The crews anesthetized all captured specimens with tricaine methanesulphonate (MS-222), and measured the fish's standard length (mm.) and the salamander's snout to vent length (mm.). After data collection, we returned all specimens to their original habitat. I report the electroshocking mortality rates in the results section.

We electroshocked a total of thirty six pools, eight riffles, and twenty four runs (Table 2). I lumped runs and glides together. All riffles sampled were low gradient riffles.

I estimated population size per habitat by the two or three pass removal-depletion method (Zippin 1958), which calculates minimum and maximum population estimates and their 95% confidence limits. For each habitat, I reported the absolute population size (the estimated population of fish per habitat) and relative population size (the number of fish per unit of living space (#/m^2)).

Habitat Utilization

To determine each species' use of a habitat type, I related the species' density found within that habitat type to the average species density for all habitats sampled. The index I used was (Ivlev 1961, Bagenal 1978, Bisson et. al. 1982):

Habitat Utilization =

$$\frac{\text{habitat specific density - average total density}}{\text{average total density}}$$

Where:

habitat specific density = average density in the habitat type of interest average total density = average density over the entire stream, all habitats combined

As with other indices, the habitat utilization index highlights data trends, but cannot impart the statistical significance *of* the observed trends (Bagenal 1978). Theoretically, values may range from minus one, indicating absolute habitat avoidance, to infinity indicating varying degrees of habitat selection. I used the following criteria to find a species' use or avoidance of a habitat type. The more a species habitat utilization index value fell below zero for a habitat type, the greater the species' avoidance of that habitat type. Values between signify varying degrees of habitat selection. Zero denotes no avoidance or selection since the species density in that habitat is equivalent to its density throughout the stream. The greater the habitat utilization coefficient rose above zero, the greater species use of that habitat.

Age, Growth, and Survival

I separated age classes by the Petersen length frequency method (Bagenal 1978). This method uses the individual lengths of a large sample from the same population. It assumes an unimodal size distribution of all fish of the same age where there is no large overlap in the size of the individuals in adjacent age-groups. This method works well with the youngest age groups of a population (Bagenal 1978).

I designated steelhead and coho less than one year as young of the year, and lumped older trout as a single age group, Age one+. During electroshocking, we did not discover any coho over one year old. I determined survival in each habitat as the percentage of the species alive at the second electroshocking relative to the number that were alive at the first electroshocking.

To determine fish growth in the habitat types, I calculated both the species average growth in length per day (mm./d) and the instantaneous growth rate (G). The instantaneous growth rate (G) is a natural logarithm of the ratio of the final length (L_i) to initial length (L_o) over a unit time (Schreck and Moyle 1990). The equation I used was:

$$G = \frac{\log_e L_i - \log_e L_o}{t_2 - t_1}$$

Statistical Analysis

To test for difference in species density, survival, and growth, per habitat type, I employed one-way randomized analysis of variance tables (ANOVA's). The density, growth, and survival per habitat category were the "main grouping factors" and the species were "within factors" (Sokal and

Rohlf 1969, Schreck and Moyle 1990). My null hypothesis was there were no differences among the habitat types. Because growth data tends to be exponential than linear, I transformed the density data ($Density_{trans}$=log (density + 1)) prior to analysis (Watt 1968). To increased sample size, I lumped the habitats into categories of pools, riffles, and runs and glides. I tested any significant F values ($P < 0.1$) with the Student-Newman-Kuels test (Sokal and Rohlf 1969). Since I found few fish and salamanders in the backwater and secondary pools, I left these out of the pool category.

RESULTS

Habitat Characteristics

Pools contributed the greatest total stream volume (51%), while runs contributed the largest total stream length and surface area (56% and 55%, respectively; Table 3). Riffles accounted for 19% of the entire stream length, but less than 7% of the volume. Runs contributed the largest total stream length and surface area of any habitat type. Pools were the dominant habitat type, followed by runs and riffles.

Within the pool category, the most frequent habitat type encountered was lateral scour pools. Lateral scour pools accounted for the majority of the stream volume (39%), and 21% of the total stream surface area (Table 3). Most of the run habitats were step runs, contributing 32% and 30%, respectively, of the total stream area and length. Of the riffle habitats, low gradient riffles were the most common, accounting for 18% of total stream surface area and length (Table 3). The least common habitat types were confluence, dammed, and trench pools, and cascade riffles.

Study Sites

The pools I electroshocked during July ranged in surface

Table 3. Average length, area, and volume of major habitat types in Caspar Creek, 1986. Number in parenthesis is percent of total stream occupied by the habitat type.

Habitat Categories and Types	n	Average length (m)		Average area (m^2)		Average volume (m^3)	
		Average Habitat Size and % of Total Stream					
Total Pools	107	4.9	(24.2)	12.8	(26.3)	3.5	(50.7)
Lateral Scour	77	5.6	(19.5)	14.3	(21.2)	3.8	(39.4)
Plunge	18	2.8	(2.3)	9.0	(3.1)	3.3	(8.1)
Secondary Channel	4	4.0	(0.7)	7.2	(0.6)	1.2	(0.7)
Confluence	1	5.0	(0.2)	20.0	(0.4)	5.0	(0.7)
Backwater	5	4.0	(0.9)	7.2	(0.7)	1.4	(1.0)
Dammed	1	2.2	(0.1)	2.6	(0.1)	0.8	(0.1)
Trench	1	8.0	(0.4)	17.6	(0.3)	5.3	(0.7)
Riffles	77	5.6	(19.6)	12.7	(18.8)	0.6	(6.7)
Low Gradient	68	6.0	(18.5)	14.0	(18.3)	0.7	(6.6)
High Gradient	8	3.0	(1.1)	2.9	(0.5)	>0.1	(>0.1)
Cascade	1	0.9	(>0.1)	1.7	(>0.1)	0.3	(>0.1)
Runs and Glides	90	13.7	(56.0)	31.8	(54.9)	3.5	(42.6)
Runs	31	10.8	(15.2)	24.7	(14.7)	2.7	(11.5)
Step Runs	36	19.4	(31.6)	43.9	(30.3)	4.2	(20.3)
Glides	23	8.9	(9.2)	22.5	(9.9)	3.5	(10.8)

area from 7.4 m^2 to 21.7 m^2 with volumes from 0.3 m^3 to 4.1 m^3. Mean depths varied from 0.1 m to 0.3 m. By September, pool surface area and volume had decreased and ranged from 0 to 21 m^2 with volumes ranging from 0 to 4.1 m^3. Mean depths varied from 0 to .2 m.

The runs I electroshocked during July ranged in surface area from 3.4 m^2 to 36.7 m^2 with volumes from 0.2 m^3 to 4.8 m^3. Mean depths varied from 0.04 m to 0.1 m. By September, runs surfaced area and volume decreased from 3.3 m^2 to 22.2 m^2 with volumes from 0.2 m^3 to 0.8 m^3. Mean depths varied from 0.03 m to 0.1 m.

The riffles ranged in surface area from 14.1 m^2 to 37.9 m^2 with volumes ranging from 0.6 m^3 to 1.1 m^3. July mean depths varied from 0.04 m to 0.1 m. As with the other habitats, riffle surface area decreased by September and ranged from 5.8 m' to 22.9 m^2 with volumes from 0.2 m^3 to 0.7 m^3. Mean depth varied from 0.03 m to 0.4 m.

Coho, Steelhead, and Salamander Populations

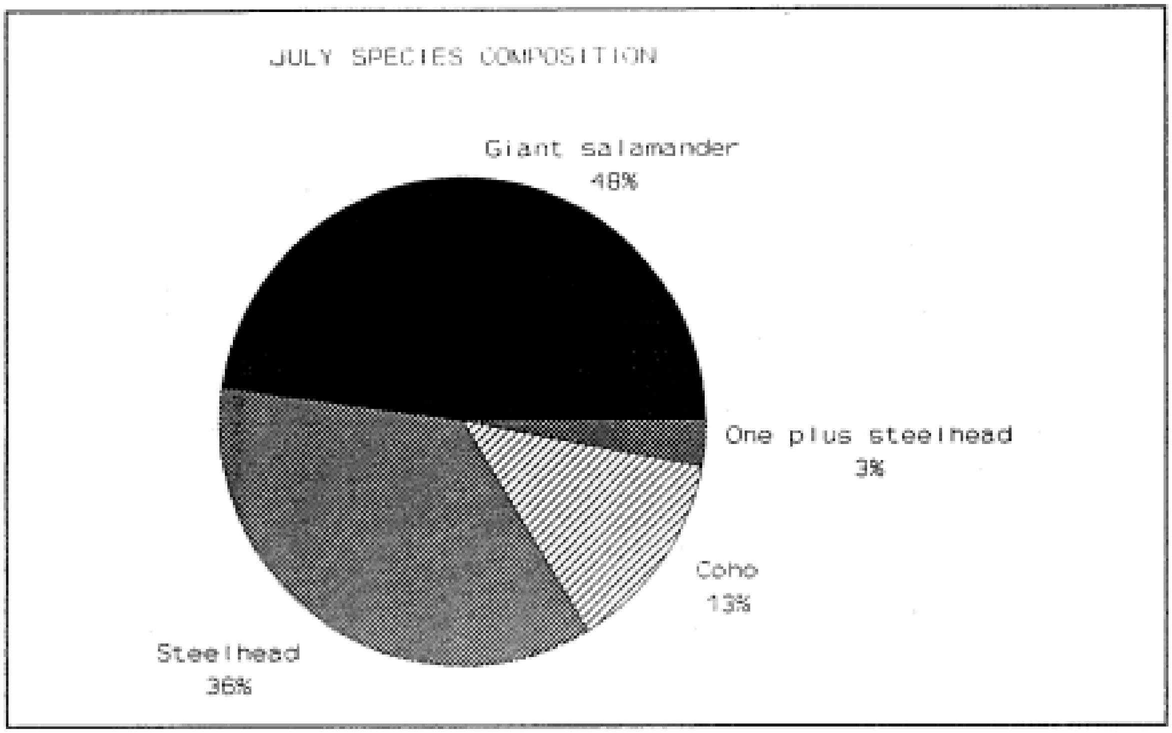
During the July sampling, the electroshocking mortality rates were 15% for YOY steelhead (124/824), 4% for coho salmon (12/315), and less than 1% (1/1,013) for larval salamanders. During the September sampling, the mortality rates were 16% for YOY steelhead (43/265), 2% for coho (5/239), and 0% for larval salamanders.

I estimated the average percentage of larval salamanders, steelhead, and coho in each habitat during July at 32 *D. tenebrosus* (48%), 24 steelhead trout (36%), 2 one plus steelhead (2%), and 9 coho salmon (13%, Figure 2). September's percentage was 13 *D. tenebrosus* (45%), 8 steelhead trout (280), and 7 coho salmon (24%), 1 one plus steelhead (3%, Figure 2). During this study, larval salamanders were the most abundant species, coho salmon juveniles the least.

Habitat Utilization

Steelhead

I found steelhead trout in pool habitats at the same abundance as the pool frequency within the stream, indicating neither habitat selection or avoidance (Table 4). September surveys showed as the stream flow decreased, steelhead had a very slight preference for lateral scour pools over other habitat types.



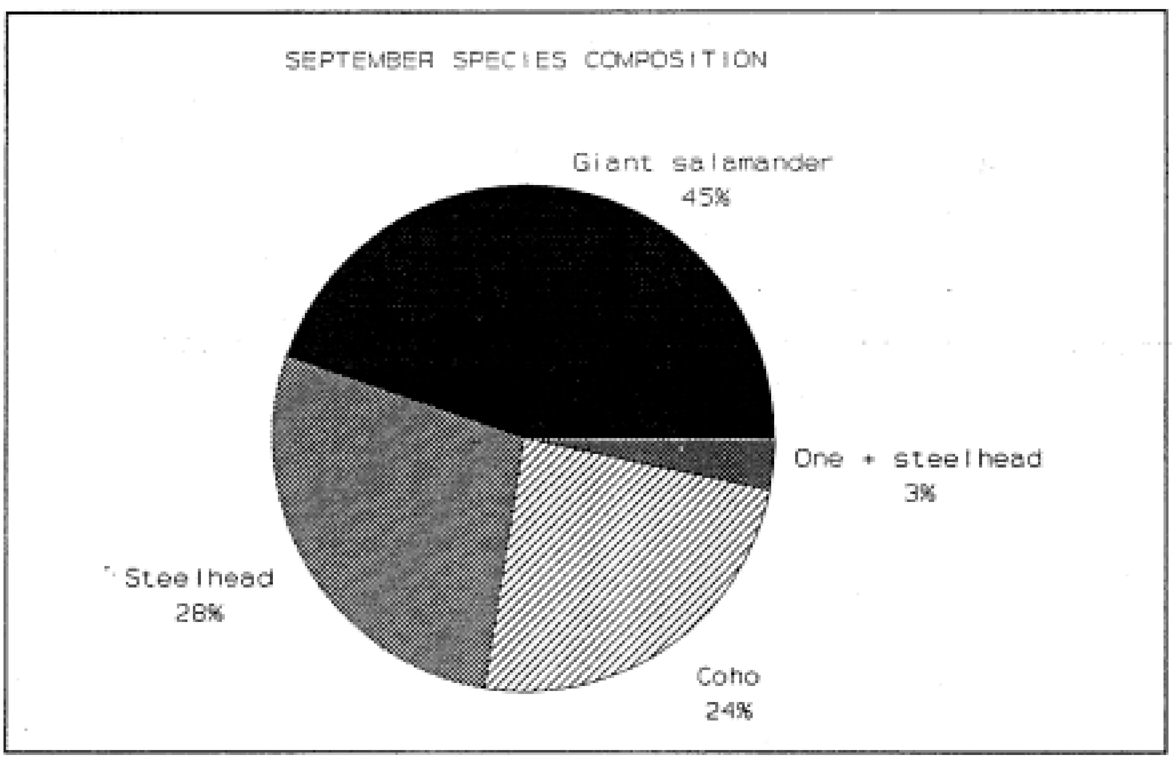


Figure 2. Average percentages of larval salamanders, coho, and steelhead per habitat during July and September, 1987 in Caspar Creek.

Table 4. Steelhead, coho, and larval salamanders utilization index for all habitat categories in Caspar Creek during July and September, 1987.

Habitat Type	Steelhead		Coho		Larval salamander	
	July	Sept.	July	Sept.	July	Sept.
Pools						
Lateral Scour	0.03	0.29	0.22	0.32	-0.11	0.25
Plunge	0.06	-0.05	0.31	0.16	0.17	-0.27
Secondary & Backwater	-0.22	0.01	-0.11	0.05	0.10	-0.14
Total Pools	-0.02	0.20	0.17	0.26	-0.01	0.11
Riffles	-0.07	-0.10	-0.89	-0.88	-0.18	0.03
Runs	0.04	-0.26	-0.04	0.00	0.05	-0.19

habitat types in July or September (Table 4).

Coho

Coho juveniles strongly avoided riffle habitats (Table 4). Coho had the greatest avoidance value than any of the other species. Coho exhibited no preference or avoidance for run habitats (Table 4). Coho salmon did not have any preference or avoidance for any pool habitat types in both July and September (Table 4). Coho had a slight preference for plunge pools during July, and lateral scour pools by September. Although slight, these pool utilization indexes were greater than any the other species indexes.

Larval Salamanders

Larval salamanders used pools according to the pool frequency within the stream indicating no preference or avoidance (Table 4). Larval *D. tenebrosus* demonstrated no selection or avoidance of both riffles, and run habitats (Table 4).

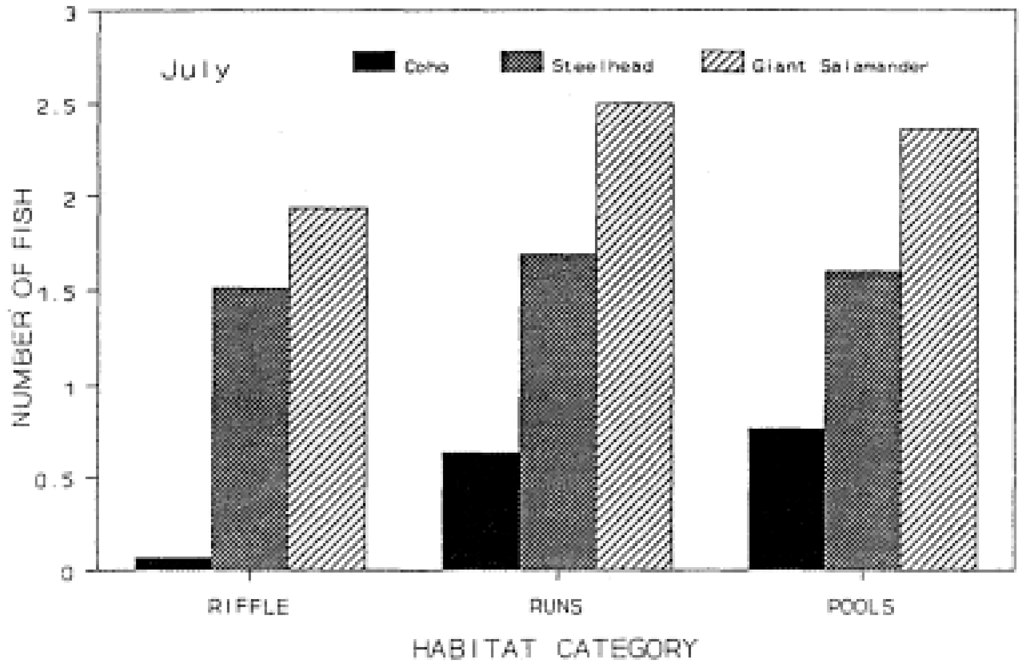
To summarize, no species had any strong preference for any of the habitat types. All species had a very slight preference for lateral scour pools in September. Coho response to riffles was the strongest avoidance of a habitat type. Steelhead and larval *D. tenebrosus* did not show any habitat types avoidance.

Densities and Survival in the Habitats

I found that coho densities in both the pool and run habitats were significantly greater than the coho riffle densities for September ($P<0.01$). The coho densities in the pool and run habitat's during July were not significantly greater than the riffle habitats at $P<0.01$. However, results were statistically significant at $P<0.1$ (Table 5). I found no significant statistical difference ($p>.05$, one-way ANOVA) in coho densities between the pool and run habitats (Figure 3). I did not capture enough coho in the riffle habitats to calculate survival.

Coho's survival in the pool and run habitats were similar (Table 6). However, in the lateral scour pool habitats coho salmon had 115% survival. These habitats must have received coho recruits from other habitat types to achieve greater than 100% survival. I do not know from which habitat types these recruits originated. Coho salmon exhibited the greatest survival (94%) of all three species.

I found no significant statistical difference ($p>.05$, one-way ANOVA) in the densities of steelhead trout in any of the



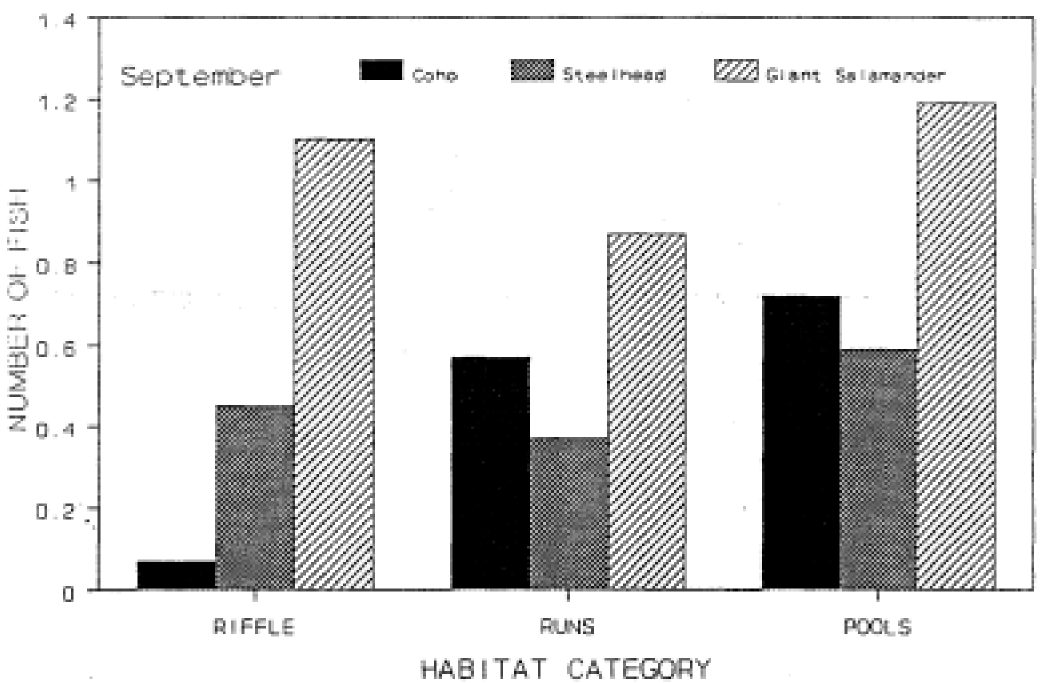


Figure 3. Average densities ($\#/m^2$) of coho, steelhead, and salamanders during July and September, 1987 in Caspar Creek.

Table 5. Mean densities (#/m²) steelhead, coho, and larval salamanders in the habitat types of Caspar Creek during July and September, 1987.

Species	Pools: Plunge July	Pools: Plunge Sept	Pools: Scour July	Pools: Scour Sept	Pools: Total July	Pools: Total Sept	Riffles July	Riffles Sept	Runs- July	Runs- Sept	Average Stream July	Average Stream Sept
Trout	1.7	0.5	1.7	0.6	1.6	0.6	1.5	0.4	1.7	0.4	1.6	0.5
Coho	0.9	0.7	0.8	0.8	0.8	0.7	>0.1	>0.1	0.6	0.6	0.6	0.6
Salamanders	2.8	0.8	2.1	1.3	2.4	1.2	1.9	1.1	2.5	1.0	2.4	1.1

Table 6. Percent survival of steelhead, coho, and larval salamanders based on density (#/m²) in Caspar Creek and its major habitat types between July and September, 1987.

Species	Pools: Plunge	Pools: Scour	Pools: Total	Riffles	Runs	Average Stream
Steelhead	28.7	44.6	39.4	41.4	18.6	31.7
Coho	65.5	115.2	95.6	insufficient samples	96.9	94.0
Larval salamander	29.8	87.4	63.7	72.8	43.9	57.2

three species combined for a survival of 47%.

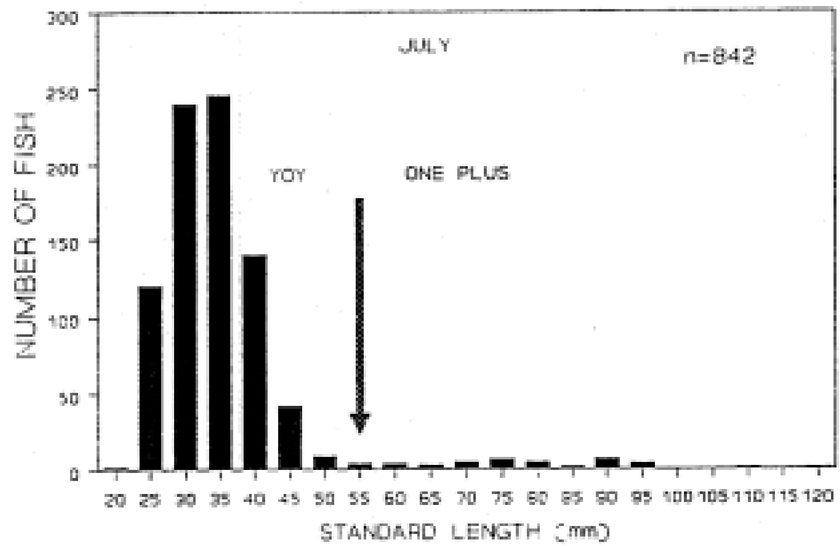
Survival in the plunge pool habitats for all three species were lower than their average survival throughout the stream. Conversely, survival was higher in the lateral scour habitats than the average survival throughout the stream (Table 6).

Growth and Length

Steelhead

Any steelhead trout ≤ 55 millimeters standard length (mm.) were young of the year (Figure 4). Any larger steelhead I considered one year plus. The average steelhead YOY standard length for July and September was 36 (range 34-36) mm. and 38 (range 36-41) mm., respectively (Table 7). Steelhead grew an average of 2 mm. during this study.

Steelhead growth in length per day (mm./d) during this study averaged 0.04 mm./d and ranged from 0.02 mm./d in the run habitats to 0.08 mm./d in the lateral scour pools (Table 8). Daily instantaneous growth averaged 0.06 and ranged from 0.03 in the run habitats to 0.11 in the lateral scour pools (Table 8). I found no significant difference between steelhead growth and the different habitat types ($p>.05$, one-way ANOVA).



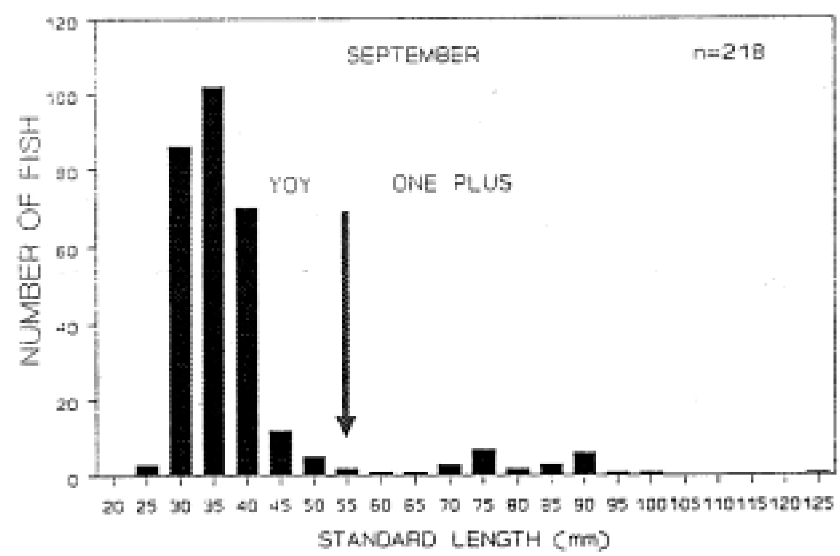


Figure 4. Length frequency composition of steelhead trout in Caspar Creek during July and September, 1987.

Table 7. Mean standard length (mm.) of steelhead, coho, and larval salamanders in major habitat types in Caspar Creek during July and September, 1987.

Species	Pools Plunge	Pools Scour	Pools Total	Riffles	Runs	Average Stream
Steelhead						
July	35	36	36	34	36	36
September	38	41	40	36	37	38
Coho						
July	43	45	45	39	46	45
September	49	50	50	43	50	49
Larval salamanders						
July	42	42	41	35	37	39
September	36	39	39	34	39	38

Table 8. Daily instantaneous growth (G) and growth in length per day (mm./d) of steelhead, and coho salmon in Caspar Creek's major habitat types during July through September, 1987.

Species	Pools Plunge	Pools Scour	Pools Total	Riffles	Runs	Average Stream
Steelhead						
G	0.10	0.11	0.09	0.06	0.03	0.06.
length/day	0.07	0.08	0.07	0.04	0.02	0.04
Coho						
G	0.12	0.11	0.11	insufficient	0.08	0.08
length/day	0.11	0.10	0.10	samples	0.08	0.07

Coho

Coho salmon length frequency indicates a single age class (Figure 5). Coho average standard length for July and September was 45 (range 39 to 46) mm. and 49 (range 43-50) mm., respectively (Table 6). Coho grew an average of 4 mm. during this study (Table 7).

Coho growth in length per day (mm./d) during this study averaged 0.08 mm./d and ranged from 0.08 mm./d in the run habitats to 0.11 mm./d in the plunge pool habitats (Table 8). Daily instantaneous growth rates averaged 0.08 and ranged from 0.08 in the run habitats to 0.12 in the plunge pool habitats (Table 8). I found no significant difference between coho growth and the different habitat types ($p>.05$, one-way ANOVA). I did not capture enough coho juveniles to calculate growth rates for the riffle habitat types.

Larval Salamanders

Larval *D. tenebrosus*'s July length frequency suggests two overlapping age groups (Figure 6). Its September length frequency describes a single young of the year age group (Figure 6). The older age group present in July transformed and left the stream by September. I address the consequences of the salamander transformations on the data

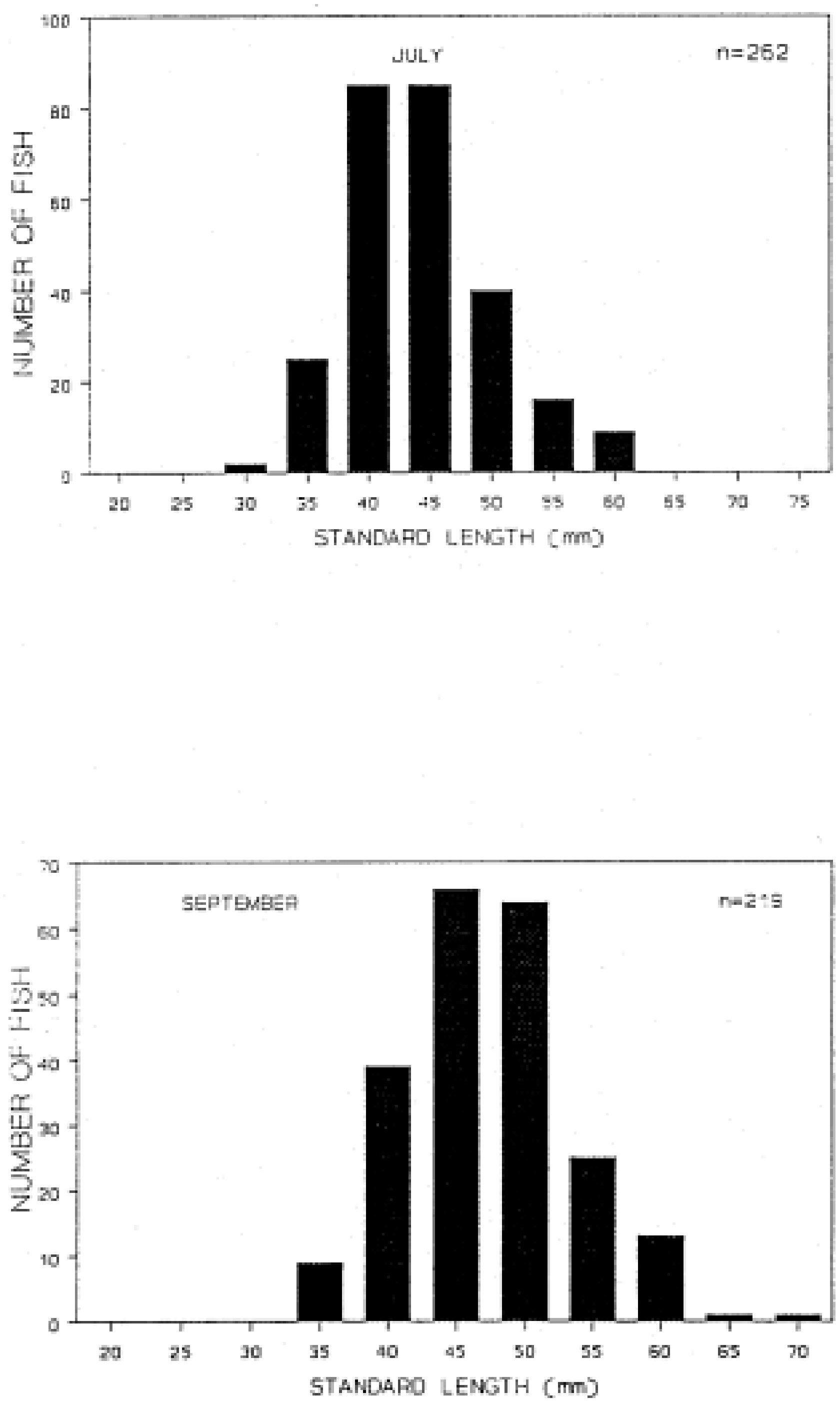
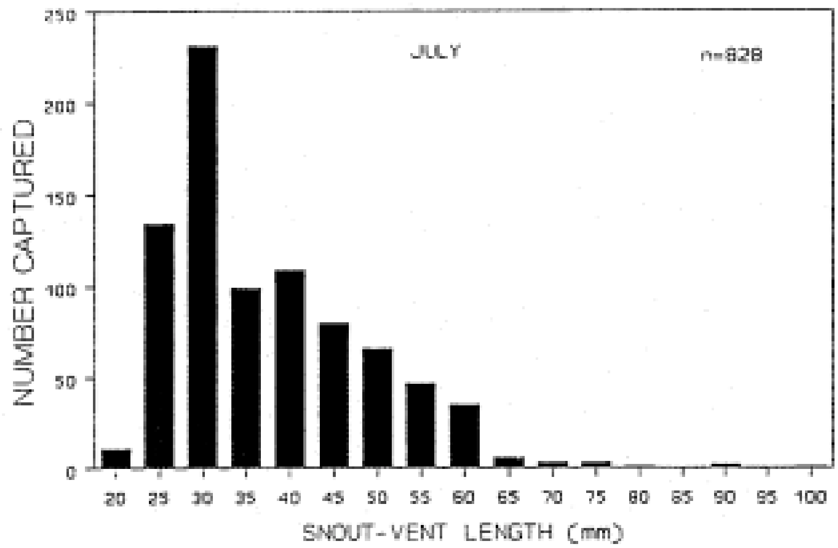


Figure 5. Length frequency composition of coho salmon in Caspar Creek during July and September, 1987.
in the discussion.



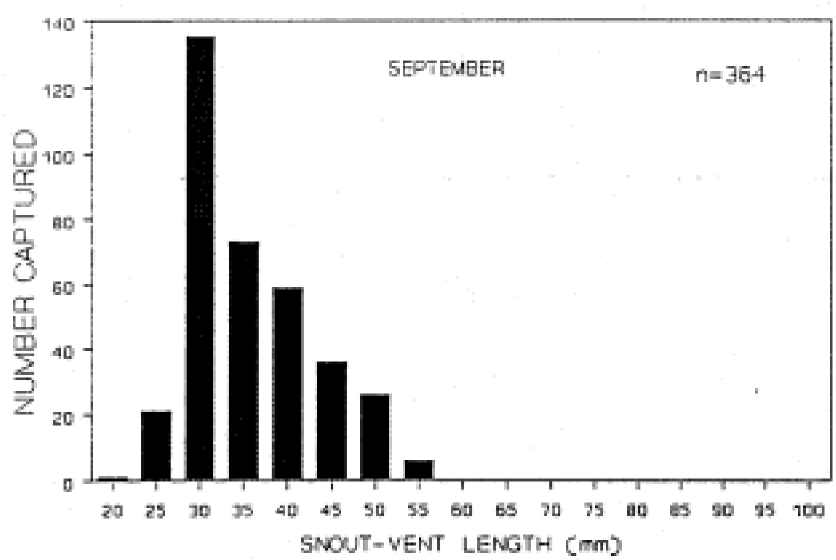


Figure 6. Length frequency composition of larval salamanders in Caspar Creek during July and September, 1987.

in the discussion.

D. tenebrosus's average snout to vent length for July and September was 39 (range 35-42) mm. and 38 (range 34-39) mm., respectively (Table 7). I found no significant difference between the larval salamander's average mean length and the different habitat types ($p>.05$, one-way ANOVA).

DISCUSSION

Habitat Utilization

Steelhead, coho, and larval salamanders utilized all available habitat types. The greatest habitat use occurred in pools, riffles the least, with runs intermediate between the two (Table 4). Pool habitat utilization slightly increased in September, as summer stream flows decreased. As flow declined, shallow habitat lost more available living space than pools, forcing fish into these pools.

The value of cover depends on the size of the fish. I found the smallest mean lengths for all species in the riffle habitats. The mean lengths in pool habitats were larger than average (Table 7). Runs were intermediate between the two. Pool habitats have better quality cover, such as large woody debris or rocks suitable for larger fish or larval salamanders (Bisson et. al. 1982). The riffle habitat's cover consists of small rocks and surface turbulence, suitable for smaller individuals. With predators present in the pool habitats, riffles provide cover for smaller fish and larval salamanders.

Cover and predator avoidance also may account for the differences between lateral scour and plunge pool use.

Lateral scour pools contain large rocks, exposed bedrock, undercut banks, or large woody debris that provide shelter and cover. Plunge pools are scoured bowl shaped depressions; often the deepest habitats with the greatest volume. I found the largest one plus steelhead here. Smaller individuals may switch their habitat from plunge to lateral scour pools to avoid predation by the older steelhead.

Coho and Steelhead

Previous workers have established that coho salmon prefer pools and avoid riffle habitats, while steelhead utilize both riffles and pool habitats (Hartman 1965, Ruggles 1966, Bisson et. al. 1982, 1988, Glova 1978). Coho juveniles prefer habitats containing large woody debris, such as rootwads (Shirvell 1990). Shirvell (1990) demonstrated that fish do not select cover objects, but select habitats where cover is a function provided by structural elements within the habitat. However, Bjorn et. al. (1991) found cover relatively unimportant in the abundance of young of the year coho, but important to the older salmonids.

There is a good correlation between pool volume and juvenile coho standing crop (Nickleson and Reisenbichler 1977, Murphy et. al. 1984). Glova (1978) also observed comparable coho biomass in pools and runs, but little in riffle habitats. Young of the year steelhead select faster water with good cover, they avoided the center of riffles, preferring the riffle margins containing cover (Murphy et. al. 1984).

During 1987, Caspar Creek's habitat utilization values indicate that coho salmon strongly avoided riffles. Steelhead habitat values indicate no preference or avoidance to any particular habitat type (Table 4). These results are similar to Bisson's et. al. (1982) findings on which this study is based. Bisson's coho utilization values for low gradient riffles indicated avoidance (-0.75), but were lower than this study (Table 4). Their YOY steelhead utilization values of habitat types in common in this study were similar to mine and demonstrated no preference or avoidance of any habitat types.

Bisson et. al. (1988) explained his findings by the morphological difference between coho and steelhead. Coho juveniles have deep, laterally compressed bodies with large median fins adapted for maneuverability in pool habitats. Steelhead juveniles have a cylindrical body shape with short median fins adapted for less flow resistance. This body shape causes decreased maneuverability in pools while providing less resistance in flows.

Hartman (1965) also observed greater densities of coho in pools while avoiding riffles. Steelhead occupied the riffle habitats and were found at lower densities in the pools. However, both coho and steelhead preferred pool habitats in Hartman's study (1965). He explained this distribution by behavioral differences. Coho juveniles were more aggressive and drove the steelhead juveniles out of pool habitats, while steelhead tended to defend their territories in riffles against coho.

If behavioral interactions are a factor in determining habitat densities, then the distribution I observed in Caspar Creek may be explained by the low coho densities. Hartman (1965) found during July and September higher coho pool habitats densities (2.8 per m^2, 1.9 per m^2; respectively) than I observed and lower steelhead pool densities (1.0 per m^2, 0.5 per m^2; respectively, Table 4). He found similar steelhead riffle densities (1.6 per m^2, 0.5 per m^2; respectively, Table 4).

There may not have been enough coho to drive the steelhead from the preferred pool habitats. Steelhead's intraspecific interactions could lead to similar densities among the various habitat types (Table 4). Meanwhile, larger steelhead would force smaller individuals into the riffle habitats (Table 6).

Whether by morphological or behavioral mechanisms, Caspar Creek's pool and run habitats held statistically significantly greater coho densities than those found in riffle habitats for both July and September ($P<0.01$, Table 4). Steelhead utilized all available habitats including riffles. Steelhead densities were similar in all habitat types.

Coho salmon maintained greater average growth and survival than steelhead throughout all habitat categories (Table 6, 8). The low coho densities may have contributed to their greater growth and survival when compared to the steelhead's. Population characteristics reflect both intra- and interspecific population density pressures. Fraser (1966) found coho and steelhead survival and growth were species specific. Survival and growth of one at low density was not influenced by the high densities of the other. Young of the year steelhead exhibit an inverse relationship between their density and growth (Bilby and Fransen, 1992). In Caspar Creek, the steelhead greater density may have contributed to their reduced growth and survival in the habitat types.

Growth and density of coho salmon in Caspar Creek was consistent with the summer growth and density reported for coho in a small Alaskan stream (Dolloff 1987). Dolloff (1987) estimated coho growth in fork length at 0.10 (FL, mm./d) and coho density at 0.42 per m^2 (Dolloff 1987, Table 4, 7).

Steelhead density in Caspar Creek during 1987 was similar to the average density during summer in its North Fork between 1967 and 1969 (1.26 and 0.5 per m^2, respectively; Burns 1971, Table 4). Caspar Creek's coho densities during 1987 were greater than its mean density in its North Fork between 1967 and 1969 (0.21 and 0.19 per m^2, respectively; Burns 1971, Table 4).

Caspar Creek was one of seven coastal stream Burns (1971) studied. He found that intraspecific competition was more important than interspecific competition in determining salmonid carrying capacity. Burns (1971) concluded that not all Northern California streams reach salmonid carrying capacity in the summer.

Larval Salamanders

In Caspar Creek, larval salamander's habitat utilization values suggest that they do not avoid or prefer any particular habitat type (Table 4). Their density was similar throughout all habitat types (Table 5). Nussbaum and Clothier (1973) found larval *D. tenebrosus* in a wider variety of habitats in lotic environments than what was previously assumed. My habitat data support their view of *D. tenebrosus as* an ecologically generalized species.

Larval salamanders were the most abundant vertebrate I collected in Caspar Creek (Table 5). Mean densities averaged 2.4 per m^2 during July and declined to 1.1 per m^2 in September (Table 4). These densities are similar to larval *D. tenebrosus* densities (1.94 to 2.41 individuals/m^2) reported in streams along the Pacific coast (Corn and Bury 1989, Bury et. al. 1991). Parker (1991) observed similar larval *Dicamptodon* densities in Caspar Creek's North Fork in his medium stone density pools.

In Caspar Creek, average larval salamander density was similar to the average salmonid density throughout the stream (Table 5). Larval salamander density was similar to total salmonid density in the habitat types (Table 5). For streams in the Pacific region, Bury et. al. (1991) found aquatic amphibians to be 10 times more abundant than those reported for salmonids. I did not find this to be the case in Caspar Creek. If Bury et. al. (1991) are correct, the difference may be attributed to the electroshocking sampling method.

Electroshocking may be a biased sampling technique for salamanders (Corn and Bury 1989). They believe that electroshocking miss large numbers of small larvae. However, other researchers have used electroshocking to sample D. *tenebrosus larvae* populations (Hall et. al. 1978, Murphy and Hall 1981, Murphy et. al. 1981, Hawkins et. al. 1983). Since I may have missed some of the smaller larval salamanders during this study, density values should be considered minimum estimates.

As with other small streams studies on the Pacific coast, larval salamanders were the predominant predator in Caspar Creek (Corn and Bury 1989, Bury and others 1991). They may reach high densities since they are not as active as salmonids (Bury and others 1991). Their inactivity may allow more conversion of energy to biomass. Larval salamanders also may feed on prey outside the stream that are not available to fish.

Nussbaum and Clothier (1973) found that usually two size (age) classes of larval *D. tenebrosus* present in small, permanent streams during the spring and summer. A smaller young of the year class coexisting with an older, larger size class. By midsummer, individuals in their second year would begin to transform and leave the stream. one size-class remains by late summer and fall, those in their first year of growth. Some second year larvae would remain to over winter and transform during their third year, but neoteny was rare.

The average salamander length and the length frequency data supports the presence of two-size classes of salamanders during July, and a single size-class in September. The average salamander length decreased 1 mm. from July to September (Table 7). A larger size-class present in the July sampling, but absent in the September sampling would lead to a smaller average length. A single age class would have a larger average length during the final sampling period. Parker (1991) also found larval salamander in their first year of development coexisting with a few second year individuals in Caspar Creek.

July's salamander length frequency distribution is non-normal (Gaussian), with the presence of several larger individuals (Figure 6). A single age group should show a normal length distribution (Baegnal 1978). Larval salamander's September length composition approaches a normal distribution that would be expected of a single age class.

Conclusion

of the habitat types, pools contained the greatest stream volume while riffles possessed the greatest stream area. Pools were the most abundant habitat type, the riffle habitats the least. Run habitats were intermediate in abundance, stream volume and area.

Overall, steelhead trout and larval *D. tenebrosus* utilized all habitat categories available to them. Pools habitats had the greater intensity of species use, runs intermediate, and riffles the least. Of the pool habitats, plunge pools were slightly favored in July, while lateral scour pools were slightly preferred by September. I found no statistically significant differences between steelhead trout and *D. tenebrosus* densities, growth, and the different habitat types.

I found statistically significant greater coho densities in pool and run habitats when compared to riffles. Habitat utilization values suggest that coho have no preference for either both pools and runs, but strongly avoid riffles. Coho growth and survival were greater than steelhead or *D. tenebrosus,* but their density was less.

Larval salamanders were the predominant predator. There were two *D. tenebrosus* age classes present in Caspar Creek during the summer of 1987. There was an older, larger transforming class accompanied by a younger, smaller size class during July. By September, most of the larger size class had transformed and left the stream.

Bisson et. al. (1982) system of habitat classification was successful in quantifying the availability of habitats to YOY steelhead, coho and larval salamanders in Caspar Creek. By classifying habitats with this method, I found that coho salmon segregated within the stream by avoiding riffle habitats. I also found that steelhead and larval salamanders distributed themselves comparably among the different habitat types. I was also able to determine species growth and survival within each habitat.

It could be that by applying Hawkin's et. al. (1993) hierarchical approach to this methodology differences could have emerged between habitat types. Further studies in species use of diverse habitats during their different life cycle stages will lead to a better understanding of stream habitat organization (Hawkins et. al. 1993). Information on habitat organization is very important to biologists seeking to reverse the population declines of salmon and amphibians species before they reach critical levels.

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APPENDIX I. Caspar Creek North Fork's average habitat size and percent of total stream (in parenthesis).

Habitat Type	n	Average Habitat Size / % of Total: Length (m)		Area (m^2)		Volume (m^3)	
Pools	84	4.2	(23.4)	10.5	(26.1)	2.7	(51.8)
Lateral Scour	57	4.7	(17.7)	11.4	(19.1)	2.6	(34.5)
Plunge	17	2.9	(3.2)	9.2	(4.6)	3.4	(13.4)
2° Channel	3	3.8	(0.8)	7.1	(0.6)	1.3	(0.9)
Confluence	1	5.0	(0.3)	2.0	(0.6)	5.0	(1.1)
Backwater	5	4.0	(1.3)	7.2	(1.1)	1.4	(1.6)
Dammed	1	2.2	(0.1)	2.6	(0.08)	0.8	(0.2)
Riffles	60	5.4	(21.4)	11.0	(19.5)	0.6	(8.2)
Low Gradient	52	5.8	(20.0)	12.3	(18.8)	0.7	(8.1)
High Gradient	7	3.3	(1.5)	3.0	(0.6)	0.09	(0.15)
Cascades	1	0.9	(0.06)	1.7	(0.05)	0.03	(0.01)
Runs	64	13.0	(55.0)	28.7	(54.3)	2.7	(40.0)
Runs	26	9.6	(16.6)	2.5	(17.2)	2.5	(14.7)
Step Runs	24	19.4	(30.7)	3.3	(29.6)	3.3	(18.0)
Glides	14	8.3	(7.7)	4.0	(7.6)	4.0	(7.2)

APPENDIX II. Caspar Creek's South Fork average habitat size and percent of total stream (in parenthesis).

Habitat Type	n	Length (m)		Area (m^2)		Volume (m^3)	
		Average Habitat Size / % of Total					
Pools	23	8.0	(25.8)	22.0	(26.6)	6.8	(49.0)
Lateral Scour	20	8.1	(23.5)	22.6	(24.9)	7.0	(46.3)
Plunge	1	2.6	(0.4)	6.0	(0.3)	1.8	(0.6)
2^o Channel	1	4.5	(0.7)	7.6	(0.4)	1.1	(0.4)
Trench	1	8.0	(1.2)	17.6	(1.0)	5.3	(1.7)
Riffles	17	6.3	(15.6)	18.6	(17.4)	0.9	(4.6)
Low Gradient	16	6.6	(15.4)	19.6	(17.3)	0.8	(4.6)
High Gradient	1	1.5	(0.2)	2.2	(0.1)	0.1	(0.02)
Runs	26	5.4	(58.7)	39.2	(56.1)	5.4	(46.3)
Runs	5	19.3	(12.3)	48.1	(10.0)	5.9	(6.8)
Step Runs	12	9.8	(33.6)	29.0	(31.7)	5.4	(23.5)
Glides	9	16.9	(12.8)	36.6	(14.3)	4.1	(16.0)